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THE ENERGY TRANSITION IN BRAZIL

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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ABBREVIATIONS

ANEEL	*Agência Nacional de Energia Elétrica* (National Electricity Agency)
BCB	*Banco Central do Brasil* (Central Bank of Brazil)
BIP	*Plataforma Brasil de Investimentos Climáticos e para a Transformação Ecológica* (Sustainable Investment Platform for Ecological Transformation, also known as *Plataforma Brasil Invest*)
BNB	*Banco do Nordeste* (Northeast Bank)
BNDES	*Banco Nacional de Desenvolvimento Econômico e Social* (National Bank for Economic and Social Development)
BRL	Brazilian real
CCEE	*Câmara de Comercialização de Energia Elétrica* (Electric Energy Commercialisation Chamber)
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CMSE	*Comitê de Monitoramento do Setor Elétrico* (Power Sector Monitoring Committee)
CNPE	*Conselho Nacional de Política Energética* (National Energy Policy Council)
CO_2	carbon dioxide
DFIs	development finance institutions
EPE	*Empresa de Pesquisa Energética* (Energy Research Office)
ETP	Ecological Transformation Plan
EU	European Union
EV	electric vehicle
FNE	*Fundo Constitucional de Financiamento do Nordeste* (Constitutional Fund for the Northeast Region)
GDP	gross domestic product
GHG	greenhouse gas
GOWA	Global Offshore Wind Alliance
$GtCO_2eq$	gigatonne of carbon dioxide equivalent
G20	Group of 20
GWh	gigawatt hour
IRENA	International Renewable Energy Agency
kg	kilogramme
km	kilometre
LDV	light-duty vehicle
LPT	*Luz para Todos* (Light for All)
MF	*Ministério da Fazenda* (Ministry of Finance)
MMA	*Ministério do Meio Ambiente e Mudança do Clima* (Ministry of the Environment and Climate Change)

MME	*Ministério de Minas e Energia* (Ministry of Mines and Energy)
MW	megawatt
MWh	megawatt hour
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
OECD	Organisation for Economic Co-operation and Development
ONS	*Operador Nacional do Sistema Elétrico* (National Grid Operator)
PADIS	*Programa de Apoio ao Desenvolvimento Tecnológico da Indústria de Semicondutores* (Semiconductor Industry Technological Development Support Programme)
PLANTE	*Plano Nacional de Transição Energética* (National Energy Transition Plan)
PNDV	*Programa Nacional de Diesel Verde* (National Green Diesel Programme)
PNH2	*Programa Nacional de Hidrogênio* (National Hydrogen Programme)
PNMC	*Plano Nacional sobre Mudança do Clima* (National Policy on Climate Change)
PNPB	*Programa Nacional de Produção e Uso do Biodiesel* (National Programme for the Production and Use of Biodiesel)
PNTE	*Política Nacional de Transição Energética* (National Energy Transition Policy)
PPA	power purchase agreement
PPCDAm	*Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal* (Action Plan for Prevention and Control of Deforestation in the Amazon)
ProBioQAV	*Programa Nacional de Combustível Sustentável de Aviação* (National Programme for Sustainable Aviation Fuel)
PV	photovoltaic
REIDI	*Regime Especial de Incentivos para o Desenvolvimento da Infra-Estrutura* (Special Incentives Programme for Infrastructure Development)
SAF	sustainable aviation fuel
SDG	Sustainable Development Goal
tCO_2eq	tonnes of carbon dioxide equivalent
TEJ	*Transição Energética Justa* (Just Energy Transition Programme)
TPES	total primary energy supply
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar
VRE	variable renewable energy

EXECUTIVE SUMMARY

This report sets out Brazil's experience in the deployment of renewable energy as part of the country's energy transition.

One of the world's largest economies and possessing a rich endowment of natural resources, Brazil is uniquely positioned to inform energy transition and climate change initiatives elsewhere.

Chapter 1

With a comprehensive policy framework and effective government co-ordination, Brazil currently maintains a remarkably low-carbon energy mix: around 50% of its energy comes from renewable sources. This is the result of long-term energy policies that have primarily focused on energy security. As noted in Chapter 1 of this report, this approach has translated into a greenhouse gas (GHG) emission profile that differs from the global average. In 2023, Brazil's energy-related emissions accounted for less than 20% of the country's total GHG emissions. In contrast, the global average was around 75% in 2022.

Chapter 2

Brazil's current energy mix is the result of a long-term commitment to renewable energy, supported by government policies and incentives. The latter benefits include tax breaks, subsidies and favourable financing conditions. These measures aim to lower the cost barriers associated with renewable technologies, making them more competitive with traditional energy sources.

Chapter 3

Brazil's current energy transition efforts include plans to boost the share of renewable energy in the energy mix, while maintaining energy security and affordability. The country is now able to imagine a future in which solar, wind, bioenergy and efficiency play increasingly significant roles, supported by technological progress, public policies and international co-operation. This vision aligns with global efforts to reduce emissions and shift to a low-carbon economy, positioning Brazil as a potential leader in sustainable energy practices.

Chapter 4

The factors enabling Brazil's energy transition include: 1) the competitiveness of Brazil's renewable energy; 2) the country's abundant mineral resources, which support the renewable energy sector by supplying essential materials for technological development; and 3) the strong institutional governance structures that facilitate co-ordinated energy planning and policy implementation.

In addition, Brazil benefits from a robust domestic financial ecosystem that offers long-term capital in local currency at competitive rates. Furthermore, the existing physical infrastructure provides a solid foundation for integrating renewable energy resources and expanding capacity.

Chapter 5

The following lessons from the Brazilian case study are vital to the global energy transition:

- Integrating strategic energy planning and domestic financial institutions is critical in de-risking renewable energy investments, ensuring their long-term viability and success.
- Effective governance frameworks are crucial in navigating the complexities of the energy transition, fostering stakeholder collaboration and providing policy coherence.
- Investing in human capital development is fundamental in sustaining the renewable energy sector. Such investment enables adaptation to evolving technological and market demands, while also supporting continuous innovation.

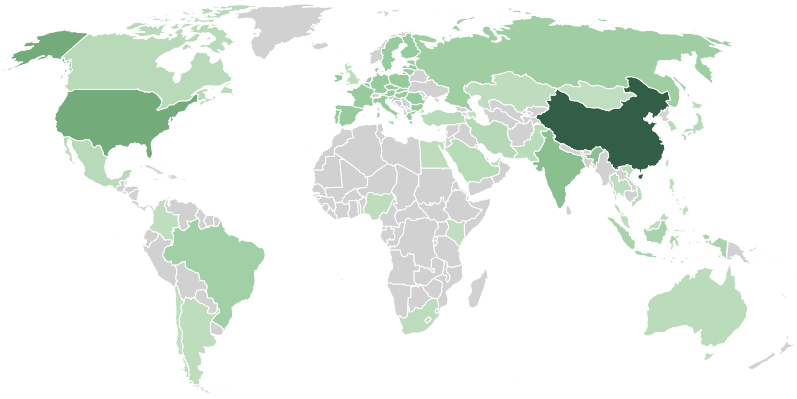
1. EMISSIONS AND THE BRAZILIAN ENERGY MIX: FACTS AND FIGURES

1.1 GREENHOUSE GAS EMISSIONS

In 2023, fourteen countries plus the European Union accounted for 75% of the world's total greenhouse gas (GHG) emissions. China was the largest emitter, with 26% of the total, followed by the United States, with nearly 11%. Brazil was among the top ten GHG emitters worldwide, with a share of less than 4.5% (Figure 1).

Figure 1 Total GHG emissions in 2023: Selected countries

Region	$MtCO_2$	%	Cumulative
China	13 969	26.0%	26.0%
United States	5 895	11.0%	36.9%
India	4 196	7.8%	44.7%
European Union (27)	3 105	5.8%	50.5%
Russian Federation	2 691	5.0%	55.5%
Brazil	2 382	4.4%	59.9%
Indonesia	1 922	3.6%	63.5%
Iran (Islamic Republic)	1 065	2.0%	65.5%
Japan	1 032	1.9%	67.4%
Saudi Arabia	879	1.6%	69.0%
Canada	800	1.5%	70.5%
Mexico	778	1.4%	71.9%
Republic of Korea	627	1.2%	73.1%
Türkiye	612	1.1%	74.2%
Australia	581	1.1%	75.3%
Viet Nam	536	1.0%	76.3%
Pakistan	522	1.0%	77.3%
South Africa	513	1.0%	78.2%
Argentina	422	0.8%	79.0%
Thailand	417	0.8%	79.8%
Malaysia	416	0.8%	80.6%
Nigeria	400	0.7%	81.3%
United Kingdom	392	0.7%	82.0%
Egypt	368	0.7%	82.7%
Kazakhstan	340	0.6%	83.4%
Philippines	284	0.5%	83.9%
United Arab Emirates	284	0.5%	84.4%
Colombia	259	0.5%	84.9%
Kenya	112	0.2%	85.1%
Chile	108	0.2%	85.3%
Mongolia	93	0.2%	85.5%



Source: (Friedlingstein *et al.*, 2024) – with major processing by (Our world in data, 2023).

Note: $MtCO_2$ = million tonnes of CO_2.

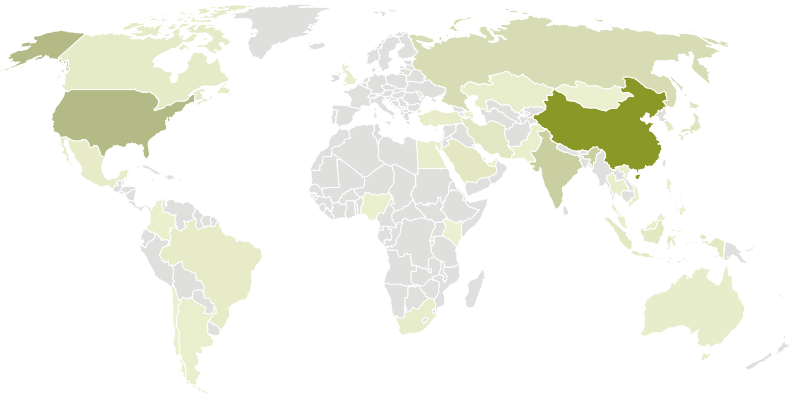
Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Approximately 75% of total global GHG emissions come from activities related to fossil emissions and industrial processes.[1] Brazil had the 12th largest fossil emissions in 2023, contributing 1.3% of the world's total emissions (Figure 2).

[1] *'Fossil emissions' is a measure of the quantity of carbon dioxide (CO_2) emitted by the burning of fossil fuels (coal, oil, gas and flaring) as well as the CO_2 emitted directly by industrial processes, such as cement and steel production. The 'fossil emissions' measure does not include emissions from changing land use, deforestation, soils or vegetation. See OurWorldinData.org (https://ourworldindata.org) for further details.*

Figure 2 GHG from fossil emissions in 2023: Selected countries

Region	$MtCO_2$	%	Cumulative
China	11903	31%	31%
United States	4911	13%	44%
India	3062	8%	53%
European Union (27)	2511	7%	59%
Russian Federation	1816	5%	64%
Japan	989	3%	67%
Iran (Islamic Republic)	818	2%	69%
Saudi Arabia	736	2%	71%
Indonesia	733	2%	73%
Republic of Korea	577	2%	74%
Canada	549	1%	76%
Brazil	486	1%	77%
Mexico	483	1%	78%
Türkiye	432	1%	79%
South Africa	402	1%	80%
Australia	383	1%	81%
Viet Nam	335	1%	82%
United Kingdom	305	1%	83%
Malaysia	289	1%	84%
Egypt	269	1%	85%
Thailand	264	1%	85%
Kazakhstan	255	1%	86%
United Arab Emirates	229	1%	87%
Pakistan	201	1%	87%
Argentina	196	1%	88%
Philippines	155	0%	88%
Nigeria	129	0%	88%
Colombia	105	0%	89%
Chile	77	0%	89%
Mongolia	47	0%	89%
Azerbaijan	44	0%	89%
Kenya	22	0%	89%



Source: (Friedlingstein *et al.*, 2024) – with major processing by (Our world in data, 2023).

Note: $MtCO_2$ = million tonnes of CO_2.

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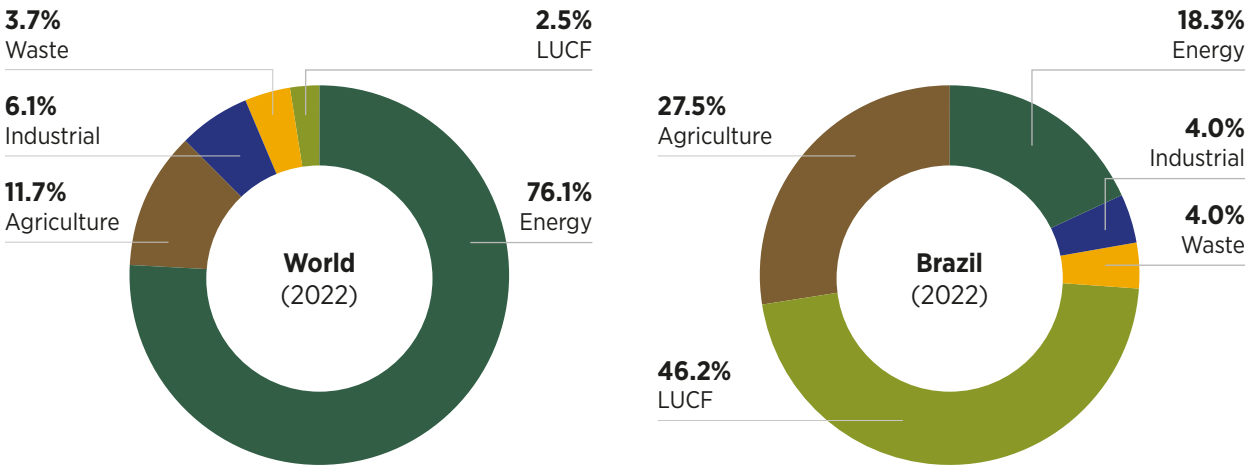
The difference in Brazil's ranking between the previous two figures shown arises from the fact that roughly 75% of the country's GHG emissions are linked to agriculture, forests and land use. In contrast, less than 20% of the country's total emissions are associated with energy use and production, while the global average is around 75% (Figure 3).

