CEBRI — BRAZILIAN CENTER FOR INTERNATIONAL RELATIONS

IDB — Inter-American Development Bank

epe — Empresa de Pesquisa Energética

ENERGY TRANSITION

PROGRAM

1ST CICLE

DIAGNOSTIC

Trends and Uncertainties of the Energy Transition in the Brazilian case

DATASHEET

Authors

Andre Bello
Breno Lyro
Gabriel Paiva
Gabriela Gonzalez
Gregório Araújo
Humberto Lima
Luciana Sampaio
Pedro Guimarães
Rafaela Guedes
Thiago Moraes
Yuri Telles

Editorial coordination

Julia Dias Leite
CEO at CEBRI

Luciana Gama Muniz
Project Director at CEBRI

Giovani Machado
Director of energy and environmental studies at EPE

Gustavo Naciff
EPE Deputy Superintendent

Editorial Support

Léa Reichert
Project Coordinator at CEBRI

Gustavo Berlie
Project Analyst at CEBRI

Graphic Design

Presto Design

Warning: This report reflects the opinion of debaters from events from the first stage of the Energy Transition Program, and not necessarily the vision of the institutions that partake in the program.

CEBRI

ENERGY PROGRAM

The Program explores the future of energy, global energetic tendencies, and searches for solutions for the creation of an environment of competitive and desirable investments for Brazil.

Jorge Camargo
Vice-President of the CEBRI Board of trustees

Rafaela Guedes
Senior Fellow at CEBRI

Gregório Araújo
Senior Researcher

CENTRO BRASILEIRO DE RELAÇÕES INTERNACIONAIS
Rua Marquês de São Vicente, 336 – Gávea
Rio de Janeiro / RJ - CEP: 22451-044
Tel + 55 21 2206-4400 - cebri@cebri.org.br
www.cebri.org

BRAZILIAN CENTER FOR INTERNATIONAL RELATIONS

Inter-American Development Bank

Empresa de Pesquisa Energética

ENERGY TRANSITION
PROGRAM

1ST CICLE
DIAGNOSTIC

Trends and Uncertainties of the Energy Transition in the Brazilian case

Sponsors:

Support:

Siemens Energy is a brand licensed by Siemens AG

ABOUT THE BRAZILIAN CENTER FOR INTERNATIONAL RELATIONS, CEBRI

The Brazilian Center for International Relations is an independent, nonpartisan and multidisciplinary organization, guided by excellence, ethics and transparency in the formulation and dissemination of high-quality content about international relations and the role of Brazil. By engaging the public and private sectors, academia and civil society in a plural debate, CEBRI influences the construction of the country's international agenda and subsidizes the formulation of public policies, thus generating impactful actions with prospective vision.

Throughout its twenty-two-year history, CEBRI has held more than 500 events, produced more than 200 publications, and operates with an international network of more than 100 high-level organizations on all continents. The Center stands out for its intellectual collection, for its capacity to bring together multiple visions from renowned specialists, and for the significance of its Board of Trustees.

Connected to the international agenda, CEBRI identifies and analyzes the most relevant international issues, promoting engagement between the production of knowledge and political action. It acts as the counterpart of strategic global institutions, such as the Council on Foreign Relations, in the US, the Chatham House, in the UK, and several other International Relations Councils in the global scene.

Its international importance is further attested by the Global Go to Think Tanks survey, conducted by the University of Pennsylvania, which considers CEBRI one of the most relevant think tanks in the world.

CEBRI
BRAZILIAN CENTER FOR INTERNATIONAL RELATIONS

ABOUT THE INTER-AMERICAN DEVELOPMENT BANK, IDB

The Inter-American Development Bank (IDB) is an international financial institution founded in 1959 and composed of forty-eight member countries. Its objective is to finance economic development projects in Latin America and the Caribbean, and to provide technical assistance to governments and private institutions. Its main initiatives are set in the areas of poverty and inequality reduction, regional and trade integration, competitiveness, productivity and innovation, and efficiency of public spending.

IDB
Inter-American
Development Bank

ABOUT THE ENERGY RESEARCH OFFICE, EPE

The Energy Research Office (EPE) prepares studies and researches to support the energy sector's planning, covering electricity, oil and natural gas and their byproducts, and biofuels within the Brazilian National Council for Energy Policy (CNPE) and the Ministry of Mines and Energy (MME). EPE prepares, among others, the Ten-Year Energy Expansion Plan (PDE), the National Energy Plan (PNE), the National Energy Balance (BEN), and the Transmission Expansion Program (PET).

epe
Empresa de Pesquisa Energética

ABOUT THE IDB-CEBRI-EPE ENERGY TRANSITION PROGRAM, PTE/ETP

Governments of several countries have been announcing carbon neutrality targets for the coming decades to contain the advances of climate change. In Brazil, the discussions are evolving, with some key factors distinguishing the country from others: such as the dynamics of emissions, the great impact of forest fires, the fact that the country already has one of the most renewable energy matrixes of the industrialized world, and that *per capita* energy consumption is still low when compared to countries that have already developed.

To contribute to this debate in Brazil in an independently and openly, CEBRI, in partnership with the IDB and EPE, established the IDB-CEBRI-EPE Energy Transition Program (PTE).

The program seeks to diagnose the main trends and critical uncertainties and the construction of long-term scenarios (2050) for the energy sector in Brazil, contributing to informing and assisting policy makers.

Acknowledgments

Between April and June 2021, the IDB-CEBRI-EPE Energy Transition Program promoted a series of virtual debates with experts and stakeholders. The debates were crucial to support the vision that we are jointly building with academic institutions, organizations of the industry and energy sectors, and counted with the distinguished participation of the following panelists:

- Carla Primavera (BNDES)
- Carlos Pascual (IHS)
- Carmen Araújo (ICCT)
- Clarissa Lins (CEBRI and Catavento)
- Claudia Sender (Embraer and Gerdau)
- Cristiano Façanha (CALSTART)
- Cristina Pinho (IBP)
- Daniel Lopes (Hytron)
- Evandro Gussi (UNICA)
- Gregório Araújo (CEBRI and Petrobras)
- Ilan Cuperstein (C40)
- Joaquim Levy (Banco Safra)
- Jorge Camargo (CEBRI)
- José Luiz Alquéres (CEBRI)
- José Pio Borges (CEBRI)
- Luiz Barroso (PSR)
- Luiz Horta (UNIFEI)
- Marcel Martin (iCS)
- Mechthild Wörsdörfer (IEA)
- Morgan Doyle (IDB)
- Rafaela Guedes (CEBRI and Petrobras)
- Roberto Bocca (World Economic Forum)
- Roberto Schaeffer (COPPE/UFRJ)
- Solange Ribeiro (Neoenergia)
- Thiago Barral (EPE)

TABLE OF CONTENTS

ENERGY
TRANSITION
PROGRAM

Introduction

For decades, a gradual and ongoing process of understanding the consequences of climate change, together with the development of technologies that enable energy production in a sustainable, affordable, and secure way, has been driving popular movements to demand action to replace fossil fuels with less carbon-intensive energy sources, characterizing the ongoing energy transition (ET).

To this social pressure were added the geopolitical disputes on the global stage. Energy geopolitics gained new contours, with decarbonization becoming a central element of the diplomatic agenda. Conflicts that were traditionally associated with access to oil and gas reserves began to migrate to issues related to technological and market leadership, with countries like China, the U.S., and the European Union as the main drivers of this movement.

China, with access to key raw materials and leadership in clean energy technologies and investments, has come to define ET as a national security issue in its five-year plans. The U.S., under Joe Biden's administration, pointed to the need to secure access to the supply chain of these new energy sources and storage.

Europe, which was the first continent to announce a goal of carbon neutrality by 2050, deepens its actions, driven by the Covid-19 pandemic, by announcing much more than a decarbonization plan, but also an economic recovery plan based on investments for the development of green infrastructure.

The "European Green Deal", as it is being called, provides for investments of about one-third of the 1.8 trillion euros in the NextGenerationEU Recovery Plan and the European Union's seven-year budget to finance, among other things, the renovation of thirty-five million buildings by 2030 and the creation of 160,000 additional green jobs in the construction sector by 2030[1]. In addition, by the end of 2020, the previous target of dropping greenhouse gas emissions by at least 40 percent by 2030 (when compared to 1990 levels) was raised to 55 percent. A big challenge, since in 2019 total emissions in the European Union were 25% below the 1990 level.

1. European Commission, at https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

Economic recovery plans with initiatives that incorporate sectors associated with energy transition may allow a re-acceleration of the energy transition pace in the medium and long terms. This is because, even though the short-term human and economic costs are clear, as well as their impacts on the drop in global energy demand in 2020 - the paralysis of investments in energy projects, the increase in poverty, and the drop in global GDP -, there is still no consensus on which behaviors and habits of manufacturers and consumers brought about by COVID-19 will consolidate in our society. The global impact of the pandemic on the pace of the energy transition remains uncertain.