Figure 3 GHG emissions by economic activity: World and Brazil

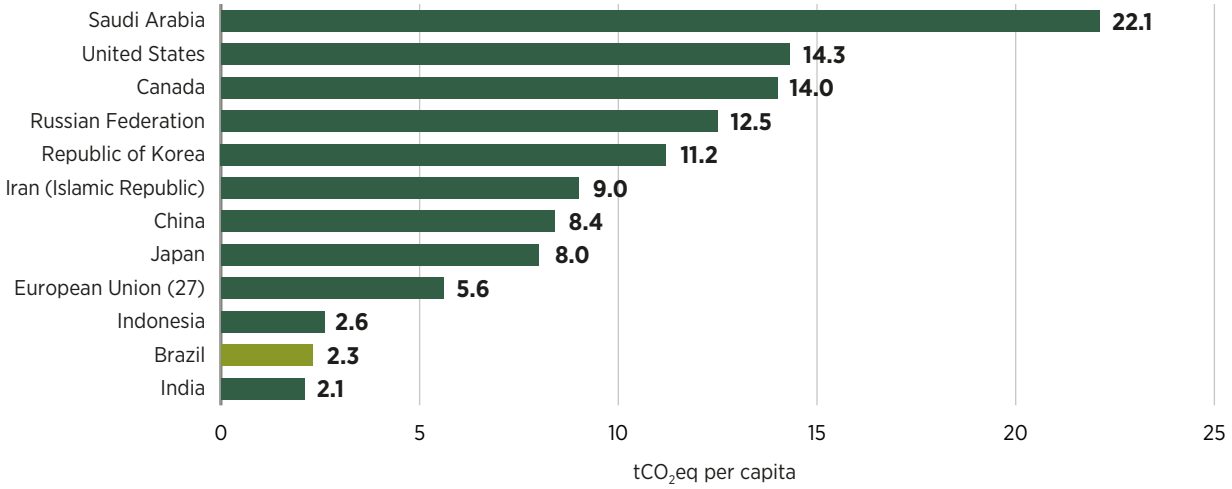


Source: (World Resources Institute, 2025) with major processing by (Our world in data, 2023) and (Observatório do Clima, 2024).

Note: LUCF = land use change and forestry.

It is also important to understand Brazil's GHG emissions in relative terms. Per capita, for example, in 2023, Brazil had one of the lowest energy-related emissions levels among the world's ten largest CO_2 emitters. The country emitted only 40% of the European per capita figure, or 16% of per capita emissions in the United States (Figure 4). This suggests that the country still has the opportunity to expand energy services for its population while still maintaining a low fossil emission profile in its energy mix.

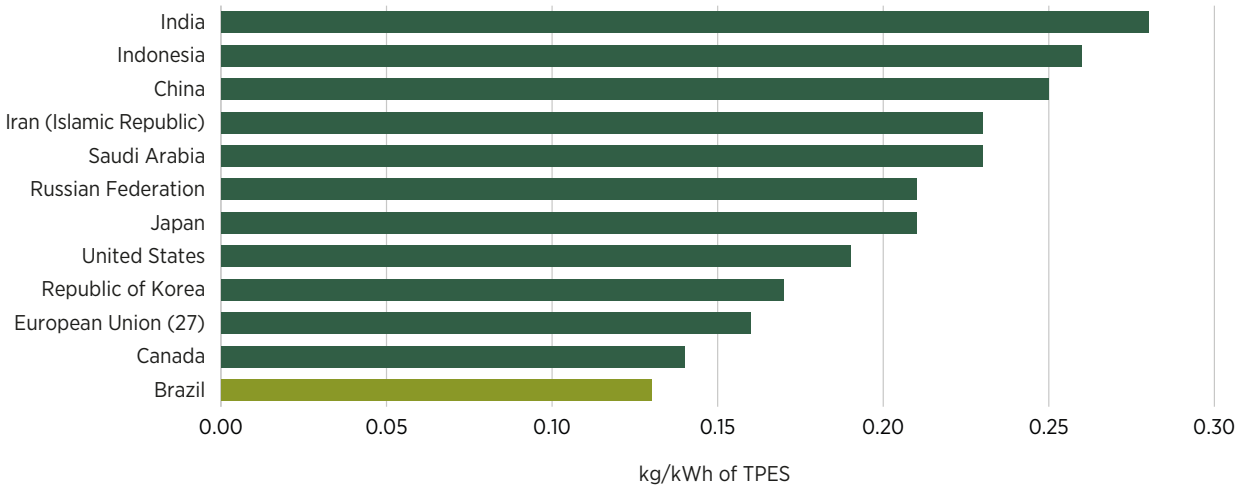
Figure 4 Annual CO_2 fossil emissions per capita: Global top 12 largest CO_2 emitters, 2023



Source: (Friedlingstein *et al.*, 2024) – with major processing by (Our world in data, 2023).
Note: tCO_2eq = tonnes of CO_2 equivalent.

Compared to its primary energy consumption, figures from 2023 show that Brazil's total annual CO_2 emissions associated with fossil fuels and industrial processes were approximately half those of China or India, or roughly 80% of those in the European Union (EU) (Figure 5).

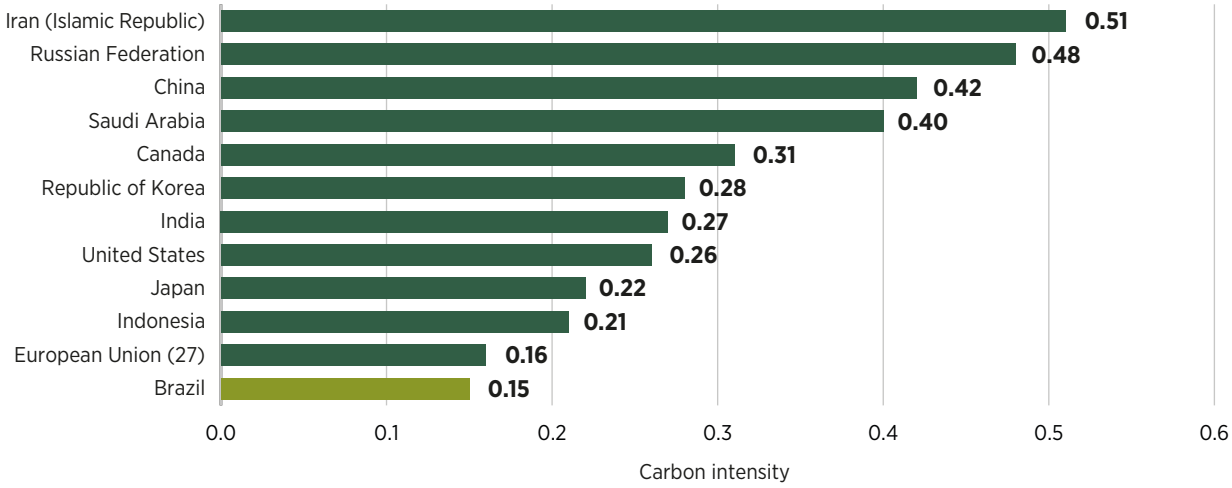
Figure 5 Annual CO_2 fossil emissions per primary energy consumption: 12 largest CO_2 emitters, 2023



Source: (Friedlingstein *et al.*, 2024); (U.S. Energy Information Administration, 2023);(Energy Institute, 2024) – with major processing by (Our world in data, 2023).
Note: kg = kilogramme; kWh = kilowatt hour; TPES = total primary energy supply.

When ranked by carbon intensity, Brazil also stands out as a low-emissions country (Figure 6).

Figure 6 Carbon intensity: 12 largest CO_2 emitters, 2023

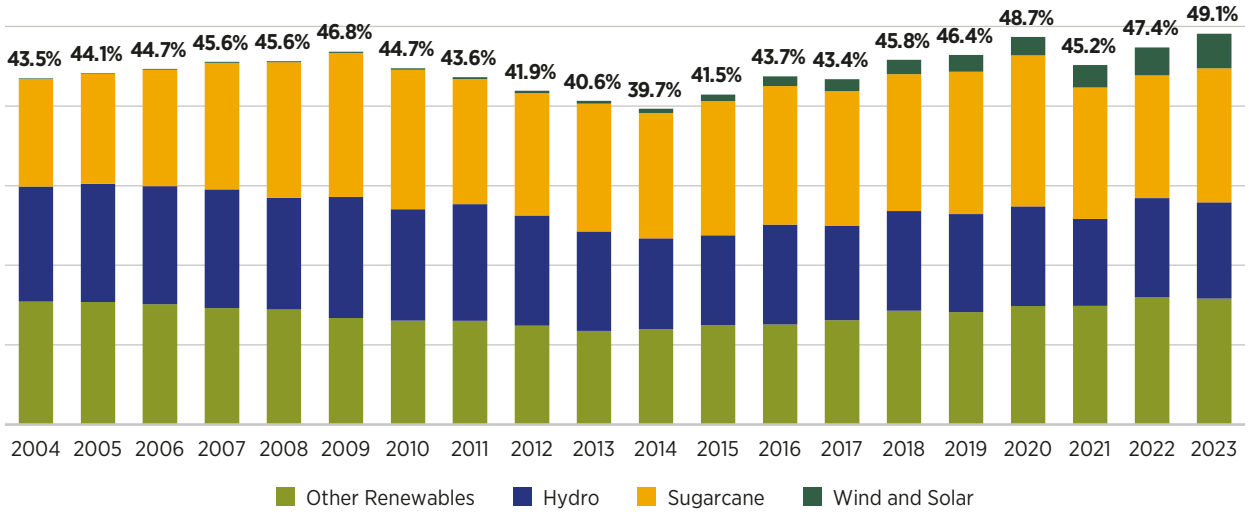


Source: (Friedlingstein *et al.*, 2024); (Bolt *et al.*, 2023) – with major processing by (Our world in data, 2023).

1.2 THE BRAZILIAN ENERGY MIX

Brazil's low ranking among the world's most significant emitters of CO_2 from fossil fuels and industrial processes is primarily because the country's energy mix contains a significantly high proportion of renewable sources. This, in turn, is the result of actions that have been implemented over many years. Indeed, the importance of hydropower and sugarcane products throughout those years – and, more recently, the increasing participation of wind and solar – have allowed Brazil to obtain almost 50% of its total primary energy supply (TPES) from renewable sources (Figure 7).

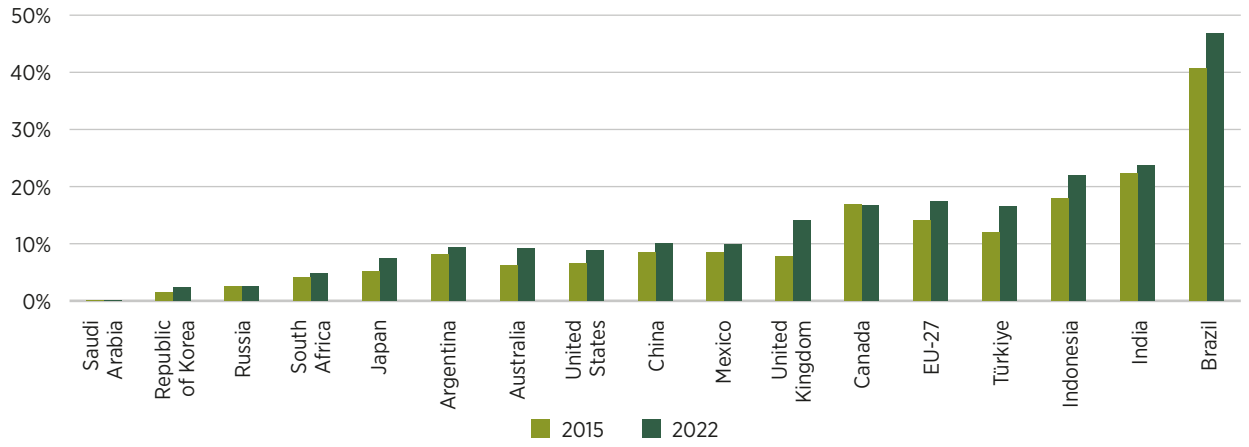
Figure 7 Evolution of the share of renewables in the Brazilian energy mix



Source: (MME/EPE, 2024a).

Brazil's share of renewable energy is significantly higher than that of other countries (see Figure 8). This highlights Brazil's extraordinary commitment to clean energy, with recent years seeing an increasing share taken by renewables in the country's energy mix. This also highlights the country's leadership in the global energy transition. This report explores the strategies and measures that have contributed to this achievement.

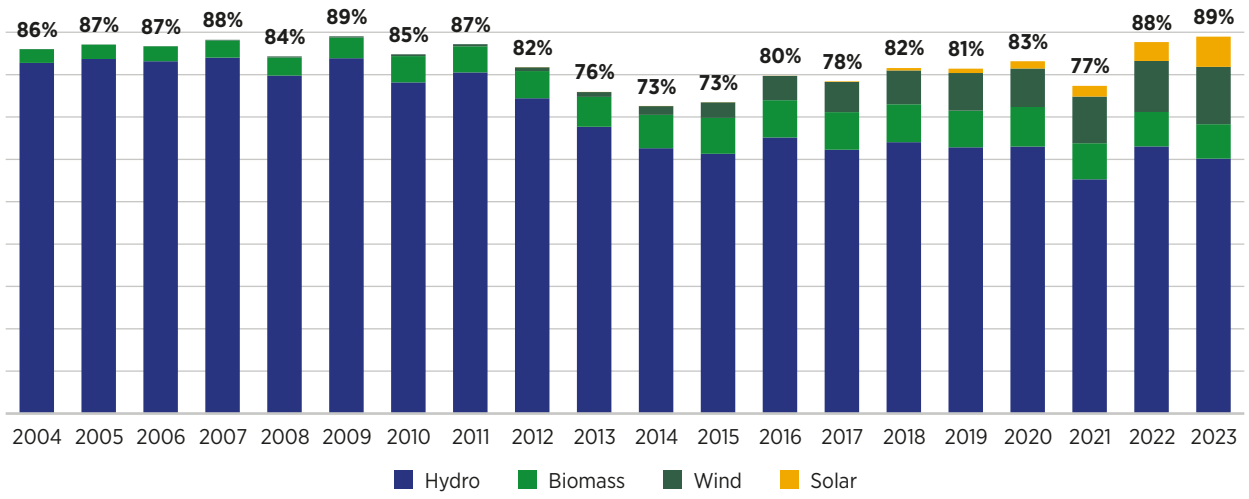
Figure 8 Share of renewables in the total primary energy mix: International comparison



Source: (COP28 Presidency, IRENA and GRA, 2023).

Regarding emissions related to the power mix, Brazil also stands out for its historically significant participation in hydropower plants. More recently, too, the country is notable for the increasing importance it has given to wind and solar energy. As a result, the share of renewables in the Brazilian power mix ranges between 80% and 90% in standard rain years. In drought years, thermal power plants increase their share of generation to approximately 25%. In 2021, for example, Brazil experienced one of the worst droughts in the last 90 years. As a result, GHG-emitting thermal power generation increased its share of the energy mix to 20% (Figure 9).

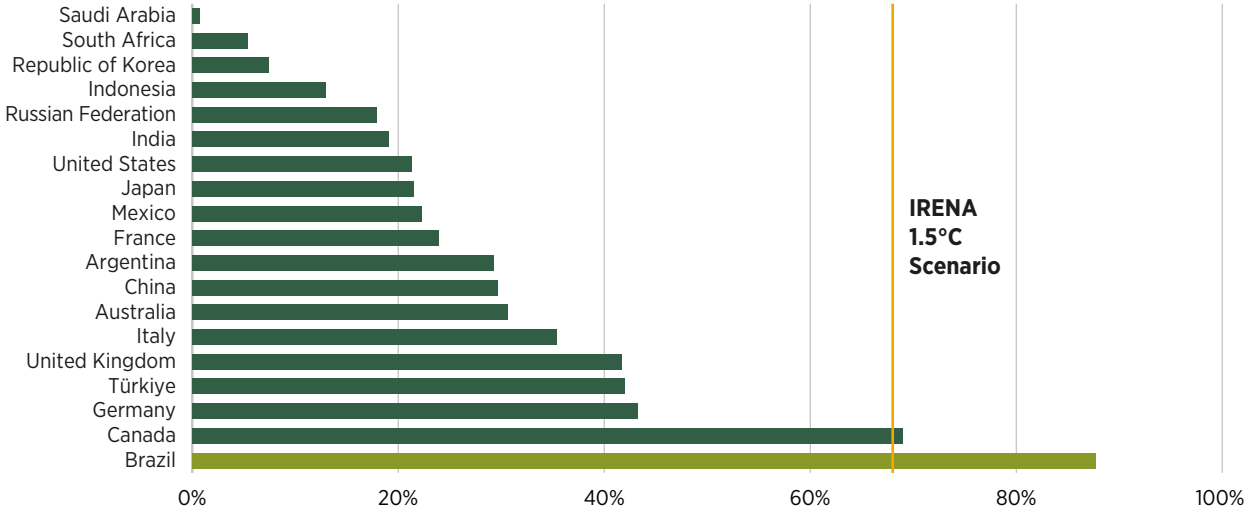
Figure 9 Share of renewables in the Brazilian power mix, 2004-2023



Source: (MME/EPE, 2024b).

The 1.5°C Scenario of the International Renewable Energy Agency (IRENA) aims for renewables to constitute 68% of total electricity generation by 2030 (COP28 Presidency, IRENA and GRA, 2023). This means that the world has to triple its renewable capacity and double its energy efficiency by the target date, if the 1.5°C Scenario is to be achieved (IRENA and BNDES, 2024). Brazil's current high proportion of renewables in electricity generation makes it one of the few countries already above that 68% threshold (Figure 10).

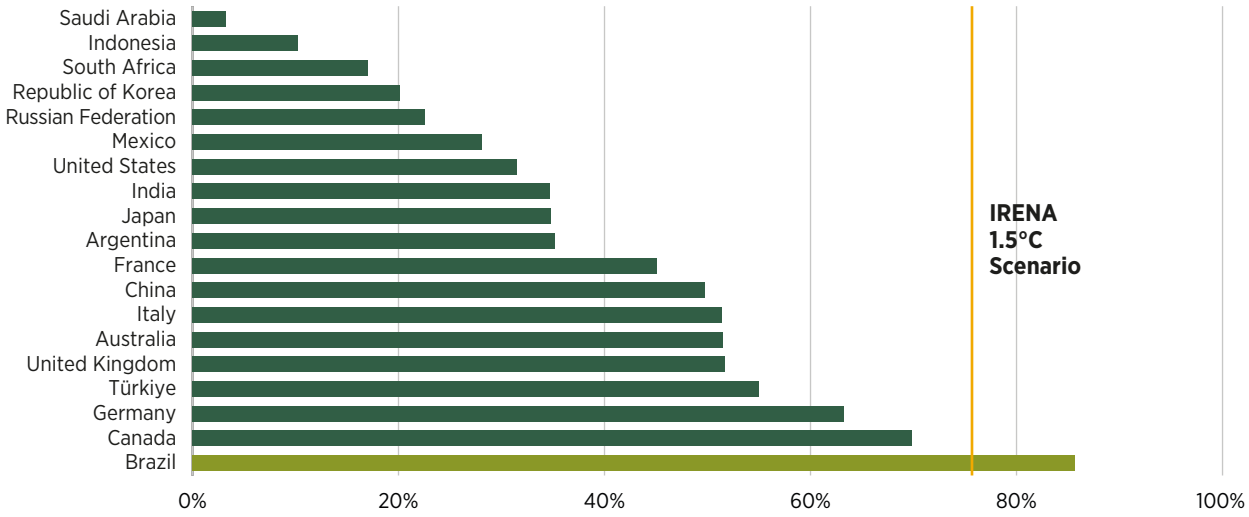
Figure 10 Share of renewables in electricity generation in 2022, selected countries



Source: (COP28 Presidency, IRENA and GRA, 2023).

In terms of installed power capacity, fossil-fuelled power plants represented 13% of Brazil's total in December 2023 (MME/EPE, 2024b). Hydropower plants accounted for 49%, solar 17%, wind 13% and biomass 8%. Again, compared to other countries, Brazil stands out, as the share taken by renewable energy in its total installed capacity is 86% – well aligned with IRENA's 1.5°C Scenario (Figure 11).

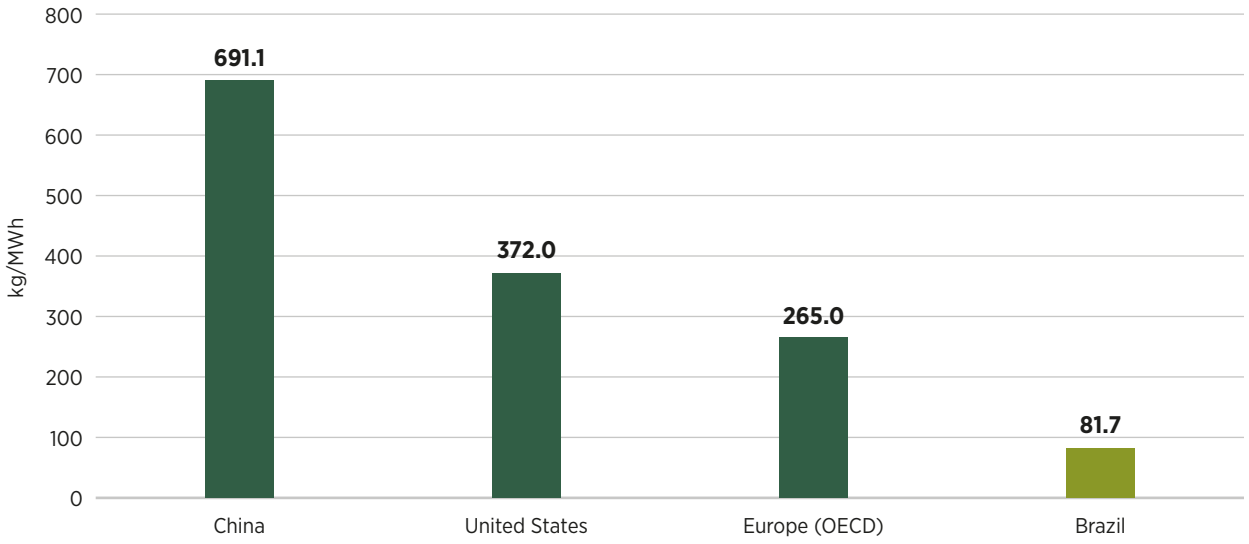
Figure 11 Share of renewables in installed capacity in 2022



Source: (COP28 Presidency, IRENA and GRA, 2023).

As a result, Brazil's emissions related to the energy mix represent only one-third of those of the EU, or one-eighth of those of China (Figure 12).

Figure 12 CO_2 emissions in the power sector: Brazil and the world, 2022

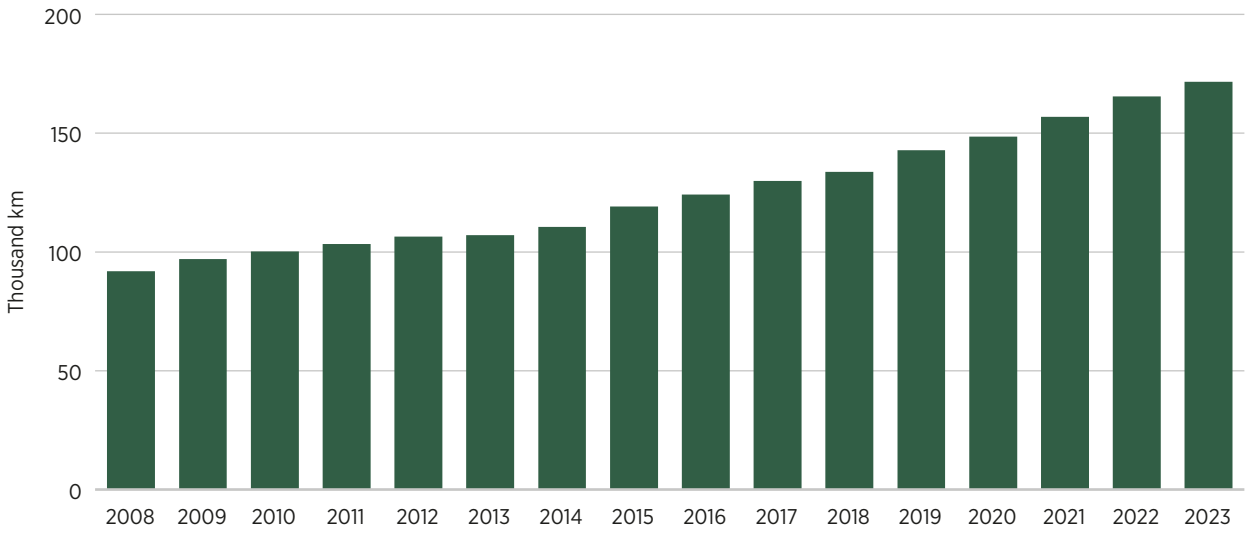


Source: (MME/EPE, 2024b).
Notes: kg = kilogramme; MWh = megawatt hour; OECD = Organisation for Economic Co-operation and Development.

The transmission system

One fundamental aspect of the Brazilian power system is the critical role transmission plays in connecting scattered renewable energy sources to the country's main load centres. Transmission lines have nearly doubled in number over the past 15 years (Figure 13).

Figure 13 Expansion of Brazil's transmission lines, 2008-2023

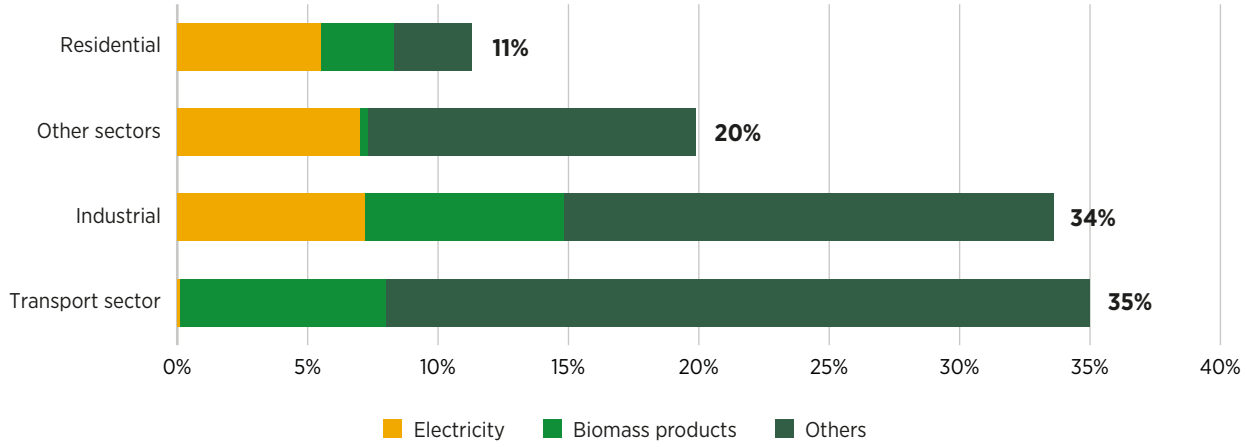


Source: (ONS, 2025).
Note: km = kilometre.

Electricity and biofuels

Electricity is more relevant in residential and industrial consumption, in which it has shares of 48% and 22% of total energy consumption, respectively. In contrast, electricity is insignificant in the transport sector, due to the relative importance of biofuels such as ethanol and biodiesel (Figure 14).