> The global impact of the pandemic on the pace of the energy transition remains uncertain

To evaluate the status quo and the potential of ET specifically in Brazil and to contribute to the formulation of public policies for the Brazilian energy matrix of 2050, the IDB-CEBRI-EPE Energy Transition Program is composed of three phases: diagnostic, convergence and scenario development.

The **diagnostic phase**, which took place in the first half of 2021, aimed to map the main trends and critical uncertainties through a series of virtual events, in debates with experts, society and stakeholders, seeking elements that would answer three key questions:

1. What structural effects can the pandemic provoke on the global energy sector and what are its ramifications for Brazil?

2. What technologies and energy sources make the most sense for Brazil in the search for compliance with the climate agreements?

3. Which energy transition alternatives bring greater benefits to Brazil? What is the contribution of each of the segments to this process?

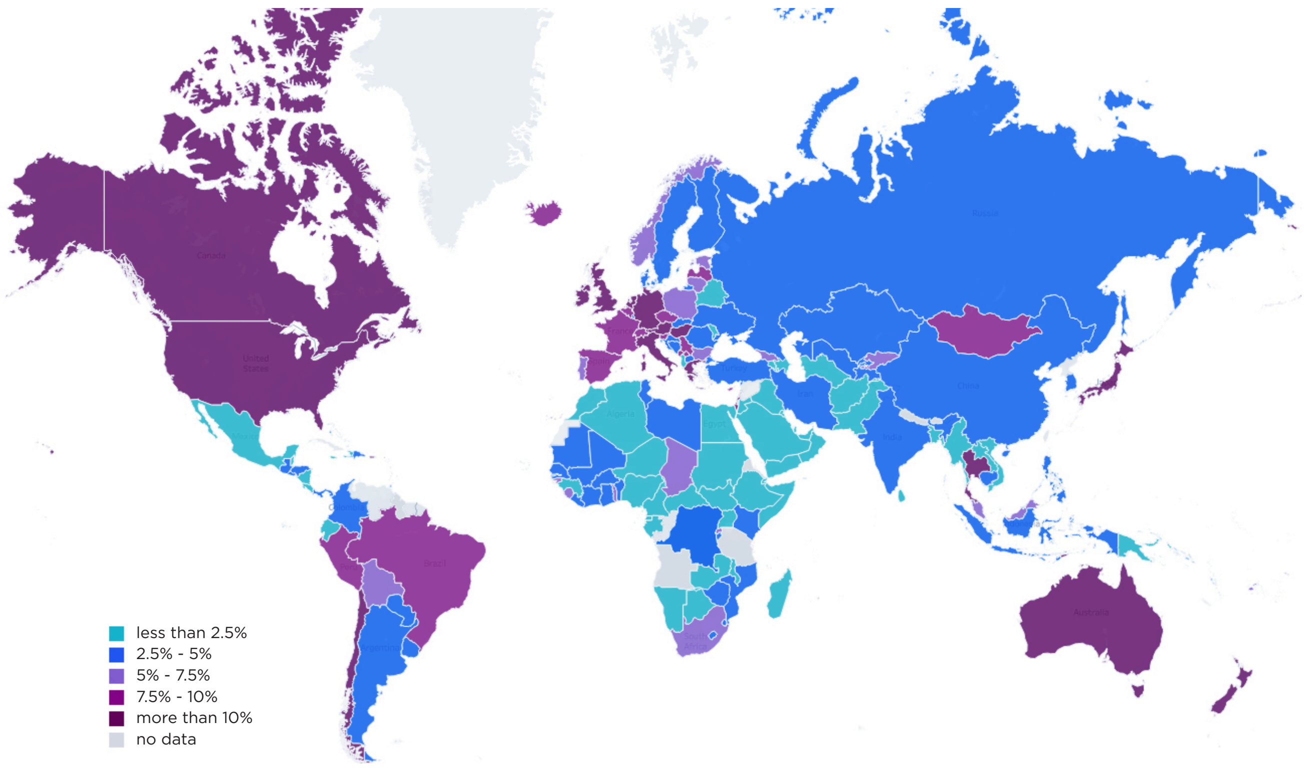
The **convergence phase** began in the second half of 2021 seeking to consolidate a vision of the future for the main explanatory variables identified in the previous phase. And finally, the **scenario development phase**, where future scenarios will be modeled based on the methodology adopted by the Cenergia/PPE/COPPE/UFRJ group.

The main points of the diagnostic phase will be presented in the following chapters.

Contextualization

The economic crisis unleashed by the Covid-19 pandemic materialized as high risk-aversion, unemployment and impoverishment. Governments around the world reacted by announcing recovery plans, mostly based on fiscal expansion aimed at maintaining minimum income levels. This movement occurred mainly in developed countries, where measures of isolation, social distancing and closure of economic activities were taken, particularly in North America and Western Europe.

CHART 1. FISCAL BUDGET FOR AID IN 2020 (% OF GDP)



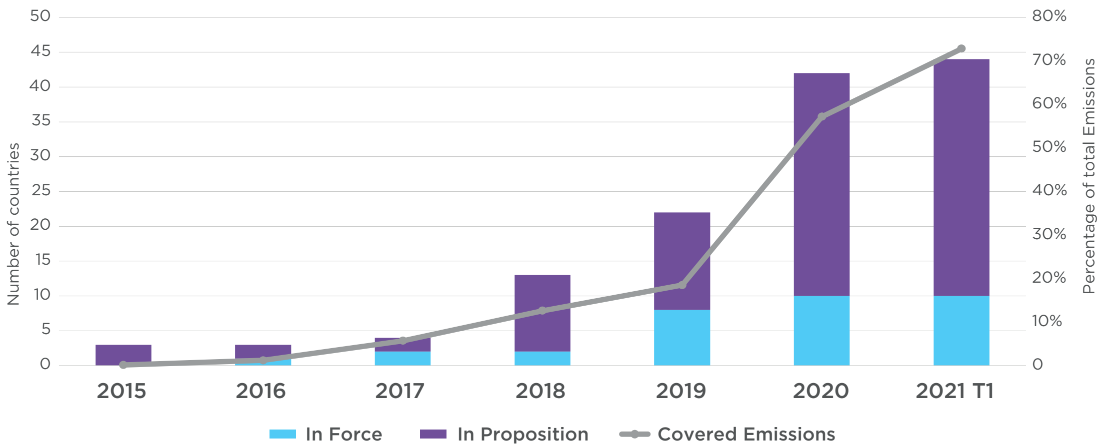
Source: International Monetary Fund, 2021[2]

2. IMF. Fiscal Monitor Database of Country Fiscal Measures in Response to the COVID-19 Pandemic. 2021

Among emerging economies, Brazil's level of expenditure drew attention (previous chart), since relative to GDP, it was well above that seen in the economies of Eastern Europe, Asia, Africa and Latin America itself. The resources focused on cash transfers to the most vulnerable households, via emergency aid and had important results in minimizing the drop in income. The result, in an international comparison, was also superior to that of several developed countries, limiting GDP decrease to 4.1%, while Spain, Italy and the UK, registered, respectively, GDP drops of -10.9%, -8.9% and -9.9%. In the USA, the contraction of the GDP was slightly less than in Brazil, at -3.5%.

Another point that stands out in the recovery plans released globally, was the stimulus for investments aimed at developing the so-called "green economy" or "low-carbon economy". During the economic and health crisis, social pressure for answers to the climate crisis continued to grow. As a result, in 2020, the number of countries that have declared commitments to reduce their net emissions to zero by mid-century has multiplied (chart below), intensifying a movement that has been taking shape since the Paris Agreement.

CHART 2. NET ZERO COMMITMENTS ANNOUNCED BY COUNTRIES



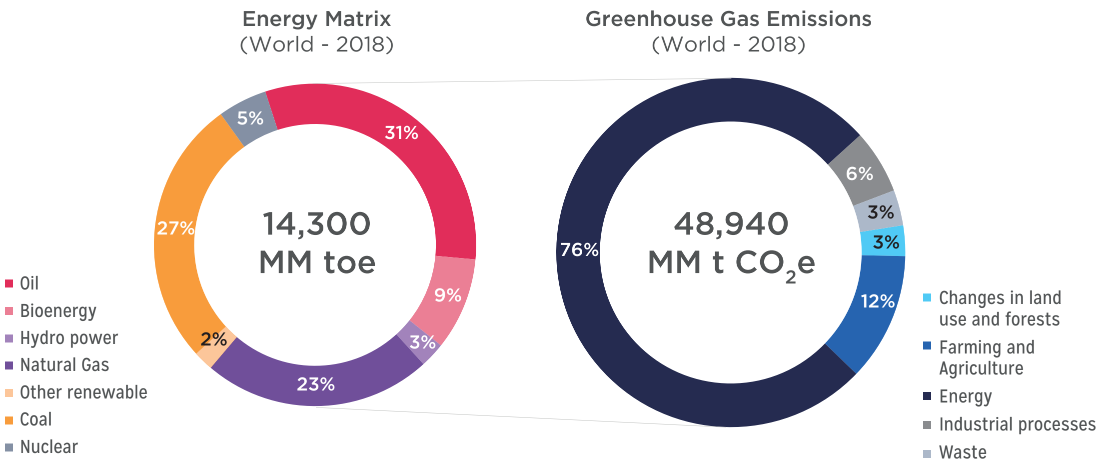
Source: IEA, 2021. All rights reserved. [3]

The various net-zero announcements have been well received by the international community, but the trajectory is still worrying. According to the International Energy Agency (IEA), although CO_2 emissions have fallen 6% in 2020, estimates for 2021 - driven by pent-up demand - are for rapid growth, indicating what would be the second-highest rise in the past 30 years. This is because these changes are long-term movements, in which the global energy and production infraestruture are hardly ever altered by short-term ruptures, but by gradual adaptations, arising from evolutionary and competitive processes, often subject to technological lock-in.