Figure 14 Share of electricity and biomass products in total final energy consumption

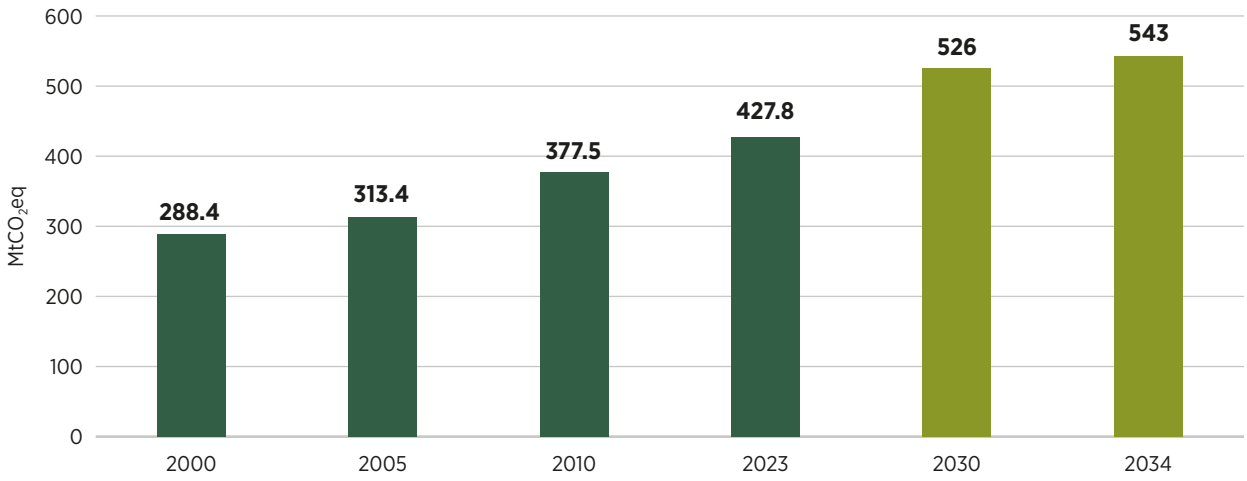


Source: (MME/EPE, 2024b).
Notes: Biomass products include ethanol, biodiesel, sugarcane bagasse and firewood; Others include non-renewable sources.

1.3 PERSPECTIVES

Due to growth in Brazil's per capita gross domestic product (GDP), energy consumption per capita is also expected to increase over the next ten years. This will likely contribute to a rise in the total CO_2 emissions associated with energy production and use (MME/EPE, 2024b) (Figure 15).

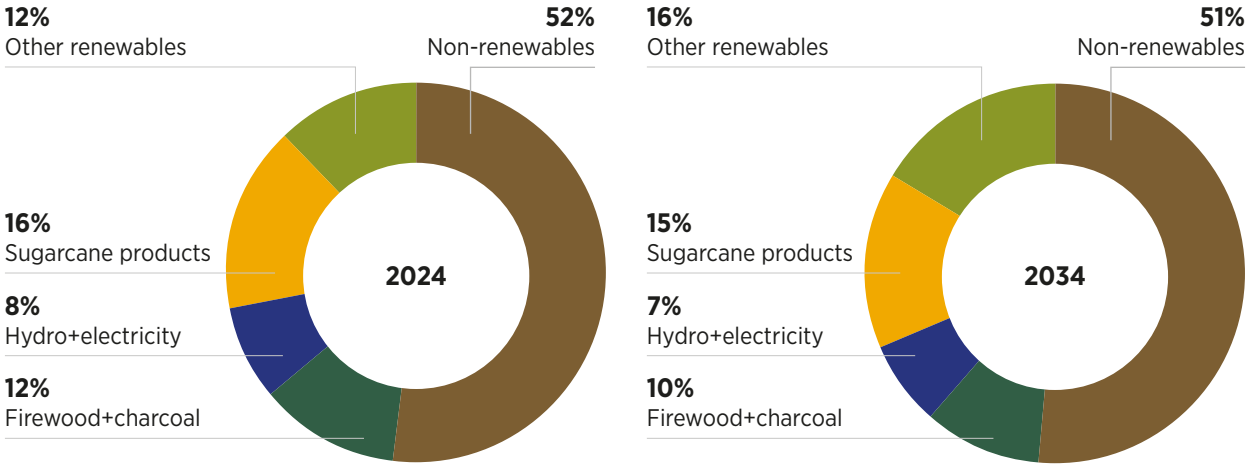
Figure 15 Evolution of total CO_2 emissions associated with the energy mix



Source: (MME/EPE, 2024b).
Note: $MtCO_2eq$ = million tonnes of carbon dioxide equivalent.

At the same time, however, the use of renewable energy sources is also expected to increase, mainly because of their relative price competitiveness. According to the Brazilian *Ministério de Minas e Energia* (Ministry of Mines and Energy – MME) and *Empresa de Pesquisa Energética* (Energy Research Company – EPE), this will lead to renewables taking a 49% share of TPES by 2034 (MME/EPE, 2024b). Meanwhile, between 2024 and 2034 the share of oil and oil products in TPES will fall from 35% to 30% (Figure 16).

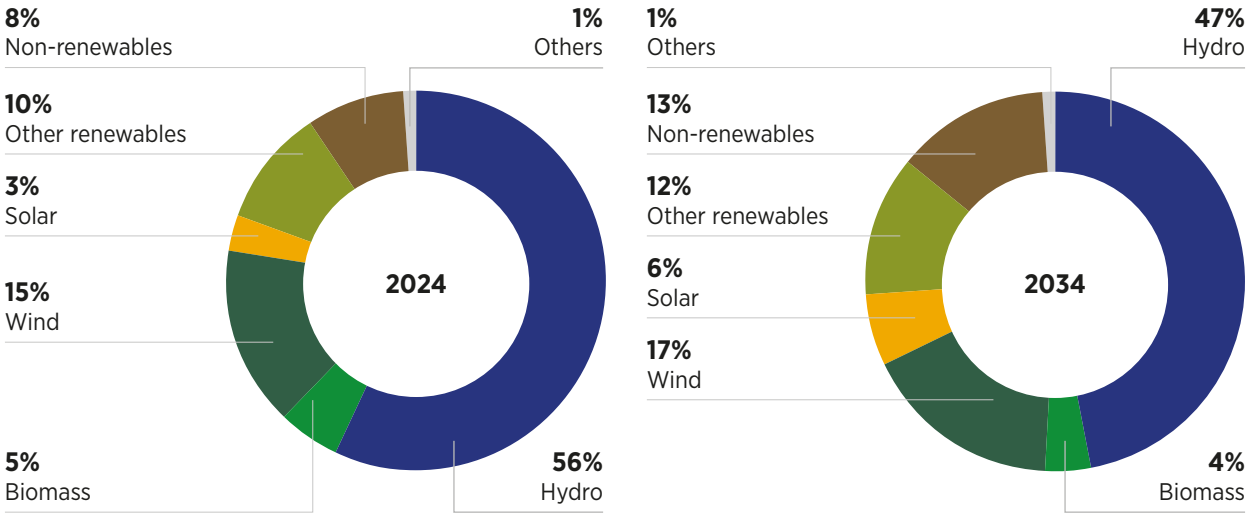
Figure 16 Changes in the energy mix, 2024-2034



Source: (MME/EPE, 2024b).

In Brazil's power sector, over the next 10 years renewable energy is expected to continue to dominate generation, reaching 85% of the total by 2034 (MME/EPE, 2024b). Regarding installed capacity, the power mix is expected to diversify considerably, however, with the reduced relative share of hydropower compensated by increases in wind and solar (Figure 17).

Figure 17 Changes in the power generation mix, 2024-2034



Source: (MME/EPE, 2024b).

Table 1 Share of renewables in the Brazilian power and energy mix, 2024, 2029 and 2034

MIX	INDICATOR	2024	2029	2034
Power	Share of wind, solar, and biomass	33%	34%	39%
	Share of hydro	54%	49%	46%
Energy	Share of renewables	48%	48%	49%
	Share of renewables, except hydro	37%	37%	39%
	Share of sugarcane and biodiesel	19%	19%	19%

Source: (MME/EPE, 2024b).

The section above demonstrates that Brazil has already met its commitments to the global goals of tripling renewable energy capacity and doubling energy efficiency by 2030. The country's previous initiatives and current efforts have together created a strong foundation for the achievement of its climate policy ambitions. This sets the stage for a deeper exploration of the specific strategies and actions Brazil is currently implementing in order to maintain this trajectory. In the following chapters, we examine the ongoing policies, programmes and other initiatives that reflect Brazil's dedication to enhancing its energy landscape and significantly contributing to global renewable energy goals.

2. BRAZIL'S LONG-TERM COMMITMENT TO RENEWABLE ENERGY

Brazil's primary energy objective is to ensure a sufficient energy supply to support its economic growth. Historically, the country has also been an energy importer, however. Therefore, to achieve the goal of supply security, the country has developed a series of public policies that focus on fostering competitive domestic solutions.

These public policies have played a crucial role in diversifying energy sources, strengthening energy security and taking advantage of national resources. They have also resulted in a reliable, affordable and low-emissions energy mix for Brazilian society (MME/EPE, 2024b).

Over the years, two central pillars have supported the country's energy policies: 1) exploiting Brazil's vast hydroelectric potential in the electricity sector; and 2) using biomass in transport and industry. In addition, energy conservation policies have been implemented, with a special focus on electrical equipment and transport (MME/EPE, 2007).

This chapter presents a brief history of Brazil's policies in the electricity, biofuels and energy efficiency fields, illustrating how these initiatives have shaped the country's current energy matrix.

2.1 RENEWABLE ENERGY IN BRAZIL

Up to the start of the 21st century, Brazil had focused on expanding generation and building hydroelectric plants, considering this strategy vital for the country's development. Large projects, such as the 12 600 megawatt (MW) Itaipu hydroelectric plant – a joint Brazilian and Paraguayan initiative agreed in 1973 – exemplify this approach (MME/EPE, 2007).

However, artificially low tariff policies aimed at controlling inflation during the 1980s and 1990s and high international interest rates made financing hydroelectric projects increasingly difficult, especially during the 1980s. In addition, there were growing concerns about the socio-environmental impacts of large dam projects. Combined, these factors reduced the pace of installed capacity expansion (Tolmasquim, 2015).

Following a global trend, the Brazilian electricity sector underwent successive reforms from the late 1990s onwards, focusing on increasing private sector participation. This restructuring led to a number of developments, including: the creation of regulatory agencies; deregulation policies emphasising free access to transmission networks; and the sector opening to new agents, promoting unbundling and privatising distributors (Tolmasquim, 2015). Despite these changes, however, the expected investment in expansion did not materialise. This led to the depletion of the system's large hydropower reservoirs and eventually resulted in electricity rationing in 2001.

Among the issues that this electricity crisis highlighted were: the need to diversify the energy mix; the need to reinforce transmission lines between regions of the country; and the need to improve government co-ordination in the long-term planning of the sector and the environmental licensing of power plants (Tolmasquim, 2015).

As a result, in 2004 Brazil adopted a new model for the electricity sector. This was based on the auction of long-term power purchasing agreements (PPAs), long-term energy planning and improved governmental co-ordination and governance. The main goals of the new model were to restore resource adequacy to investment, ensure energy security and attract private capital to the power sector. It aimed to do this by establishing a stable regulatory framework based on energy supply security, affordable tariffs and energy planning to meet demand growth (IRENA and BNDES, 2024).

Power auctions

Since it was introduced, the power auction programme has played a crucial role in mobilising private investment. Between 2005 and 2024 the Brazilian government conducted more than 40 rounds of greenfield power project auctions, predominantly for renewable energy.

One central aspect of fostering competition in these auctions was the appropriate design of the PPA. The MME/EPE and the *Banco Nacional de Desenvolvimento Econômico e Social* (National Bank for Economic and Social Development – BNDES) worked together to ensure a fixed-price sale of energy over the long term. This was indexed annually to consumer inflation, providing a stable revenue stream for energy projects.

Power auctions and contracts have since evolved to include different risk allocations and delivery obligations for various energy sources. One notable example was the PPA for wind power projects during their initial stages of development in Brazil. The MME/EPE collaborated with the BNDES to formulate a mechanism to accommodate generation uncertainty, enhancing the financial viability of the projects and thereby boosting investors' confidence (IRENA and BNDES, 2024).

In addition to technology-specific auctions, the government has also granted fiscal and cost incentives to less-mature renewables. These incentives have included tax exemptions on equipment and components, a reduction in the tariff for the use of transmission and distribution systems, and a band system that guarantees revenue within a generation limit of the energy contracted.

Conditions for long-term finance from BNDES have also been adapted to the industrial supply chain associated with wind energy. This reform led to a diversified energy supply mix, reducing reliance on large hydropower plants and integrating significant contributions from wind, biomass and solar energy (Tolmasquim *et al.*, 2021).

Historically, the regulated market has driven renewable energy expansion in Brazil through public energy auctions that offer long-term, publicly traded PPAs. Yet recently, the free market has emerged as a fundamental alternative for wind and solar power projects. This became especially so after 2019, when BNDES implemented essential changes in its financial policies for projects in the free market (IRENA and BNDES, 2024).[2]

In future, the free market is likely to be the principal driver of power supply expansion, especially as more consumers become eligible to participate. This shift is partly due to consumer migration from the regulated to the free market, motivated by the better price conditions of the latter.

Power transmission

In its efforts to ensure power transmission expansion, Brazil's historical preference for large hydropower projects also led to the expansion of the power transmission system. This is because the locations of the hydropower plants were typically distant from the country's main load centres. Centralised transmission planning then ensured interconnection and enabled energy transfer between regional electricity systems, known as sub-systems. This approach also allows for the diversity among hydrological and wind regimes in different parts of the country to be exploited (Tolmasquim *et al.*, 2021).

Increasing socio-environmental and land-use concerns have, however, posed significant obstacles to expanding the transmission network to the degree necessary to accommodate not only hydropower plants but – more recently – wind and solar power projects. These renewable sources are also often located far from existing transmission infrastructure. Yet, while the timelines for constructing wind and solar plants are becoming shorter due to their smaller scale, socio-environmental and land-use concerns continue to impact the timely development of transmission networks.

As a result, in order to avoid misalignments between generation and transmission, critical studies on expanding regional interconnections have been undertaken. These have considered the evolution of the socio-environmental aspects of the transmission project corridors deemed necessary to facilitate the integration of significant amounts of renewable energy from distant regions. Furthermore, transmission planning studies have played a critical role in proposing solutions to transmission bottlenecks that have prevented the integration of renewable energy sources into the main grid (IRENA and BNDES, 2024).

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[2] *Free market PPAs are traded over the counter, exposing consumers to the developer's credit risk and much shorter horizons. About 30% of the PPAs are for less than 10 years (IRENA, 2024a).*

2.2 GOVERNMENT CO-ORDINATION

Institutional governance of the power sector in Brazil is relatively complex and relies on several bodies. The *Conselho Nacional de Política Energética* (National Energy Policy Council – CNPE), a cabinet-level advisory board to the country's president, sets Brazil's primary energy directives. Co-ordinated by the MME, the CNPE proposes the national energy policy and the country's reliability criterion for the power sector. It also indicates which power plant projects are deemed strategic and in the public interest (IRENA and BNDES, 2024).

The other leading authorities in the power sector are:

- The MME, which formulates and implements energy policies approved by the CNPE and oversees the energy sector – although it delegates some authority to other regulatory agencies.
- The *Agência Nacional de Energia Eléctrica* (National Electricity Agency – ANEEL) regulates the electricity sector, managing service standards, tariff regulation, power auctions, and grants for research and energy-efficiency projects.
- The *Operador Nacional do Sistema Eléctrico* (National Grid Operator – ONS) handles power plant dispatch and short-term transmission planning under ANEEL's oversight.
- The *Câmara de Comercialização de Energia Elétrica* (Electric Energy Commercialisation Chamber – CCEE) manages power trading, conducts energy procurement auctions, and oversees market settlements in the Brazilian power system.
- The Empresa de Pesquisa Energética (Energy Research Office [EPE]) supports the MME with technical studies for energy planning, hydropower licensing and project qualification for power auctions.
- The *Comitê de Monitoramento do Setor Elétrico* (Power Sector Monitoring Committee – CMSE) is co-ordinated by the MME and monitors short-term power supply. It can also override ONS dispatch decisions for energy security.

Resource adequacy in the long term is addressed through regular long-term studies conducted by the EPE. It does this under an integrated energy planning approach in support of MME policies and CNPE directives (EPE, 2008).

2.3 INCENTIVES FOR RENEWABLE ENERGY RESOURCES

In Brazil, a range of measures have been implemented to support the growth of renewable energy projects, particularly in the wind and solar photovoltaic (PV) fields. These measures include incentive programmes, technology-specific auctions, tariff discounts and tax benefits. These initiatives aim to attract private investment, particularly by de-risking projects and reducing financial burdens.[3]

Specific programmes

One of Brazil's first measures to encourage new renewable energy sources, the *Programa de Incentivo às Fontes Alternativas de Energia Eléctrica* (Programme for Alternative Sources of Energy – PROINFA) was a feed-in tariff scheme implemented in 2002 to promote wind, biomass and small hydroelectric plants.

Although the PROINFA's contracted power volumes were lower than expected, the programme did play a crucial role in the expansion of variable renewable energy (VRE) in Brazil. This was for two main reasons. First, the programme marked the country's first large-scale introduction of wind technology. Second, it led to large-scale project finance for these technologies for the first time in Brazil. The BNDES was instrumental in this, structuring PPAs and providing finance guarantees for PROINFA. By helping projects' de-risk and attract finance, PROINFA was fundamental in paving the way for the implementation of the power auction mechanism since established and allowed for the development of a local supply chain (IRENA and BNDES, 2024; Losekann and Hallack, 2018).

Technology-specific power auctions

Brazil has used technology-specific power auctions to promote renewable technologies such as wind and solar power.

The first specific auction for new renewable energy projects was held in 2007. However, no wind energy projects were successful at that time. Learning from this experience, a dedicated auction for wind power took place in 2009. This contracted 71 projects with a total 1805 MW of capacity.

Several factors contributed to the success of the 2009 wind-specific auction. These included:

- discounts on the tariff for the use of transmission and distribution systems (see the section on tariff discounts below);
- an attractive ceiling price;
- tax incentives, such as the *Regime Especial de Incentivos para o Desenvolvimento da Infra-Estrutura* (Special Incentives Programme for Infrastructure Development – REIDI) (see the section on tax incentives below);
- exemptions, such as on wind energy equipment purchases;
- favourable financing conditions from BNDES ; and
- a guaranteed revenue mechanism for a generation within a band of the contracted energy (Tolmasquim, 2015).

[3] *See IRENA (2024) for insights into the key risks affecting long-term renewable energy projects and how Brazil has addressed them.*

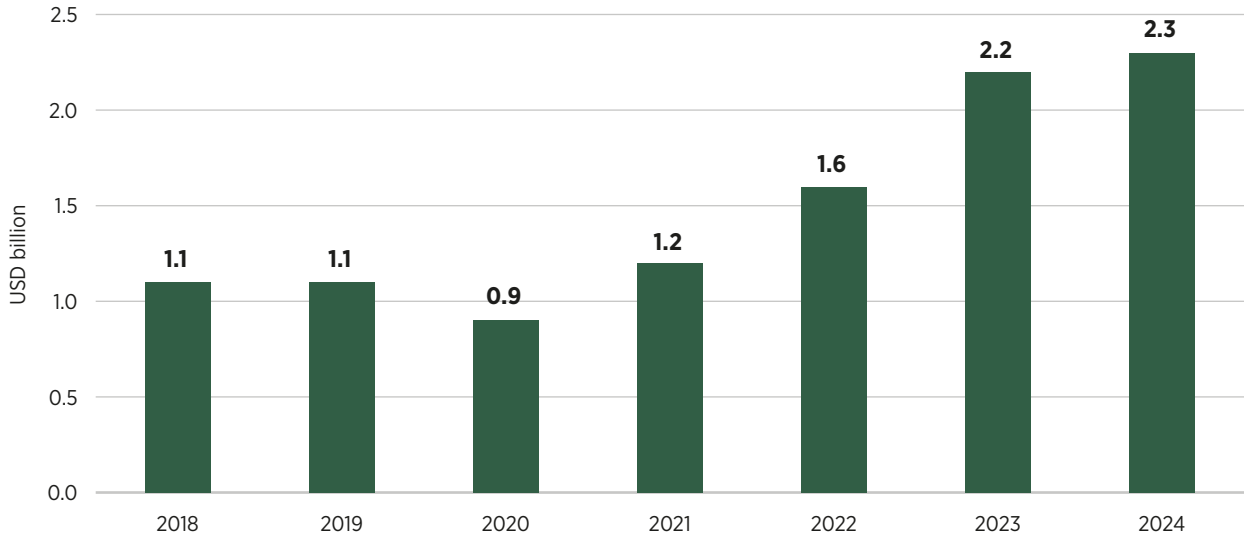
Other technology-specific auctions for wind power and solar power were held during the 2010s. Due to increased price-competitiveness, however, specific auctions for only solar and/or wind were no longer conducted after 2018.

Tariff discounts

Since 2002 in particular, tariff discounts have been widely used to encourage renewable energy adoption. Law 10.438 of 2002 – which established PROINFA – also contained a reduction of at least 50% in the tariff for the use of transmission and distribution infrastructure for small hydro, wind and biomass energy projects, paid for by final consumers through a tariff surcharge.[4]

The successful expansion of renewable energy, however, resulted in a rapid increase in tariff surcharges, as final consumers paid these discounts (see Figure 18). Consequently, questions about the necessity of subsidies for highly competitive energy sources led to changes in legislation, such as Law 14.120/2021, which established deadlines for these benefits.

Figure 18 Evolution of subsidies for renewable energy technologies associated with tariff discounts



Based on: Data from ANEEL.

Notes: The values include subsidies to small hydroelectric power plants, biomass and qualified cogeneration; the values in USD were calculated from ANEEL data in Brazilian reals (BRL) and converted at the average exchange rate of the respective year.

Tax benefits

REIDI was established in 2007 and implemented exemptions from some federal taxes on goods and services for energy projects, including wind and solar PV plants. The REIDI initiative aimed to alleviate tax burdens and encourage infrastructure development. Other federal incentives to attract investments

[4] *Initially, the tariff discounts were conceded for small hydropower plants with capacities between 1 MW and 30 MW. In 2002, these discounts were extended to wind, biomass and qualified cogeneration projects, applying the reduction to both energy production and consumption. Posterior laws extended the tariff discounts for small solar projects and then to larger projects up to 300 MW (Tolmasquim, 2015).*

in the semiconductor and solar PV industries were offered through specific programmes. One such was the *Programa de Apoio ao Desenvolvimento Tecnológico da Indústria de Semicondutores* (Semiconductor Industry Technological Development Support Programme – PADIS) for the technological growth of the semiconductor industry.

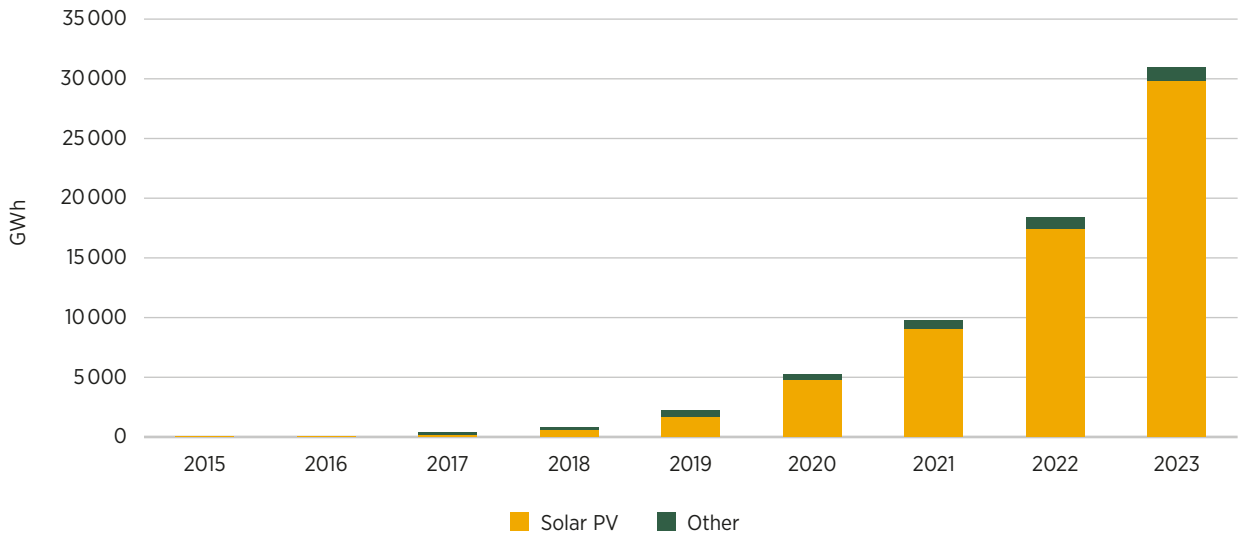
Federal and state-level tax reliefs, alongside regulatory incentives, were also fundamental to the expansion of small distribution generation systems in Brazil, particularly for solar PV (see the section below).

Specific conditions for distributed generation

In 2012, ANEEL established a net-metering system for small distributed generation systems using qualified cogeneration or renewable sources. This resolution marked a significant milestone in promoting solar PV energy in Brazil, as it provided an important mechanism to foster the dissemination of small solar systems (US EIA, 2023).

To further incentivise distributed generation, in late 2015 the Brazilian government launched a programme with a particular focus on solar PV. The initiative proposed new lines of credit from BNDES and improvements to ANEEL's net-metering system. In addition, federal taxes on energy supplied by electric utilities through net-metering were reduced to zero, while Brazilian states were allowed to exempt state-level taxes on energy transactions billed through net-metering. This combination of net metering and tax exemptions significantly promoted the growth of solar microgeneration (see Figure 19).

Figure 19 Evolution of micro- and mini-distributed generation in Brazil, 2015-2023



Source: (MME/EPE, 2024a).
Notes: GWh = gigawatt hour; Other includes renewables and non-renewable sources.

In 2022, new legislation was enacted to ensure economic sustainability in the electricity sector, as the original net-metering system involved high subsidies.

While the lack of clarity regarding the new remuneration scheme may present challenges for the future development of the country's distributed generation, this method should experience significant growth over the next ten years (MME/EPE, 2024b).

Favourable financing conditions from the public sector

Brazil's energy sector has a robust financing ecosystem that supports the development of renewable and infrastructure projects, primarily through public financing and favourable conditions. BNDES has traditionally been the country's primary source of debt funding for energy infrastructure. The bank offers credit lines specifically designed for energy projects of varying sizes, such as BNDES Finem. These credit lines often provide more favourable conditions for renewable energy technologies than for traditional ones (IRENA and BNDES, 2024).

Furthermore, BNDES also manages the *Fundo Nacional sobre Mudança do Clima* (the National Climate Fund – FNMC). This has seen substantial contributions from international partners in recent years, demonstrating global commitment to Brazil's climate initiatives. The bank's accreditation policy further extends its reach, enabling a broader network of financial institutions to offer BNDES-backed financing, thereby amplifying public support for projects, nationwide (IRENA and BNDES, 2024).

Increasingly, incentivised infrastructure debenture bonds[5] – with strong support from BNDES[6] – have been used to finance renewable energy projects and transmission system expansion.

Another source of funding for renewable infrastructure is the *Banco do Nordeste* (Northeast Bank – BNB). This is a significant player in financing renewable micro-generation and small distributed generation schemes in Brazil's northeast region. The *Fundo Constitucional de Financiamento do Nordeste* (Constitutional Fund for the Northeast Region – FNE) also subsidises specific credit lines and offers special terms for citizens and small to medium-sized businesses.