In its publication *Net Zero by 2050*, the IEA warns that, as the energy sector is the world's largest carbon emitter, accounting for about three/fourths of global emissions, there is no way to reduce global emissions without a meaningful change in the level of emissions of the energy sector. Thus, the new challenge is to reconcile the dynamics of global economic recovery with the construction of a cleaner and more sustainable energy system in a timeframe that is feasible for the goals outlined in the Paris Agreement.

3. IEA. Net Zero by 2050, A Roadmap for the Global Energy Sector. 2021

CHART 3. ENERGY MATRIX *VERSUS* GREENHOUSE GAS EMISSIONS IN THE WORLD



Source: IEA, 2021. All rights reserved. [4]

Compared to the transition from the use of firewood and coal to the use of oil and natural gas, the change may not occur at the necessary speed, since even today coal still represents a significant 27% of the global energy matrix (previous chart). Added to oil and gas, fossil fuels account for 81% of the world's energy matrix.

To assist in this challenge, the IEA has proposed to function as a catalyst for global energy transition, highlighting the urgency to transform the announcements and ambitions into concrete actions. The Agency notes that for this, it is necessary to make the transition resilient to crisis, guiding actions and policies through guidelines aimed at: i) inclusion, reducing inequalities and, consequently, mitigating resistance to the process; ii) the search for an integrated vision, encompassing energy demanders and suppliers in a complementary way, with policies directed at both sides; and iii) guaranteeing the necessary financing for the productive restructuring of the industrial-energy system.

> The new challenge is to reconcile the dynamics of global economic recovery with the construction of a cleaner and more sustainable energy system in a timeframe that is feasible for the goals outlined in the Paris Agreement

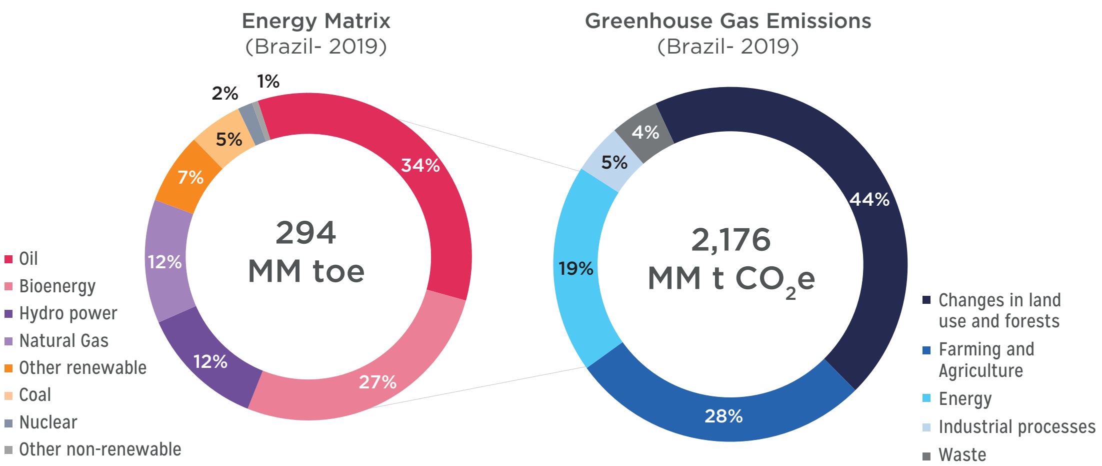
4. IEA. Climate Watch. 2021

The Brazilian Reality

Brazil is considered a country with low intensity of greenhouse gas emissions per inhabitant. In 2020, each Brazilian emitted, on average, 1.9 tCO_2eq. This represents about one-seventh of the emissions of a North American and one-third of a European or Chinese citizen's (BEN, 2021).

The particularity of Brazil is that the generation of GHG (greenhouse gases) in the country is strongly related to land use and agriculture and cattle ranching (which together represent 72% of total emissions in the country) and not to the generation of energy. While the energy sector is responsible for 76% of greenhouse gas emissions in the world, in Brazil the energy matrix corresponds to 19% of the country's GHG emissions (graph below), due to 44% of the Brazilian energy matrix coming from renewable sources.

CHART 4. ENERGY MATRIX X GREENHOUSE GAS EMISSIONS IN BRAZIL



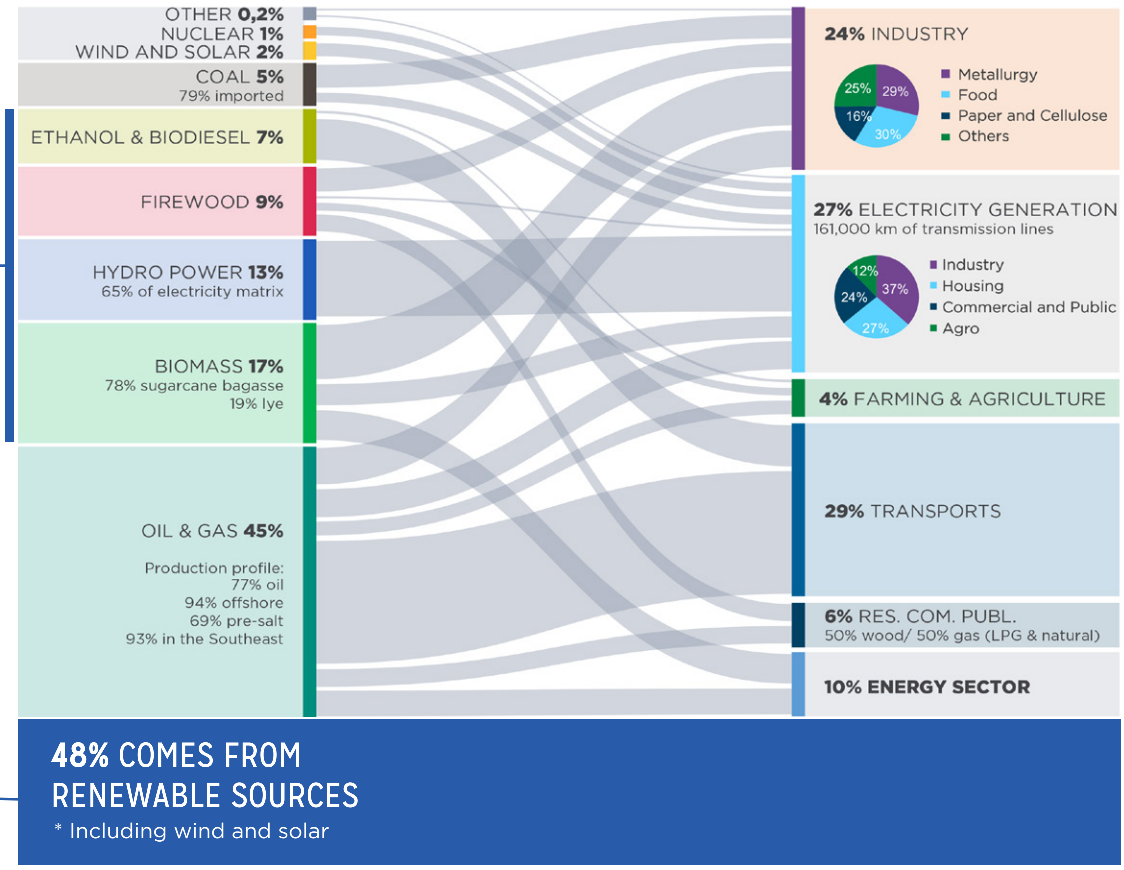
Source: Observatório do Clima (Climate Observatory), 2021[5]

5. Observatório do Clima. Greenhouse Gas Emissions and Removals Estimating System (SEEG). 2021

> The particularity of Brazil is that the generation of GHG in the country is strongly related to land use and agriculture and cattle ranching (which together represent 72% of total emissions in the country) and not to the generation of energy

Even so, there is a lot of room for the opportunities for emission reductions in energy generation. Data regarding the energy consumption of the most economically relevant sectors in Brazil by source (graph below), shows that it is possible to identify drivers for a decarbonization strategy for the energy matrix from both the supply and consumption perspectives. These perspectives will be presented in the following chapters.