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[5] *Incentivised debentures are bonds given special tax treatment.*

[6] *For example, BNDES facilitates the certification of these debentures as green bonds by the Climate Bonds Initiative. It also manages Sustainable Energy Fund investment in energy project debentures that meet Climate Bonds Initiative standards (IRENA and BNDES, 2024).*

3. OVERVIEW OF CURRENT ENERGY TRANSITION EFFORTS

While it already has a relatively high share of renewable energy in its energy mix, Brazil is taking further steps to collaborate with global energy transition efforts.

For decades, Brazil has developed and implemented a comprehensive methodology in its long-term strategy – one that effectively combines climate and energy considerations. Through strategic planning, the country has set a precedent in aligning its climate goals with national energy strategies, ensuring its path to sustainability is ambitious and pragmatic. This legacy of combining climate and energy planning has informed the country's high ambitions ever since its first Nationally Determined Contribution (NDC) in 2016, in which it proposed an absolute reduction in the country's GHG emissions. This policy is at the core of Brazil's current energy transition efforts (EPE, 2016). These continue to focus on energy security within the framework of energy affordability, inequality reduction and the fight against the adverse effects of climate change (MME/EPE, 2024b).

In this regard, the country aims to benefit from opportunities related to the global energy transition effort, attracting more investment, promoting sustainable development and achieving significant participation in the global economy through low-carbon intensity products.

In line with the objectives of the national energy policy (established by Law 9.478 in 1997), Brazil's energy transition efforts seek to leverage its sustainable development by focusing on its competitive renewable energy industry and structuring its regulatory framework to account for technological advances and international commitments.

3.1 POLICIES

The National Policy on Climate Change

Launched in 2009, the *Política Nacional sobre Mudança do Clima* (National Policy on Climate Change – PNMC) is Brazil's first and – so far – only legally binding commitment to reducing GHG emissions. The policy introduced significant legal innovations and established mechanisms for measuring emissions.

The PNMC also set ambitious targets for 2020, aiming to reduce GHG emissions by between 36.1% and 38.9%, compared to 2005 levels. Primarily, these targets were to be achieved through efforts to reduce deforestation rates in the Amazon, as outlined in the Action Plan for Prevention and Control of Deforestation in the Amazon (PPCDAm). This strategy resulted in a reduction in GHG emissions by 48.2%; however, this was below projected estimations (Silverwood-Cope *et al.*, 2024).

The PNMC guidelines set the government's actions within the framework of national mitigation and adaptation strategies that run up to 2035. Instruments for the implementation of these strategies include: the National

Plan on Climate Change (*Plano Clima*, or 'Climate Plan' – see section below); the National Climate Change Fund (or 'Climate Fund'); and Brazil's communications with the United Nations Framework Convention on Climate Change (UNFCCC), utilising tools such as the Clean Development Mechanism (CDM) and the Nationally Appropriate Mitigation Actions (NAMAs).

Since the PNMC was launched, the country has experienced both progress and setbacks in sectoral mitigation and adaptation efforts. There have been fluctuations in investments and mixed results in deforestation control. Yet despite these challenges, Brazil's national climate policy has evolved beyond its initial focus on deforestation (Silverwood-Cope *et al.*, 2024).

A new climate plan is currently under discussion and will be finalised by 2025 (Government of Brazil, 2024a). This new programme is expected to align with various national policies and initiatives to create a cohesive strategy integrating energy transition efforts with broader economic and environmental goals. It is also expected to ensure a comprehensive approach to sustainable development aimed at social development and further integrating Brazil into global carbon markets. A key challenge for the upcoming plan will be in ensuring that economic growth aligns with reducing carbon intensity (Silverwood-Cope *et al.*, 2024).

The National Energy Transition Policy

The *Política Nacional de Transição Energética* (National Energy Transition Policy – PNTE) was launched by the CNPE in August 2024. The policy introduces key proposals to enhance renewable energy incentives, create a more favourable environment for distributed generation, and strengthen mechanisms to attract investments in clean technologies. The PNTE also aims to broaden public participation in energy transition discussions (Government of Brazil, 2024b).

The PNTE is designed to complement and support the Climate Plan and other sector-focussed and financing initiatives by outlining the actions that are necessary to facilitate the energy transition across multiple economic sectors. In this, the policy focuses on energy use and – in the case of the energy sector – its renewable energy profile.

The PNTE also focuses on addressing the legal and regulatory framework, identifying investment and financing opportunities, and considering the social dimensions of the proposed policies (Government of Brazil, 2024b). One of the main instruments of the PNTE is the *Plano Nacional de Transição Energética* (National Energy Transition Plan – PLANTE), which is discussed below.

3.2 PLANS

During COP29, Brazil submitted its second NDC for the 2031-2035 period. This set an economy-wide target of reducing GHG emissions by between 59% and 67% by 2035, compared to 2005 levels.[7] As a signatory to the Paris Agreement and in order to achieve climate neutrality by 2050, Brazil has pledged to cut GHG emissions by 48.4% by 2025 and 53.1% by 2030. Furthermore, Brazil joined the Global Methane Pledge in 2021, targeting a 30% reduction in methane emissions by 2030, using 2020 as a baseline (MME/EPE, 2024b).

[7] *This is consistent, in absolute terms, with an emissions level of 1.05 gigatons of carbon dioxide equivalent ($GtCO_2eq$) to 0.85 $GtCO_2eq$, according to the most recent inventory data. In a favourable international scenario of exponential growth in co-operation and technological diffusion, Brazil will be able to achieve the highest level of its climate ambitions. Conversely, a scenario of fragmented international co-operation could limit Brazil's potential to reduce GHG emissions (Government of Brazil, 2024a).*

To meet these national targets, Brazil will rely on its updated Climate Plan, integrated with the Ecological Transformation Plan (see section below). The Climate Plan will guide mitigation and adaptation efforts by delineating the country's National Adaptation and Mitigation Strategies, ensuring alignment with national sustainable development goals (SDGs). After concluding the National Adaptation and Mitigation Strategies, Brazil will elaborate specific sectoral plans, of which 16 concern adaptation and seven concern mitigation. These will detail each sector's respective contribution to national efforts towards implementing the 2035 NDC target. Sectoral plans will also include detailed action plans and their implementation strategies.

The Climate Plan

The *Plano Nacional sobre Mudança Climática* (National Plan on Climate Change) is a key instrument of the PNMC and currently under development. Defined by the Interministerial Committee on Climate Change – Brazil's highest climate governance body – the Climate Plan's objective is to guide the transition to a net-zero GHG emissions economy by 2050. It aims to do this by promoting and monitoring co-ordinated actions related to mitigation and adaptation strategies and their sectoral policies.

In the energy sector, the Climate Plan is expected to detail:

- the expansion of electricity generation
- the gradual, long-term replacement of fossil fuels with electrification and advanced biofuels
- the expansion of biofuel production associated with carbon capture and storage (CCS) to meet the demand for negative emissions.

One central instrument of the Climate Plan is the Climate Fund. This was established to provide financial support for GHG emissions reduction projects and facilitate climate adaptation. Managed by the *Ministério do Meio Ambiente e Mudança do Clima* (Ministry of the Environment and Climate Change – MMA) and the BNDES, the fund offers direct financing with reduced rates and terms of up to 25 years.

Despite capacity challenges in execution and fluctuating investment levels, in 2023 the Climate Fund underwent a significant reform aimed at expanding its financing capabilities. This reform enabled Brazil to issue its first sustainable sovereign bonds, which have raised USD 4 billion over the last two years. This increased funding aims to align with the Ecological Transformation Plan (ETP) and scale up actions across various sectors, contributing to the broader goal of a low-carbon economy.

The PLANTE

One of the main instruments of the PNTE, the PLANTE is a comprehensive long-term action plan addressing energy transition scenarios, net-zero emissions goals and socio-economic development.

Co-ordinated by the MME and with the support of the EPE and other ministries, the PLANTE has a number of goals, including: 1) to articulate Brazil's energy transition ambitions clearly; 2) to consolidate federal energy transition initiatives; 3) to identify any additional efforts needed; 4) to attract investments; and 5) to align with the Climate Plan and subnational initiatives (Government of Brazil, 2024b).

The PLANTE is to be implemented over four years, with revisions. The plan will adopt sectoral and transversal approaches to advance energy transition across a variety of economic sectors, including industry and transport. The PLANTE will also contain legal, regulatory, investment and social dimensions. The plan will also be supported by a forum consisting of representatives from government, civil society and the productive sector, ensuring diverse participation and accountability (Government of Brazil, 2024b).

The ETP

Supporting the implementation of the Climate Plan, the ETP is an investment plan aiming to promote sustainable development based on technological innovation and the rational use of natural resources. In this regard, it will encourage and support the development and incorporation into production processes of innovative technologies, as well as the modernisation of the manufacturing sector (Maximo, 2023).

The ETP consists of two main financial mechanisms: the *Plataforma Brasil de Investimentos Climáticos e para a Transformação Ecológica* (Sustainable Investment Platform for Ecological Transformation, also known as *Plataforma Brasil Invest* – BIP) and *Eco Invest Brasil*.

Both mechanisms were set up to achieve two main goals: 1) to channel investments in the development and transfer of technology; 2) to build capacity in sustainable finance, the bio-economy, agricultural and food systems, energy transition, the circular economy, and new green infrastructure for adaptation.

The ETP's two instruments also have the following aims:

- **The BIP:** This aims to connect a vast network of financiers primarily with three groups of Brazilian projects: energy, industry and mobility, and natural climate solutions. The BIP's goal is to enhance the mobilisation of both public and private resources, strategically leveraging public capital to attract private investments that are aligned with Brazil's 2050 climate neutrality goals.
- **Eco Invest Brazil***:* Jointly co-ordinated by the *Ministério da Fazenda* (Ministry of Finance – MF), the MMA and Brazil's central bank, the *Banco Central do Brasil* (BCB), Eco Invest Brazil's full title is the "Foreign Private Capital Mobilisation and Currency Hedging Programme". It was established in 2024 in order to address the challenge of attracting long-term foreign private investment to Brazil, while also decreasing the cost of capital for energy transition projects and other areas, such as bio-economy and green infrastructure.

  The programme sets out four financing mechanisms:

  - **Blended finance:** this offers partial financing for credit operations aligned with the ETP, which utilises international fundraising.
  - **Long-term foreign exchange liquidity:** this initiative helps companies with debts in hard currency and revenues generated in BRL to manage cash effectively and enhance credit in situations of significant currency devaluation.
  - **Exchange rate protection:** this supports the provision or feasibility of exchange rate derivatives or other financial assets, aiming to mitigate investors' exchange rate risks.
  - **Project structuring**: this line of financing focuses on credit operations that support sustainable studies and projects in specific sectors.

New Industry Brazil

The widespread availability of inexpensive, clean electricity is a key advantage for Brazilian manufacturing. This potential for "powershoring", in which industries relocate to take advantage of an expanded Brazilian clean grid, can position the country as a leader in a variety of sectors. These include low-carbon steel, fertilisers, sustainable aviation fuels (SAF) and machinery manufacturing for wind and battery supply chains.

In order to realise this green industrial potential, Brazil depends on various ministry-led transition plans, particularly *Nova Indústria Brasil* (New Industry Brazil). This sets out a number of ways to encourage production and investment in specific firms and sectors. The plan's primary innovation is that it organises

economic sectors around “missions” that emphasise the inter-sectoral synergies necessary for their achievement (Guerra *et al.*, 2025).

To support these missions, Brazil has pledged significant funding, complemented by policies such as subsidised credit, tax breaks and preferential procurement favouring national products.

Despite the promising initiatives, however, the New Industry Brazil policy faces challenges in co-ordination and execution. Achieving its green industrial potential requires enhanced stakeholder collaboration and a focus on long-term strategic goals to build a competitive ecosystem (Guerra *et al.*, 2025).

3.3 REGULATORY INITIATIVES

Recent regulatory initiatives aimed at facilitating the energy transition in Brazil have focused on establishing frameworks that encourage new technology and market solutions. These efforts have been essential in sustaining the remarkable recent evolution of the country’s low-carbon energy mix. By concentrating on resilience and maintaining the quality of supply, these initiatives strive to meet growing energy demands, while also addressing environmental challenges.

The Brazilian Emissions Trading System

After almost a decade of congressional debate, in 2024 Brazil approved a pivotal legal framework regulating the carbon market. This was a significant step toward decarbonising the country’s economy. The legislation introduced the *Sistema Brasileiro de Comércio de Emissões* (Brazilian Emissions Trading System – SBCE) to align the country's economic development with its climate goals.

The SBCE is a cap-and-trade system that sets emissions limits for various sectors. Companies that exceed these limits must purchase allowances or credits. This incentivises them to reduce emissions and advance Brazil's commitments under international climate agreements.

The SBCE divides the carbon credit market into regulated and voluntary sectors. The regulated market encompasses public initiatives and mandates emissions reporting and reduction plans. The voluntary market allows private transactions for carbon offsetting without affecting national emission accounts (Agencia Senado, 2024).

The regulated market involves trading emissions quotas and certificates for verified emissions reductions or removals. Each quota represents 1 tCO_2eq, allowing businesses to offset emissions by cancelling an emissions quota.

Industries emitting over 10 000 tCO_2eq annually are subject to regulation. Companies emitting between 10 000 tCO_2eq and 25 000 tCO_2eq must submit an emissions monitoring plan, provide annual emissions reports and comply with other specified obligations. Those exceeding 25 000 tCO_2eq must also submit a yearly reconciliation report.

In addition to the regulated market, there are rules for carbon credits traded on the voluntary market. These carbon credits can be generated by preservation, reforestation projects, or other GHG capture methods, with their earnings taxed under the same rules as certificates. When voluntary emissions compensation occurs outside the regulated SBCE environment, the certificate must be cancelled at the central registry.

The SBCE is currently in the implementation phase. This includes its initial regulation, the creation of a governing body and a definition of the sectors to be regulated. During this phase, operational details and the legal framework for the market's functioning are to be established (Agencia Senado, 2024).