CHART 5. NET ENERGY CONSUMPTION BY SOURCE IN BRAZIL (2019)



Source: Prepared by author. Data from ANP and BEN, 2021

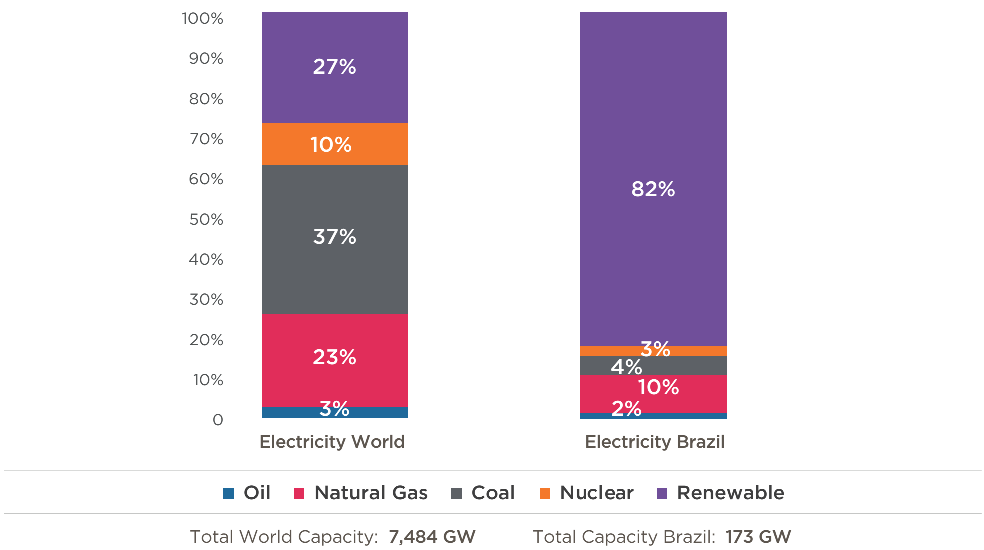
Pathways to Transition
(The Supply Perspective)

Electricity

The generation of energy from renewable sources, associated with the electrification of consumption, has emerged as a necessary condition for achieving climate goals in several economies. The electric power generation sector is at the heart of the energy transition process mainly because the sector acts as a means of achieving the decarbonization of of the consumers segments.

In Brazil, the electric matrix is adapted to allow the decarbonization of other sectors, which guarantees advantages in a low carbon economy. While in the world, countries seek to reduce coal-fired generation, in Brazil the starting condition is already an 82% renewable matrix (graph below).

CHART 6. MATRIX WORLD AND BRAZIL (2019)



Source: IEA, WEO 2020.

> In a context of concern with *ESG* measures, better financing options, expansion of the free market, and the establishment of a local equipment chain, wind and solar sources had a significant cost reduction, becoming economically competitive with other energy sources in Brazil

Having been favored by the country's abundant water resources, and developed based upon them, the Brazilian electricity sector is characterized in its essence by having large-capacity hydroelectric power plants with pluriannual regularization reservoirs, and long transmission lines interconnecting the national subsystems, constituting an interconnected generation and transmission system of continental dimensions, coordinated in a centralized way.

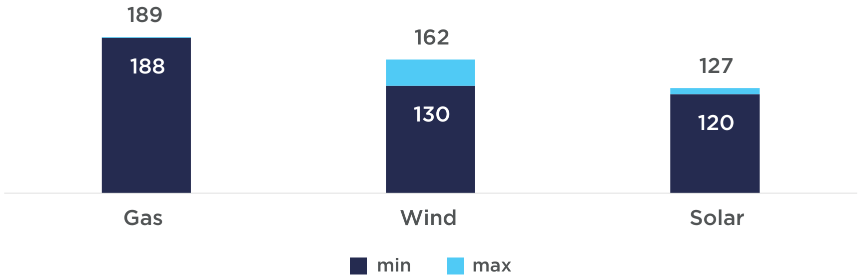
From the beginning of the 21st century, with the occasional decrease in the water levels of the reservoirs, this system began to present a certain vulnerability. As a result, natural gas emerged as a complementary source, establishing itself in the role of supporter of the country's energy security, and gaining space in a context of restricted hydroelectric expansion and reduction in the regularization capacity of the reservoirs with the entry into operation of run-of-the-river hydropower plants.

In this landscape, starting in 2011, a significant expansion of wind and solar sources began in Brazil. In that same year, wind represented 0.5% of the country's electricity matrix, while hydro sources represented 81%. Today, wind represents 9% and hydro represents 65%. The same occurred with the solar source, which started from zero in 2017 to represent almost 2% of the electric matrix in 2020 (BEN, 2021).

Wind and solar sources debuted in the energy matrix via the Proinfra, Incentive Program for Alternative Sources, created in 2002, and expanded through the holding of long-term contracting auctions, dedicated exclusively to these sources. In the other modalities of contracting, these sources have also counted on discounts in tariffs for the use of the transmission and distribution systems, and have been promoted by corporate PPAs (Power Purchase Agreements).

In a context of concern with ESG (*Environmental, Social and Corporate Governance*) measures, better financing options, expansion of the free market, and the establishment of a local supply chain, wind and solar sources had a significant cost reduction, becoming economically competitive with other energy sources in Brazil (chart below).

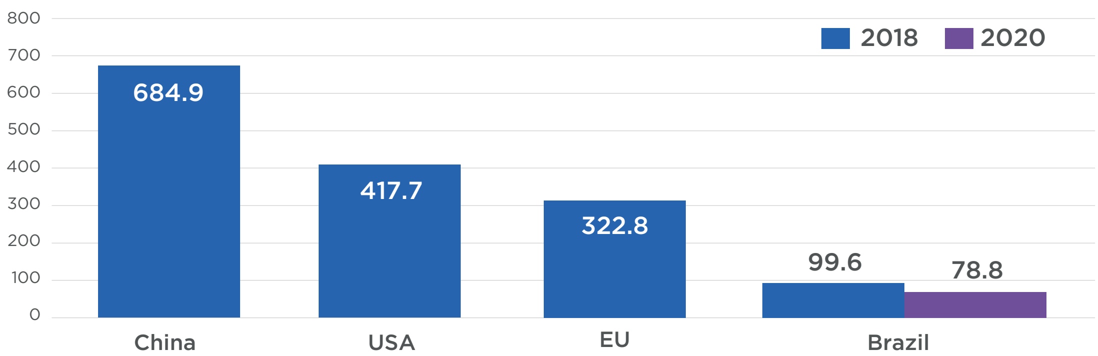
CHART 7. SALES PRICES AT THE 30th LEN - A-6/2019 (R$/MWh)



Source: CCEE, 2020[6]

The abundance of renewable resources for energy generation in the country gives the Brazilian electricity sector not only a lower level of CO_2 emission per MWh than many economies in the world (graph below), but also the possibility to electrify the economy and leverage other energy vectors or even - by having a much higher supply capacity than the growth in demand[7] - to take advantage of the technological and climate race of other countries to attract investments and export electricity.

CHART 8. CO_2 EMISSIONS (Kg) BY MWh GENERATED



Source: IEA, 2021.

One of these opportunities is related to the export of hydrogen, ammonia, methanol, or *electrofuels*, should the country advance in green hydrogen production and conversion technology. Because H_2 does not emit GHGs, it can be used both as a fuel and a storage solution, with advantages over conventional batteries when substantial amounts of energy need to be stored for a prolonged period.

Renewable sources represent investment opportunities mainly for the Northeastern region of the country, because, even though Brazil's whole territory has a high potential for renewable generation, the Northeast gains competitive advantage in wind generation by presenting strong, constant and unidirectional winds and, in solar generation, by presenting the highest average radiation indices and the smallest variations of solar incidence during the year. Today, considering only the assets in operation, 89% of the wind power already installed in Brazil is in this region, as well as 74% of the solar power.

6. Câmara de Comercialização de Energia Elétrica - Electricity Chamber of Commercialization

7. The National Energy Plan, PNE 2050, published by EPE in 2020, estimates an energy potential of 280 billion toe, accumulated until 2050, which largely exceeds the expected demand for the same period, of 15 billion toe.

Producing above its demand, the Northeastern region is also favored with the possibility of generating green hydrogen[8], potentially becoming an energy exporter through a Hydrogen Hub, or with the expansion of the electric energy transmission network to the Southeast, which is already forecasted to be expanded from the current 6 GW to more than 12 GW in 2023.

Since the country has fiscal limitations to foster its energy transition by offering subsidies, as we observe in developed countries, Brazil's great challenge will be to use all its potential in in the energy generation of as much sources as possible as a lever of value, taking advantage of the alignment between economic competitiveness and climate interests. The regulation and planning of the sector must advance to guarantee the correct signaling of prices as a stimulus for investment, as well as facilitating and guiding the trajectory for distributed generation, the opening of the market and the development of different energy solutions.