The Low-Emission Hydrogen Law

Brazil is considered highly promising as a location for hydrogen production through water electrolysis using renewable sources, such as wind and solar. Other hydrogen production routes through the conversion of biomass (such as ethanol and biogas) also hold potential.

To fully capitalise on these emerging opportunities in the hydrogen market, the federal government launched the *Programa Nacional de Hidrogênio* (National Hydrogen Programme – PNH2) in 2022. More recently, it also enacted Law 14.948/2024, which established the legal framework for low-emissions hydrogen.

This framework sets the foundation for a national low-emissions hydrogen policy, outlining its principles, objectives, governance structures and instruments for encouraging industry growth. The *Regime Especial de Incentivos para a Produção de Hidrogênio de Baixa Emissão de Carbono* (Special Incentive Regime for Low-Emission Hydrogen Production – Rehidro) and the *Programa de Desenvolvimento do Hidrogênio de Baixa Emissão de Carbono* (Low-Emission Hydrogen Development Program – PHBC) are central instruments in moving the industry forward – in low-carbon steel and fertilisers in particular – through targeted incentives and development initiatives.

In addition, the law has established a national fund to support the energy transition through low-emission hydrogen, further underscoring the government's commitment to this clean energy source. This is due to the technological maturity of electrolysers and the competitive costs of renewables in Brazil.

Challenges remain, however, particularly in the economic viability of electrolysis. This is due to high electrolyser costs and the significant level of water consumption required. The latter necessitates efficient water use and the provision of alternative sources, such as reclaimed or desalinated water, in water-scarce regions in particular. There is also the challenge of complexity in planning electrical grid expansions, which require substantial investments that could become under-utilised, if projects do not materialise (MME/EPE, 2024b).

The Fuel for The Future Law

The approval of the *Lei dos Combustíveis do Futuro* (Fuel for the Future Law) No. 14.993, on 8 October 2024 marked a significant step in the promotion of sustainable low-carbon mobility and the capture and geological storage of CO_2 in Brazil.

The law contains several key initiatives, including the *Programa Nacional de Combustível Sustentável de Aviação* (National Programme for Sustainable Aviation Fuel – ProBioQAV), the *Programa Nacional de Diesel Verde* (National Green Diesel Programme – PNDV), and the *Programa de Descarbonização do Produtor e Importador de Gás Natural e de Incentivo ao Biometano* (National Programme for the Decarbonisation of Producers and Importers of Natural Gas and the Promotion of Biomethane).

With its solid foundation in biofuels, Brazil continues to prioritise them through programmes such as the *Política Nacional de Bicombustíveis* (National Programme for Biofuels – RENOVABIO) and the *Programa Nacional de Produção e Uso do Biodiesel* (National Programme for the Production and Use of Biodiesel – PNPB). While biofuels remain a focal point, the country also recognises the role of electricity as an alternative in the decarbonisation of specific niches in road transport, such as urban buses, commercial vehicles, light trucks for last-mile delivery and premium light-duty vehicles (LDVs).

The Offshore Wind Energy Law

Brazil has one of the world's most significant offshore wind resources, with an estimated technical potential of approximately 1 200 gigawatts (GW). In addition, the geographical diversity and proximity to consumption centres of this offshore resource may give it a substantial advantage in its eventual integration into the country's energy mix (World Bank, 2024).

During COP28 in 2023, Brazil joined the Global Offshore Wind Alliance (GOWA), reinforcing the country's commitment to the development of its offshore wind industry.

In December 2024, after three years of deliberation, the Brazilian Congress then approved a law establishing the legal framework for the country's offshore wind energy strategy.

The primary objective of the law is to set guidelines for the auctioning of lease areas for energy potential assessments, facilitating research and identifying future sites for offshore wind development. Notably, the law does not include any provisions for subsidies, energy auctions, or procurement measures to support offshore wind generation (ABEEólica, 2024). Nonetheless, the Brazilian Wind Trade Association (Abeeolica) expects that the approved framework will foster the country's offshore wind development. This, in turn, is expected to encourage the establishment of a robust local supply chain, enabling the production of wind turbine components, cables and other essential materials. This would create opportunities for a variety of domestic industries, including marine, ports and steel, as well as other related technologies (ABEEólica, 2024).

3.4 OTHER INITIATIVES

A number of other initiatives underscore Brazil's commitment to advancing sustainable transportation and energy while also developing a technologically neutral regulatory framework that addresses its socio-environmental concerns:

- **The *Programa Mobilidade Verde* (Green Mobility and Innovation Programme – MOVER):** Established in 2024, this initiative aims to support technological development, global competitiveness, decarbonisation and integration into global value chains. It also targets alignment with a low-carbon economy in the productive and innovative ecosystems of cars, trucks and other road equipment, buses, chassis with engines, self-propelled machinery, and auto parts.
- **Sustainable aviation fuel (SAF) and methane zero initiatives:** These efforts are part of Brazil's broader strategy to diversify its energy sources and reduce GHG emissions.
- **Energy of the Amazon Programme**: Created by Decree No. 11 648 of 16 August 2023, this aims to reduce the use of diesel oil in energy production. The goal of the programme is to gradually replace diesel with renewable technologies in the isolated systems located in the Amazon region. The programme was a pioneer in the adoption of price mechanisms to differentiate fuels according to their emissions (MME/EPE, 2024b).

  The definition of guidelines to promote the decarbonisation of oil and natural gas exploration and production activities. These were approved by the CNPE via Resolution No. 8 of 26 August 2024 and have a focus on reducing methane emissions.
- **The *Transição Energética Justa* (Just Energy Transition Programme – TEJ):** Established in 2022, the TEJ program focuses on promoting an energy transition for the coal region of the State of Santa Catarina. This transition is aligned with the carbon neutrality goals set out by the federal government.
- **The *Programa de Aceleração da Transição Energética* (Programme for the Acceleration of the Energy Transition – PATEN):** Established by Law 15 103 of 2025, this helps companies that hold receivables from the Brazilian Union – such as tax credits – gain access to credit for financing energy transition projects. PATEN also created the Green Fund, which is managed by BNDES. This fund provides resources for low-carbon projects without requiring collateral, thereby lowering costs for entrepreneurs. PATEN also offers support in areas such as waste-to-energy projects and in modernising the energy generation and transmission infrastructure.

Finally, the increasing integration of VREs, such as solar and wind, necessitates significant advances in storage capacity to ensure grid stability and security. The introduction of energy storage systems – including batteries, hydrogen and pumped hydroelectric storage plants – offers numerous benefits to the power system, but faces regulatory, economic and operational challenges within the Brazilian national grid, the *Sistema Interligado Nacional* (National Interconnected System – SIN).

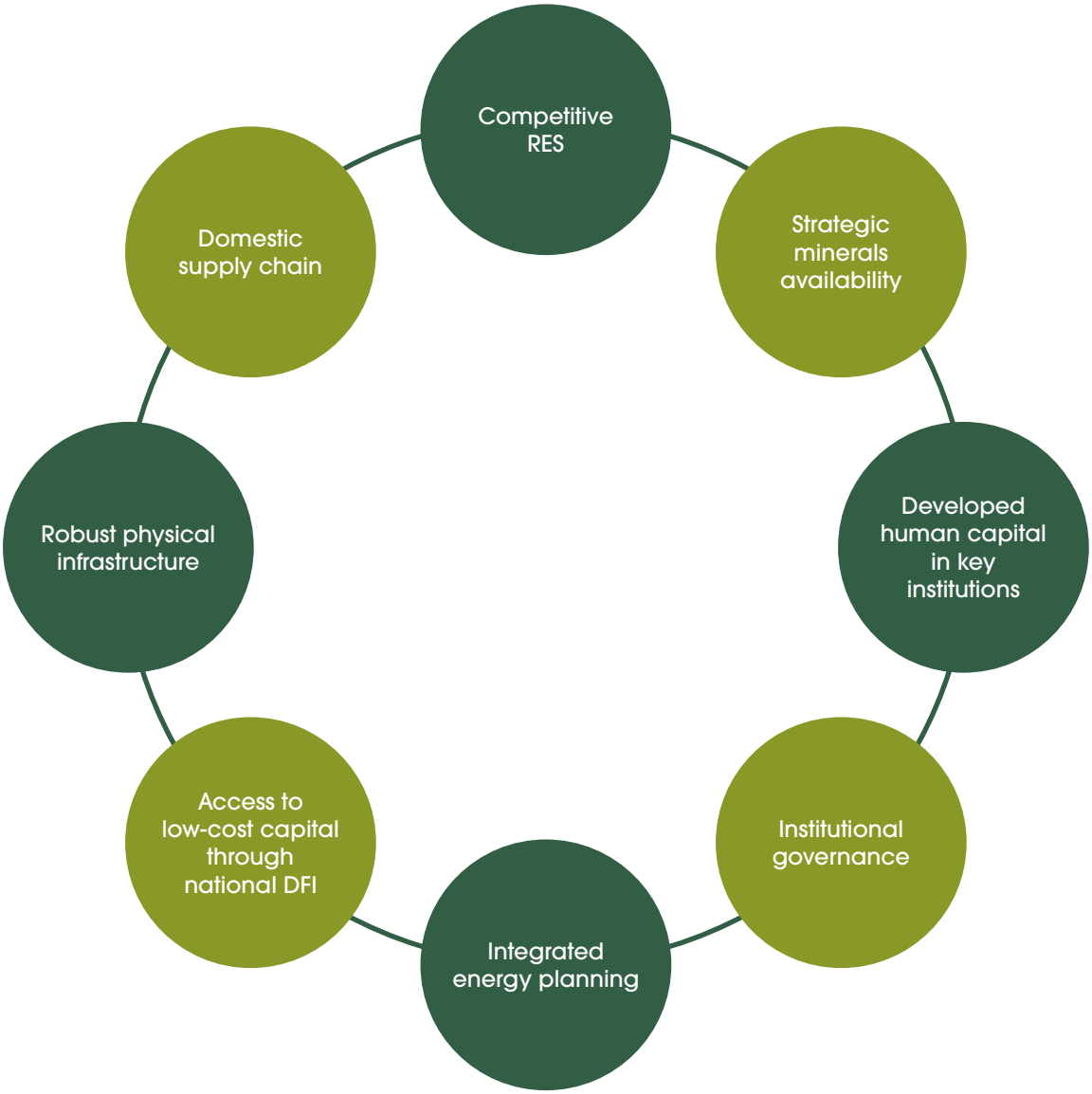
In Brazil, the lack of precise remuneration mechanisms for storage systems impacts the definition of the business model, increasing risks for investors and affecting economic viability. EPE studies, however, suggest these technologies will become competitive over the next decade, particularly with the expected increase in renewable energy integration. This outlook could prompt the government to accelerate initiatives aimed at addressing these challenges (MME/EPE, 2024a).

For behind-the-meter battery applications, there is already a regulatory framework that allows the use of storage systems for consumption management or blackout protection. Despite this, the economic viability of these batteries remains limited due to high equipment costs, heavy taxation and weak price signals to end consumers.

4. KEY ENABLERS OF THE ENERGY TRANSITION IN BRAZIL

The enablers discussed in this report primarily focus on the power sector (Figure 20). Biofuels are addressed in a separate, companion report.[8]

Figure 20 Key enablers of the Brazilian energy transition in the renewable power sector



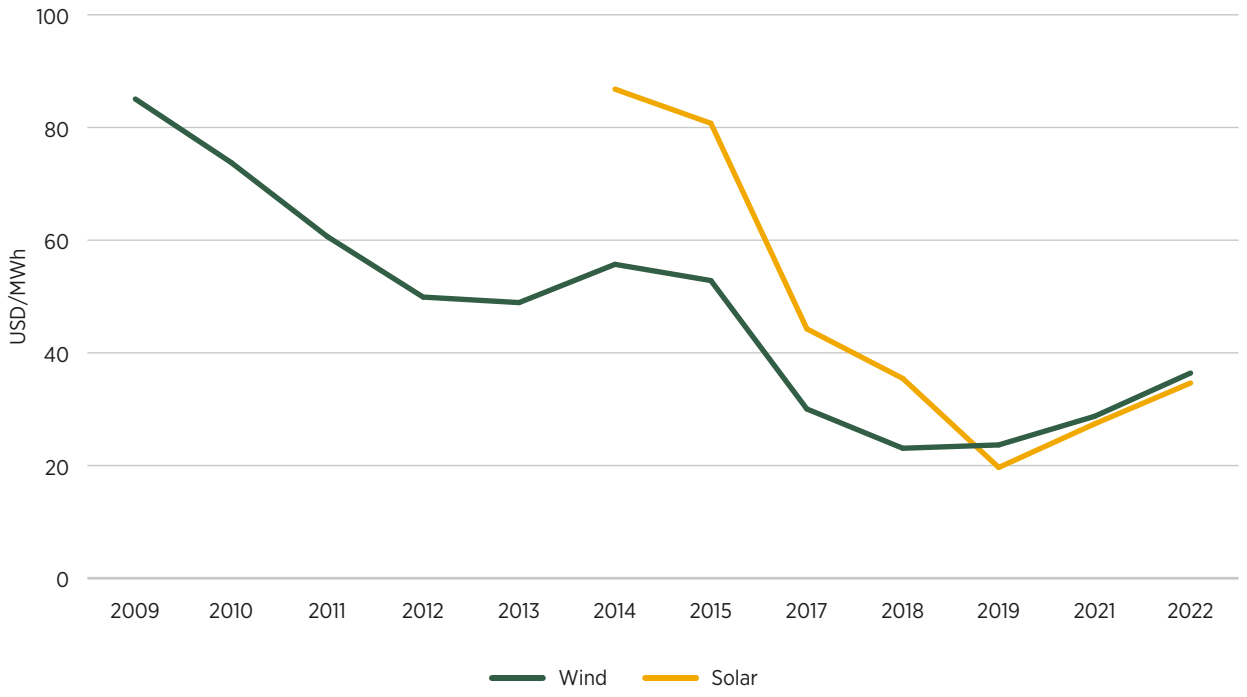
Notes: DFIs = development finance institutions; RES = renewable energy sources.