The Roles of Bioenergy and the Oil & Gas Industry in Energy Transition

Another opportunity for a possible decarbonization strategy of the Brazilian energy matrix from the supply perspective involves the oil and gas (O&G) and bioenergy industries. While the bioenergy industry presents a high degree of maturity in the country, the O&G industry has great investment capacity and technological development - compared to other sectors – and may, in the search for diversification of its portfolio, allocate relevant capital to renewable energy and become an important player in the Brazilian energy transition process.

Among the positive effects of the O&G industry's participation in the energy transition process are its experience in conducting projects in offshore environments, which can result in synergies with the country's incipient offshore wind power industry[9], and in the development of CCUS (Carbon, Capture, Utilization and Storage) technologies. In addition, leveraging the infrastructure established by the O&G industry decreases the capital effort required for the introduction of new energy sources.

In this context, refineries can be transformed to also process biomass, and pipeline networks can be leveraged to transport biomethane and, in the future, hydrogen. Refineries can also play a vital role in the development of the low-carbon economy by offering blue hydrogen[10], which can be produced by steam reforming natural gas (NG) with CCUS.

> Leveraging the infrastructure established by the O&G industry decreases the capital effort required for the introduction of new energy sources

8. "Green hydrogen" refers to hydrogen obtained from renewable sources.
9. In its 2020 Brazil Offshore Wind Roadmap study, EPE highlights that the technical potential for generation in the country reaches 700 GW.
10. "Blue hydrogen" refers to hydrogen obtained from natural gas.

With bioenergy, Brazil has for decades been preparing for a low-carbon economy in the transport sector. In the Otto cycle, Brazilian gasoline (with 27% ethanol in its composition) is one of the least GHG emitting in the world. In addition to anhydrous ethanol, the country also uses hydrated ethanol in flex-fuel vehicles. The successful use of ethanol as a complement to gasoline makes it possible to meet approximately 50% of the Otto cycle demand for biofuels. The synergy between the oil sector and the biofuels sector in fuel production requires small changes in engines but makes it possible to increase the blend of biofuels in fossil fuels, favoring the sharing of distribution systems and the use of the entire infrastructure already developed by the O&G industry, which is heavily based on liquid fuels.

Cooperation between these industries has been successfully explored in Brazil. In addition to sugarcane ethanol, which is recognized by the most demanding markets as an advanced biofuel, i.e. one with a low carbon footprint in its value chain, the country also has a growing production of ethanol from corn. Investments in a pipeline infrastructure allow the flow of up to six billion liters of ethanol per year from the producing regions to the large urban centers, making the option for hybrid vehicles interesting for the national market. Bioenergy also occupies a prominent position in the Diesel cycle, where the mixture of biodiesel is expected to reach 15% in volume on diesel by 2023. This condition allows Brazil to have its own energy transition agenda.

> In the Otto cycle, Brazilian gasoline (with 27% ethanol in its composition) is one of the least GHG emitting in the world

The successful implementation of ethanol from sugarcane and corn and biodiesel from various sources, but from soy, has consolidated the bioenergy sector in Brazil. Still, the country has other challenges such as the development of a new generation of biofuels capable of supplying sectors such as aviation and international shipping. The study Flight Plan for Aviation Biofuels in Brazil surveyed the availability of raw materials, refining routes, logistical alternatives, and the regulatory aspects for the development of biojet in the country[11].

In this context, it is worth highlighting the Fuel of the Future program, created in 2021 by the CNPE[12]. Among other objectives, the program seeks to create the necessary conditions for the introduction of biojet and an integrated policy for this biofuel with diesel and green naphtha[13]. These fuels could benefit from the supply chain already developed for the mature biodiesel industry in the country.

The use of cellulosic biomass also has a relevant scale in the Brazilian energy sector. According to BEN 2021, firewood and charcoal represent 8.9% of the country's primary energy production. The Brazilian steel industry is the only one in the world to retain significant use of charcoal as a thermo-reducing agent. Almost one-third of pig iron in Brazil uses charcoal as a reducing agent[14]. The modernization of the

11. Fapesp. "Flight Plan for Aviation Biofuels in Brazil: Action Plan". 2013 (Plano de voo para biocombustíveis de aviação no Brasil: Plano de ação).

12. National Council for Energy Policy (Conselho Nacional de Política Energética).

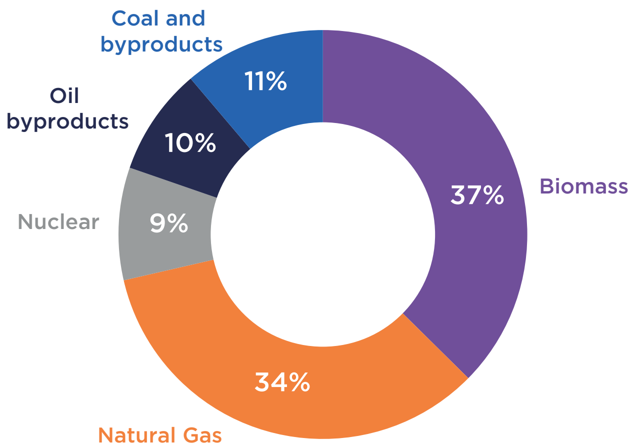
13. "Diesel and green naphtha" refer to streams similar to diesel and naphtha, but obtained from renewable sources, of plant or animal origin.

14. "Modernization of charcoal production in Brazil: subsidies for reviewing the Steel Industry Plan" - Brasília: Center for Strategic Studies and Management, 2015 (Modernização da produção de carvão vegetal no Brasil: subsídios para revisão do Plano Siderurgia" – Brasília: Centro de Gestão e Estudos Estratégicos, 2015).

charcoal production process can lead to a supply of bio-oil[15] as a co-product, thus increasing the options to produce cellulosic biofuels. In addition, although the use of excess sugarcane bagasse and sugarcane straw for cellulosic ethanol production is still incipient in the country, this biomass is widely used for generating bioelectricity. The extensive use of bagasse as a source of heat and electricity makes sugarcane biomass the second most important energy source in the country, representing 19.1% of the domestic energy supply in 2020.

Biomass thermal plants, like gas thermal plants, have as one of their main attributes the supply of firm energy to the country's interconnected electrical grid. The sugarcane crop in the Southeast allows for the generation of bioelectricity in the dry season, presenting great complementarity with hydropower plants. Biomass thermal plants, which in 2020 were the main source of thermoelectric energy, surpassing natural gas generation (graph below), may in the future be associated with carbon capture and storage technologies to produce energy with negative emissions (Bioenergy with Carbon Capture and Storage - BECCS).

CHART 9. SHARE OF EACH SOURCE IN THERMOELECTRIC GENERATION IN 2020



Source: BEN, 2021

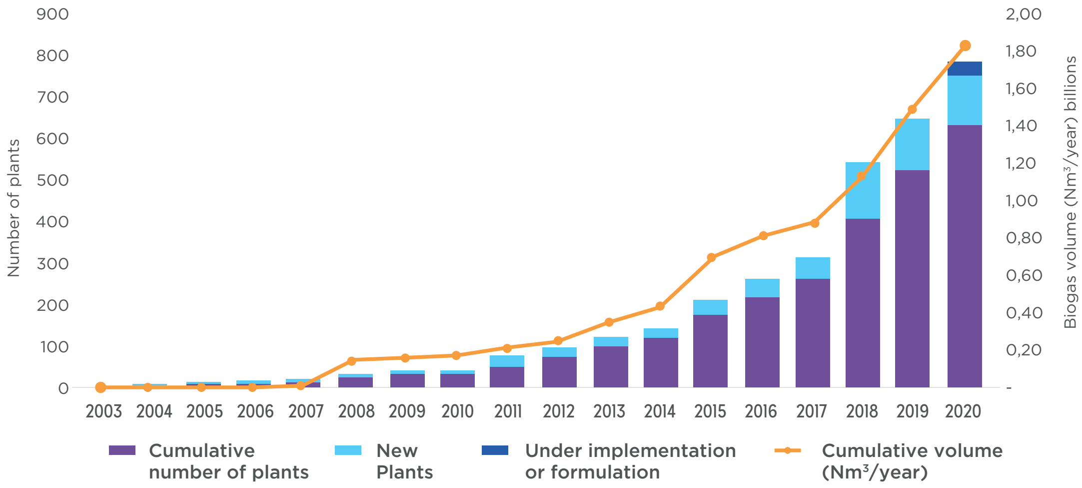
The Brazilian bioenergy industry contributes an important share in the production of liquid fuels, such as ethanol and biodiesel for the transport sector, as well as solid biomass fuels like bagasse, firewood, wood chips and charcoal, together with natural gas, which contribute as one of the main sources for the country's thermal power plants.

On the other hand, and different form of liquids and solids, the supply of biogas and biomethane is far from reaching its gross potential, although it is in the process of consolidation. A study developed by the Brazilian Biogas and Biomethane Association - Abiogás, in 2018, indicated that Brazil is the country with the highest gross biogas production potential, about 84.6 billion Nm^3/year. From 2019 to 2020 the sector grew by 23% (chart below). Despite this growth, which has been consistent over the past five years, the country currently has an annual production of 1.83 billion Nm^3/year, about 2% of its gross potential[16].

15. "Bio-oil" is a black liquid obtained through a process of pyrolysis, in which biomass is submitted to high temperatures in an isolated environment with little or no oxygen.

16. CIBIOGÁS. Overview of Biogas in Brazil 2020. Technical Note N.001/2021. 2021.

CHART 10. BIOGAS GROWTH IN BRAZIL



Source: ABIOGAS, 2020

The introduction of biomethane in the natural gas grid could gradually reduce the carbon intensity of gas consumers, while, on the other hand, the biomethane potential could develop supported by investments in existing infrastructure. In the state of São Paulo, alone, there are about sixty-six sugar-energy plants located less than 20 km from the gas pipeline network[17].

Another issue would be land use. Despite the great availability of arable land in the country, intensification of cattle ranching is one of the key issues for increasing land availability and increasing the participation of bioenergy in the Brazilian matrix without converting ecosystems. Increasing the density of cattle ranching from the current one head of cattle per hectare to two heads of cattle per hectare in 2050 could expand by 69 million hectares the area available for agriculture[18].

With the appropriate use of land and the country's favorable climate conditions, bioenergy emerges as one of the most promising alternatives to support the Brazilian energy transition process, especially in the biofuels segment, which is part of the complex solution for sectors that are difficult to decarbonize such as the aviation, maritime and industrial sectors.

17. EPE. Impacts of Biogas and Biomethane Participation in the Brazilian Matrix. IV Biogas Forum. 2017 (Impactos da Participação do Biogás e Biometano na Matriz Brasileira. IV Fórum do Biogás. 2017).
18. EPE. Energy Resource Potential in the 2050 Horizon. Technical Note PR 04/18. 2018 (Potencial de Recursos Energéticos no Horizonte 2050. Nota Técnica PR 04/18. 2018).

Changes in Energy Consumption (The Demand Perspective)

The challenge of cities: growing demands and sustainability

Cities today are home to slightly more than half the world's population, but account for almost two-thirds of energy consumption and about 70% of associated carbon emissions, according to data from the IEA[19]. Mobility in these spaces is an element of interaction among their residents and of the development of these regions. However, the predominance of individual motorized transportation for travel results not only in economic and energy inefficiencies, but also environmental ones, since the transport of people and goods in large cities is a major source of emissions, not only of GHGs, but also of local pollutants.

The solution to this problem consists in providing these populations with decentralized services, as well as the means and conditions to move around easily, eliminating the negative externalities currently associated with mobility: local pollution, traffic jams, accidents and greenhouse gases. In this sense, urban planning and public transportation appear as critical elements to address the issue of urban mobility. The intrinsic energy efficiency of the collective modal associated with new motorization technologies, intelligent traffic control systems and the encouragement of non-motorized transport are the means to achieve sustainable mobility.

19. Energy Technology Perspectives. Paris, 2016.

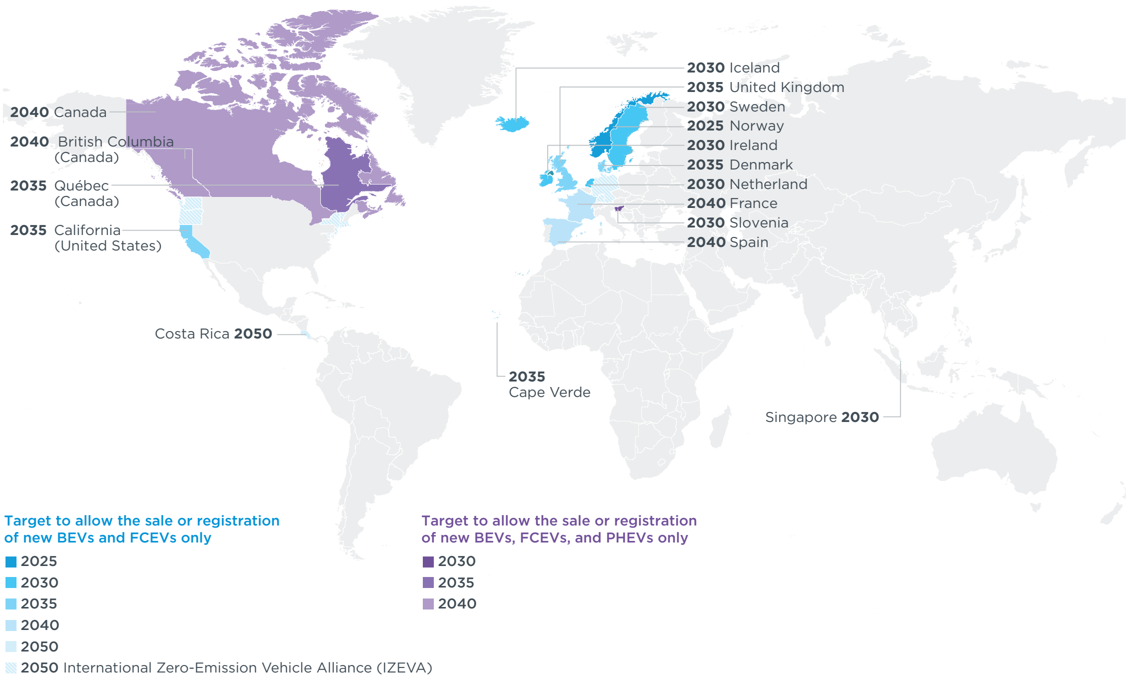
The transport sector

In this set of changes necessary to achieve sustainability, a trend is already consolidated: the gradual elimination of fossil fuels as an energy source for urban mobility through two most likely alternatives, electrification and biofuels.

In electrification, heavy-duty transport (buses and trucks for urban use) meets the conditions to be the pioneer segment, since globally it is responsible for the emission of 1/3 of the GHGs of the transport sector and about 70% of the local pollutants, despite comprising less than 5% of the total vehicle fleet. Moreover, the fact that they travel shorter distances on predetermined routes makes it easier to install charging infrastructure. Regarding costs, although electric buses still have a higher initial cost, their lower operating and maintenance costs make them economically competitive with diesel buses. However, despite these advantages, the adoption of public policies is indispensable in the initial stages to create market and scale for the industries of the sector.

To decarbonize the light-duty fleet, the global automotive industry is developing new models and investing in battery production capacity. Public policies in several countries have set targets for the electrification of their fleets (map below). As a result, we have seen a gradual rise in the share of electric vehicles in global auto sales. In 2020, almost 5% of vehicles sold globally were electric[20].

CHART 11. GOVERNMENTS WITH OFFICIAL TARGETS TO ELIMINATE 100% OF SALES OR REGISTRATIONS OF NEW CARS WITH INTERNAL COMBUSTION ENGINES BY A CERTAIN DATE



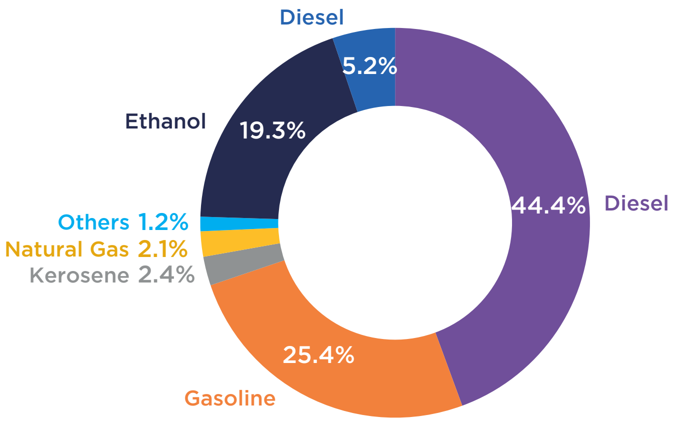
Source: ICCT, 2020

20. IEA. Global Electric Vehicles Outlook. Paris, 2021. All rights reserved.

In Brazil, the light transport matrix is already strongly renewable, with biofuels accounting for more than 40% of the energy consumed in the segment

While in the world the automotive industry has been developing new models and investing in capacity to produce batteries aiming at the decarbonization of the light fleet, in Brazil, the light transport matrix is already strongly renewable, with biofuels accounting for more than 40% of the energy consumed in the segment[21]. This role may expand during the transition process, with room for a more intense contribution to the decarbonization of long-distance freight transport after the development of advanced biofuels with an extremely low carbon footprint throughout its life cycle. The following chart explains this potential for growth in the share of alternative sources in the transportation matrix as a whole, since fossil fuels still account for three-fourths of the demand.

CHART 12. TRANSPORTATION MATRIX IN BRAZIL 2020



Source: BEN, 2021

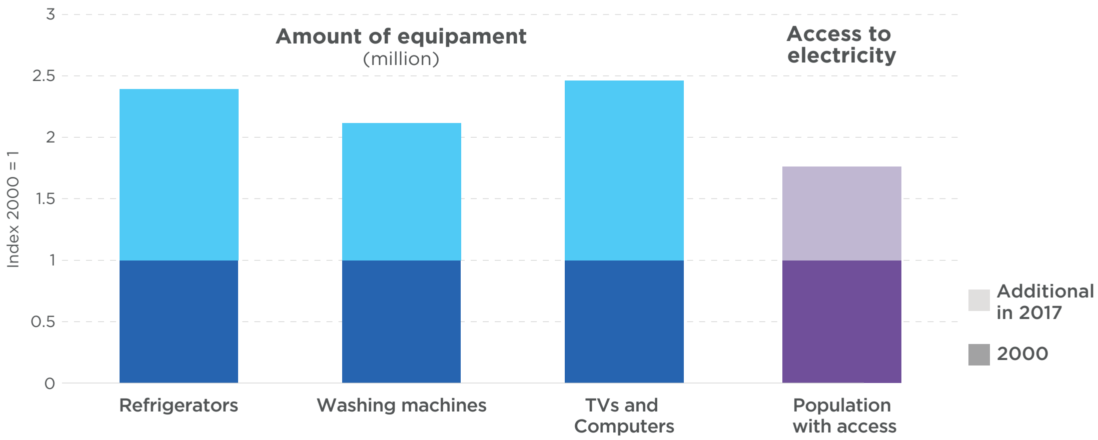
Notwithstanding this competitive advantage of biofuels in Brazil, the global movements of the automotive industry and the cost reduction of energy storage technologies represent an important driving force in the decarbonization process of the light transport sector. The result of this composition of forces constitutes one of the main uncertainties for Brazil's energy transition.

21. EPE. Relatório Síntese do Balanço Energético Nacional. Rio de Janeiro. 2021.

The Buildings and Residences Sector

Despite being the segment that can offer the greatest contributions to the mitigation of emissions in cities, the transformations underway in urban areas around the world are not limited to the issue of mobility. According to data from the IEA[22], buildings and the construction sector account for one-third of global final energy consumption and 40% of total direct and indirect CO_2 emissions. In addition, the increasing ownership and use of equipment, highlighted in the following graph, as well as the rapid expansion in the total built-up area in developing countries, indicate a rising trend in energy demand in these segments. The doubling of average incomes and the increasing purchasing power of an emerging middle class have doubled per capita electricity use in the residential sector over a twenty-year period in most developing countries. In Brazil, energy demand in the residential sector was 27.6 million tons of oil equivalent in 2020 and, according to the EPE's Ten Year Energy Plan (PDE 2030), it is expected to grow at an average annual rate of 1.5% until 2030. Also, according to the PDE 2030, the share of electricity in meeting this demand should rise from 46% in 2020 to 57% in 2030, a projection that corroborates the IEA's analysis for emerging countries. The ongoing energy transition will need to reconcile this growth trend in urbanization with sustainability.

CHART 13. MAIN DRIVERS OF GROWTH IN ELECTRICITY DEMAND IN THE RESIDENTIAL SEGMENT IN DEVELOPING ECONOMIES (2000 TO 2017)



Source: IEA, WEO 2018.

To mitigate the effects of this trend, public policies and technological innovations aimed at rationalization and efficiency are presented as alternatives in the scope of the so-called "smart and sustainable cities". Innovations for the management of decentralized production and energy demand or the management and use of waste are examples of how these smart cities can mitigate the pressure on their infrastructure and services. This is the case with sanitation and drainage systems, traditionally expensive and based on steel and concrete structures, but which can extend their coverage through relatively simple, nature-based solutions, such as the use of wetlands, natural hill coverage, and the expansion of green areas.

22. IEA. Buildings a source of enormous untapped efficiency potential. 2020.

Additionally, another form of accelerating the energy transition in cities, also provided by innovation, is the combination of the digitalization of transmission grids with distributed generation from renewable sources and the increasing spread of smart home appliances. This joint movement points to more secure, distributed, integrated, and multi-directional energy systems.

Alternatives for segments that are difficult to decarbonize

The segments of difficult decarbonization are those in which, for technical or economic reasons, there are limited prospects for replacing fossil fuels with less polluting energies. Among these are air and maritime transport and some sectors of heavy industry, such as steel, basic chemicals and cement production, whose processes themselves have CO_2 as a co-product.

At least 1.2 billion people on the planet lack decent housing and access to modern urban infrastructure. The economic development of these populations will inevitably lead to increased demand for materials such as steel and cement.

New technological routes currently under development can mitigate emissions from these sectors, such as the use of hydrogen, CCUS systems and the use of biomass. However, these routes are not yet consolidated, and do not present economic viability and/or sufficient scale. In addition, the capacity already installed cannot be quickly changed, which imposes the search for greater efficiency of assets that will continue in operation for many decades to come. In these cases, the "off-the-shelf" alternatives that can be considered to mitigate emissions from the sector would be the substitution of materials and the expansion of recycling and reuse.

> At least 1.2 billion people on the planet lack decent housing and access to modern urban infrastructure

In the case of air and maritime transport, where the use of high energy density sources to reduce the volume and mass of the fuel transported is indispensable, the options of electrification of ships and aircraft seem distant, at least in the short and medium terms. The long service life of the equipment is also an obstacle. Ships have a useful life of up to 40 years and aircraft of up to 20 years. This limits the changeover and means that new types of propulsion are not, for the time being, considered as the main route for the transition in these modes. The solution is, therefore, new drop-in fuels suitable for use in existing engines, in particular synthetic fuels such as e-fuels and advanced biofuels such as biojet (bioQAv).

From a public policy standpoint, both maritime and air transportation are subject to two distinct spheres of regulation. National and local governments establish guidelines for transport within their borders, while international transport is regulated by two United Nations bodies: the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO).

In the international maritime transport, the IMO's target is that by 2050 emissions will be 50% lower than they were in 2008[23]. In international air transport, the ICAO's target is for carbon-neutral growth from 2020. Additionally, in aviation, another body, the International Air Transport Association (IATA), which gathers airlines from around the world, has set a voluntary target to reduce the sector's emissions by half of what they were in 2005, by 2005[24].

There is an expectation that the implementation of these targets will encourage similar movements at the national level. Experts recommend, however, a systemic and multi-criteria approach in which, for each option, the entire life cycle of the alternative, the availability of raw materials, energy density, the existence of certification standards, compatibility with the current fleet, storage infrastructure, technological maturity, and safety in use are evaluated. In addition, there is also an emphasis on the importance of cross analyses, which consider the impacts and synergies of the various possible routes (products and co-products) on the other segments, as is the case, for example, of synthetic Bunker, which is a co-product of the advanced BioQAV, produced from biomass.

This demonstrates the inadequacy of strictly sectoral targets, and the importance of an integrated approach, aiming for global targets to limit global temperature, with each country selecting the set of measures best suited to their accomplishment.

A carbon-neutral world in 2050 does not mean that all sectors will be carbon neutral[25]. Some sectors, such as steel, despite efforts to contribute, may not be able to neutralize emissions, while other sectors may become "carbon negative", thus ensuring the global target.

> A carbon neutral world in 2050 does not mean that all sectors will be carbon neutral

23. IMO. Initial IMO strategy on reduction of GHG emissions from ships. Londres, 2018.

24. IATA. Aviation and climate change fact sheet. Montreal, 2021.

25. "Zero carbon" refers to the condition that any amount of CO2 released into the atmosphere from company/sector activities is balanced by an equivalent amount removed. The term negative carbon implies that a company/sector removes more carbon dioxide from the atmosphere than it emits.

Final Remarks

The Covid-19 pandemic has demanded efforts from nations, to a greater or to a lesser extent, in the form of expansionary fiscal and monetary policies to mitigate its economic and social effects. At the same time, it has reinforced the perception of urgency regarding climate change, amplifying the social clamor for concrete environmental actions to address climate risk. The global concern with climate change has intensified and the actions and policies that are being developed will consolidate, producing, over the coming decades, a structural change in the configuration of the world's energy matrix, which alone accounts for 3/4 of global emissions.

Differently from the global matrix, Brazilian GHG emissions are generated by land use and agriculture and cattle ranching, which correspond to 72% of the country's emissions. The great challenge for meeting Brazil's climate targets is the development of a low carbon agricultural sector and the control of irregular deforestation. In this field, the regulation of carbon credits, together with effective public policies to "keep the forest standing", can have an important contribution. By creating a demand for emission offsets, economic incentives are created for sectors that absorb carbon such as reforestation, pasture recovery and forest conservation. Nevertheless, it is necessary to consider in energy planning and policies the opportunities to make the energy chain even more sustainable, evaluating and promoting alternatives for sectors that are difficult to decarbonize (heavy industry and transportation), as well as developing low carbon energy resources not yet fully exploited.

Additionally, the energy transition can be an important lever for a more sustainable economy with Brazil positioning itself globally as a provider of low carbon solutions for other regions. The country already has a mostly renewable electricity sector that is expanding with renewable solutions that are extremely competitive in global terms, and this could be the vector for large-scale production of green hydrogen. Similarly, the country is set as one of the global leaders in bioenergy, with important participation of biofuels in transport (ethanol and biodiesel) and electricity generation, and can develop skills in new advanced forms of biofuels (cellulosic ethanol, hydrogenated diesel, biokerosene, renewable bunker) and biogas/biomethane.

Brazil also has a dynamic and structured O&G sector that has great technical expertise, investment capacity and technological development, which could be capitalized in projects of scale and complexity required in the transition, such as hydrogen generation and offshore wind projects, or even, based on its knowledge of geology and reservoirs, those of CCUS. The country's natural gas reserves can also be used to produce blue hydrogen, as well as form low carbon intensity blends with biogas, similar to what is done with ethanol and gasoline in Brazil. It is also possible to take advantage of the market and the institutional framework of the fossil fuel market to leverage new routes for biofuels in the country. Or even take advantage of the established infrastructure of the O&G industry, such as converting refineries into biorefineries and using existing pipelines to transport biofuels and biogas. In addition, the industry can also contribute to the decarbonization of its processes and production chain, acting in the control of flare losses, energy efficiency and control of fugitive emissions.

From the demand perspective, the challenges to improve well-being in Brazil's large cities can be addressed in conjunction with climate goals. For example, the transportation sector can collaborate with the country's energy transition by promoting the electrification of the heavy vehicle fleet, especially urban buses where electric motors are more efficient than those powered by combustion, and by investing in technological and industrial routes that produce advanced drop-in biofuels for the different transportation segments. Reducing the use of fossil fuels in developing countries, with restricted resources for building the necessary infrastructure for fleet electrification and with continental dimensions like Brazil, necessarily involves advancing the use of biofuels.

The competitiveness of renewable energy in Brazil and the international movement for climate impacts to be part, alongside social and environmental impacts, of investment project evaluations, facilitates the trajectory of the new energy sector in the country. However, despite these advantages, the adoption of public policies is crucial in the initial stages to create a market and scale for the industries in the sector.

Among the opportunities created by ET in Brazil is the possibility of the country becoming an energy hub, providing sustainable energy for itself and other countries. Brazil, with its high and competitive solar and wind potentials, benefits from the possibility of generating clean electricity for its industry, as well as producing green H2. The adoption of H_2 as a route for ET by developed countries, such as Germany, would make this segment economically viable in Brazil with a view to export (directly or through products). Moreover, the technological development of new products would create the possibility for the country to become an exporter of machinery and equipment used in the sector, or even, as in the case of the development of

> Energy transition can be an important lever for a more sustainable economy with Brazil positioning itself globally as a provider of low carbon solutions for other regions

advanced drop-in biofuels, to explore new markets aimed at transport segments that are difficult to decarbonize.

However, regulatory development and planning are critical to ensure that the available technologies are chosen for the value they add to society, as well as for their ability to promote coordination between the public and private sectors, enabling the country to prepare not only for the opportunities, but also for the risks of the energy transition.

There is no single path in the energy transition process. Each country will have to pursue its own path by seeking to capture the opportunities of bringing together economic growth and sustainability, while consolidating a low carbon economy. In this sense, Brazil will not have an agenda for ET equal to that of Europe or the U.S., since, considering its renewable electricity generation park and the weight of the biofuels sector, Brazil has already been making its transition for decades. The country could benefit from the knowledge acquired and from an already balanced and sustainable energy matrix, to create competitive advantage through low-carbon energy provision for the country's value chains, as well as to develop more advanced technological routes. It should be considered that an adequate public-private coordination, which manages the trade-offs of energy alternatives and mitigates the risks of transformation, has the merit of providing the opportunity to maximize the benefits of the transition path for society as a whole, promoting welfare while positioning the country with an energy matrix compatible with a low carbon economy.

In this sense, Brazil will not have an agenda for ET equal to that of Europe or the U.S., since, considering its renewable electricity generation park and the weight of the biofuels sector, Brazil has already been making its transition for decades

Trends and Uncertainties

The consideration of this set of factors highlights critical trends and uncertainties for Brazil's energy transition in 2050:

Trends

I.	Shift the environmental agenda to the center of countries' economic policies.
II.	Reduction in the use of fossil fuels as a source of energy for urban mobility.
III.	Increase in the demand for energy in cities.
IV.	Increase in energy demand from the global industrial sector.
V.	Increase in the decentralized generation, digitalization and use of renewable sources in the power sector
VI.	Electrification of the final consumption of energy.
VII.	Increase in the supply of biogas and biomethane.
VIII.	Trend toward the use of biofuels to meet decarbonization metrics in international air and maritime transportation.
IX.	The oil and gas industry seeking to process renewable raw materials in refining assets.

Uncertainties

- **I.** Uncertainty regarding the adequacy of incentives and investments allocated to the levels required for a successful transition.
- **II.** Uncertainty regarding the polarization (or coordination) among global potentials in the energy transition process.
- **III.** Uncertainty regarding the pace of implementation and effectiveness of public policies for mitigation of emissions.
- **IV.** Uncertainty regarding the speed of cost reduction of new motorization and energy storage technologies.
- **V.** Uncertainty regarding the change in consumer preferences regarding the adoption of ride-sharing, either in public collective modes or in transportation by applications.
- **VI.** Uncertainty regarding the speed of increase in the recycling and reuse levels of emission-intensive industrial materials.
- **VII.** Uncertainty regarding the speed of reduction in the costs of manufacturing drop-in advanced fuels for air and maritime transportation
- **VIII.** Uncertainty regarding the ability to coordinate across sectors to implement integrated multi-sector solutions.
- **IX.** Uncertainty regarding the development trajectory of offshore wind generation potential.
- **X.** Uncertainty regarding the pace of implementation of regulatory changes underway in the electricity sector and whether they will be effective in allowing the introduction of innovative technologies and ensuring that the various sources are valued for their real contribution to the system.
- **XI.** Uncertainty regarding how Brazil will insert itself in the hydrogen economy.
- **XII.** Uncertainty regarding how the energy arrangements with hydrogen will impact the development of the electric sector.
- **XIII.** Uncertainty regarding which sources and technologies can gain space in the electric sector in the context of the energy transition
- **XIV.** Uncertainty regarding what are the best energy storage alternatives for the country: hydroelectric reservoir, hydrogen, batteries, cave etc.

XV. Uncertainty regarding the impact on the electric generation and transmission operation and infrastructure because of the ongoing trend of decentralization, decarbonization and digitalization.

XVI. Uncertainty regarding what the pace of penetration of Smart power grids will look like in the coming years.

XVII. Uncertainty regarding whether Brazil will be able to export renewable electricity via H_2.

XVIII. Uncertainty regarding the role of natural gas in the energy transition.

XIX. Uncertainty regarding how to exploit the renewable potential of the Northeast, expand electricity transmission, allowing greater export of electricity to the other subsystems, or exporting H_2, ammonia or synthetic gas, for example.

XX. Uncertainty regarding whether biogas and biomethane will be used in a decentralized manner or have access to the pipeline network enabling decarbonization of NG.

XXI. Uncertainty regarding decarbonization fuels for international maritime transport.

XXII. Uncertainty regarding the supply of biofuels in the quantity needed to decarbonize heavy road transport, maritime transport, and air transport.

XXIII. Uncertainty regarding whether and how fast the bio-oil chain will develop in Brazil.

XXIV. Uncertainty regarding the regulation of biorefining routes through co-processing.

XXV. Uncertainty regarding the relative competitiveness of pure electric vehicles compared to flex or hybrid vehicles.

Next steps

The prospects for the future obtained in Phase I of the ETP need to be consolidated and prioritized to generate inputs for the scenario models that will be developed. For this convergence, specialists will be invited to evaluate and classify the consolidated trends and uncertainties as to their level of uncertainty and level of impact on the energy market. The critical mass generated will then be prioritized in a cross impact matrix, supporting the elements that will be used in the quantification of the variables that will be utilized in the scenario modeling.

The scope of the work foresees the elaboration of three energy transition trajectories that will be simulated in the third and last phase of the ETP, which is the development of scenarios, scheduled to occur in 2022.

Realization:

BRAZILIAN CENTER FOR INTERNATIONAL RELATIONS

Inter-American Development Bank

Empresa de Pesquisa Energética

cebri.org

iadb.org

epe.gov.br

Sponsors:

Support:

ADVOGADOS