[8] *See: (IRENA, 2025).*

4.1 COMPETITIVE RENEWABLE ENERGY

Over the years, the share of Brazil's energy mix taken by wind and solar power has surged. This is particularly noticeable at power auctions, where these technologies have become highly competitive (see Figure 21). This competitiveness is primarily due to two factors: the considerable low-cost potential of the country's renewable energy resources, and a reduction in installation costs. The latter factor is being driven by technological advances and the adaptation of procurement and financing mechanisms to evolving market conditions. These improvements have effectively attracted private sector investments and facilitated the expansion of the country's renewable energy capacity (EPE, 2021).

Figure 21 Average annual prices of wind and Solar PV in Brazilian power auctions, 2009-2022

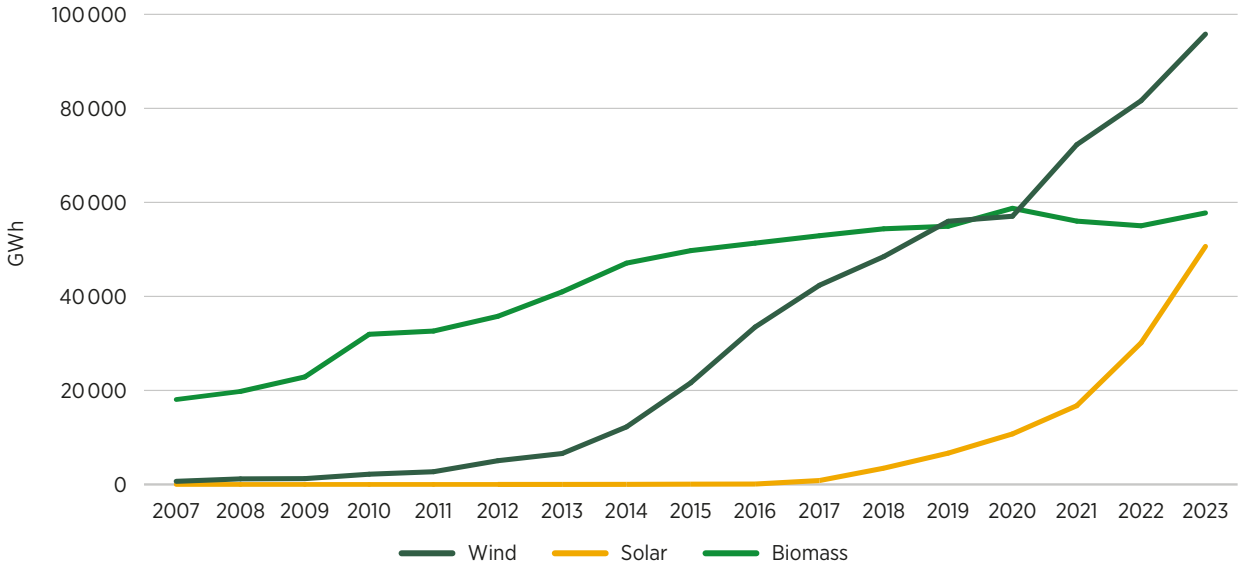


Notes: No auctions were held in 2016 and 2020; all prices derived from ANEEL; MWh = megawatt hour; USD = United States dollar.
Based on: data from ANEEL.

Wind energy in particular has experienced remarkable growth in recent years, with a substantial increase in capacity since 2009 (see Figure 22). This success can be attributed to several factors, including the quality of wind resources in specific regions, which has resulted in average capacity factors well above international levels. Another factor has been the active role of energy planning authorities and the domestic financial institute in de-risking PPAs, expanding the transmission system, and creating mechanisms to support the development of the local supply chain.

Similarly, Brazil has made significant advances in the solar energy sector. These have been driven by a strategic combination of favourable government policies, technological advances and solar's competitiveness in comparison with traditional energy sources. Tax incentives, accessible financing options and regulations facilitating solar energy adoption have been crucial in propelling this growth, which has occurred mainly through distributed generation. Furthermore, ongoing technological advances have reduced solar panel costs and improved efficiency, making solar energy an increasingly viable and attractive option.

Figure 22 Evolution of wind and solar power in the Brazilian power mix, 2007-2023



Source: (MME/EPE, 2024b).
Note: GWh = gigawatt hour.

4.2 THE AVAILABILITY OF STRATEGIC MINERALS

The expansion of renewable energy associated with the global energy transition depends heavily on those minerals that are essential for electric grids, solar panels and electric vehicles (EVs). The expected surge in global demand for critical minerals will require significant investments in mining, processing and recycling, along with investment in innovation (IRENA, 2023).

Demand growth for these minerals will depend, however, on the energy technology mix, the evolving mineral intensity of these technologies, relevant policies and the level of recycling. Nonetheless, the availability of these minerals is a crucial element in national strategies for energy transition, worldwide (IRENA, 2023).

With its substantial reserves of strategic minerals, Brazil is well-positioned to expand its mineral production capacity for domestic use and international trade. The Brazilian mining sector contributes about 4% to the country's GDP and is a key exporter of iron, manganese, tantalum, niobium and bauxite. The country's extensive territory and diverse geology suggest significant potential for new mineral discoveries, making it attractive for foreign investment in mineral production (MME/EPE, 2024b).

4.3 HUMAN CAPITAL DEVELOPMENT IN KEY INSTITUTIONS

Highly qualified staff at key Brazilian institutions involved in the energy industry development, such as BNDES and EPE, have extensive technical and financial expertise. Their proactive role in detailed planning and strategic financing of renewable energy projects has been crucial, directly supporting the successful growth of wind and solar power technologies across Brazil (IRENA and BNDES, 2024).

Established in 2004, the EPE has developed expertise in the renewable energy sector through robust in-house training programmes and international collaborations that enhance the technical capabilities of its staff and facilitate global knowledge sharing.

The regulator (ANEEL), the system operator (ONS) and the market operator (CCEE) are also well-equipped with highly trained staff. One key consideration, however, is that all these organisations must ensure they have sufficiently skilled personnel to address the increasing challenges posed by a timely energy transition. It is therefore essential to address workforce gaps within these institutions in order to maintain effective oversight and drive continued success in the electricity sector. Closing this skills gap remains a crucial requirement for further improvement in the energy transition process – particularly for ANEEL, as it is publicly funded.

On the financial side, BNDES has a skilled team in financial structuring, risk assessment and sustainable investment strategies, ensuring that renewable energy projects are viable and aligned with Brazil's goals. The expertise of its staff has enabled BNDES to offer customised financing solutions. Examples of these include those that have supported the expansion of renewable energy in the non-regulated market, where bilateral contracts were usually shorter than traditional PPAs (IRENA and BNDES, 2024).

4.4 ESTABLISHED INSTITUTIONAL GOVERNANCE

One of the main lessons of Brazil's 2001 electricity crisis was the importance of establishing institutional governance in the power sector (Tolmasquim, 2015). Even when institutions with well-established roles are present, the lack of co-ordination and effective information among them may fail to adequately highlight the risks and scope of crises within the sector.

Therefore, one of the main pillars of the current power sector model, which was introduced in 2004, is a more integrated approach to institutional governance – one that emphasises explicit and transparent accountability in the energy sector.

4.5 ROBUST AND INTEGRATED ENERGY PLANNING

Centralised energy planning is a key aspect of the Brazilian electricity sector. In this regard, the EPE was created to reorganise and strategically align Brazil's national energy planning, ensuring the timely deployment of energy supply and addressing demand growth with competitive costs and a minimum of socio-environmental impact (IRENA and BNDES, 2024).

The EPE has played a key role in strategic planning and risk mitigation, ensuring the efficient integration of wind and solar energy into Brazil's power mix. The EPE's innovative contracting models for these energy sources have been instrumental in this integration. In addition, the planning studies conducted by EPE have been critical in outlining a long-term power expansion plan that aims to deliver reliable and affordable power services across the country. These studies have also helped identify potential socio-environmental conflicts and facilitated the expansion of the transmission network, thereby ensuring a robust infrastructure for renewable energy (IRENA, 2024).

The rapid expansion of distributed generation, however, poses significant challenges to energy planning. In the Northeast Region, for example, electricity surplus is leading to the curtailment of wind and solar power plants to ensure energy supply reliability.

Additionally, integrated energy planning requires solid cross-sector co-ordination and the involvement of a broader range of stakeholders. This is exemplified by the *Luz para Todos* (Light for All – LPT) programme (see Box 1), which was designed to enhance access for impoverished and remote communities (IRENA, 2024).

Box 1
The LPT programme

The National Programme for Universal Access and Use of Electric Energy – usually referred to as the LPT – is a significant initiative that aims to extend the benefits of electricity access and energy transition to rural and remote communities.

Launched in November 2003, the LPT has since impacted over 17 million people in rural Brazil. In its latest phase, the programme aims to reach an additional 0.5 million households by 2026 through grid extensions and the increased deployment of solar PV systems.

The programme's success can be attributed to effective co-ordination among various governmental agencies and robust stakeholder engagement. Co-ordinated by the MME and grounded in a solid legislative framework, the LPT has expanded electricity access and made it affordable by utilising subsidised and financed resources. This approach encourages the productive use of electricity to improve livelihoods sustainably. By the end of 2023, planned investments in the LPT amounted to BRL 32.36 billion (approximately USD 5 billion).

The programme's funding comes from federal government subsidies and executing agents who use their funds or financing. Under the MME's overall co-ordination, Brazil's largest electricity company, Eletrobras, operates the programme, with concessionaires, permit holders, public electricity distributors and rural electrification co-operatives serving as executing agents.

The MME defines the LPT's operational aspects, while ANEEL monitors the universalisation plans of the executing agents and ensures compliance with programme's goals and timelines. Continued co-ordination among governmental agencies and stakeholders is essential in ensuring the long-term sustainability of the LPT programme's social benefits (MME, 2024).

4.6 ACCESS TO LOW-COST CAPITAL THROUGH DEVELOPMENT FINANCE

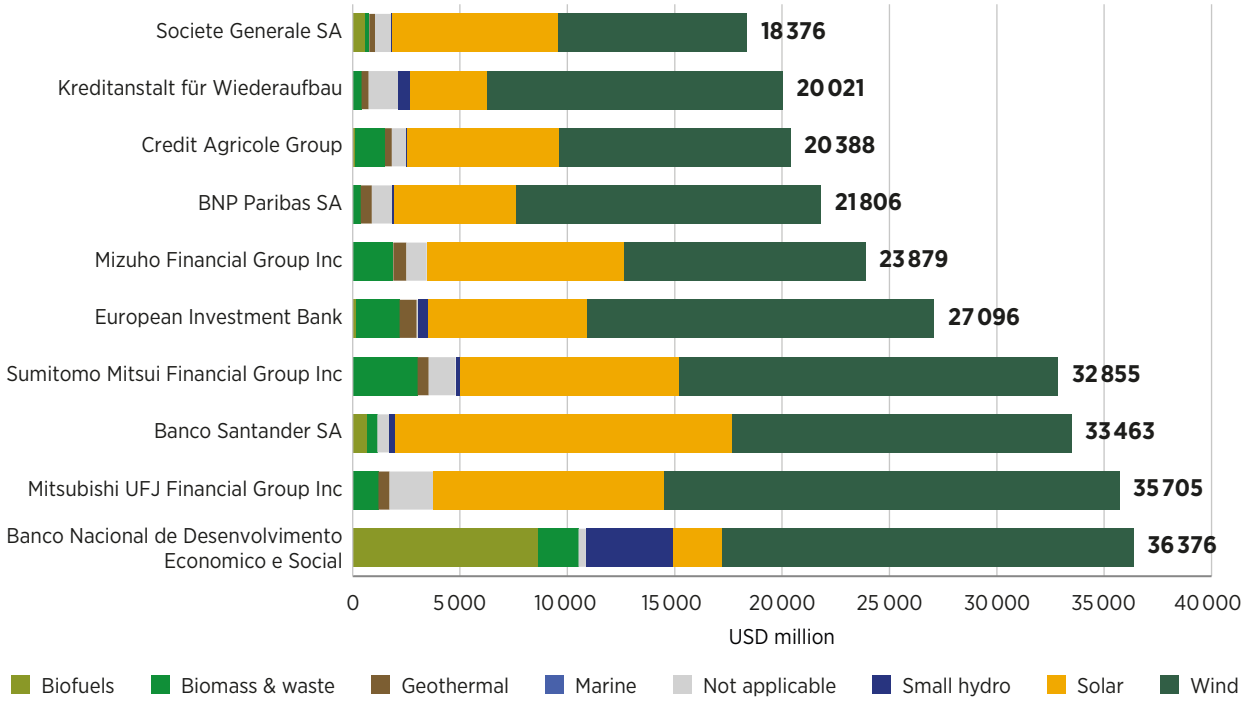
For power sector investors in Brazil, the long-term, local currency financing conditions offered by BNDES are a central aspect of project finance. By providing development finance in the form of long-term funds in local currency, BNDES has successfully lowered financial barriers and fostered a supportive ecosystem for renewable energy. This approach has been further enhanced by innovative financing mechanisms, risk mitigation strategies and international collaboration (IRENA and BNDES, 2024). Indeed, the bank's extensive experience in funding infrastructure projects positions the BNDES as a global leader in renewable energy financing. The bank has been active in introducing and utilising financial instruments such as blended finance, green bonds and guarantee sharing within the Brazilian financial market. This broad experience, supported by its specialised staff, enhances the BNDES's capacity to effectively support complex, long-term projects.

Regarding the electricity sector, the BNDES has been fundamental in financing the deployment of new power capacity and transmission lines. Investors participating in a power auction are not required to secure funding through BNDES – they can seek financial support internationally – yet, if they choose to utilise BNDES funding, they must contribute to strengthening the local energy industry supply chain.

This restriction has not limited the bank's importance in the market, however. On the contrary, between 2000 and 2023, financing from the BNDES for projects in the generation and transmission sectors amounted to around USD 100 billion. This corresponded to some 81.6 GW of additional power capacity from a total of 125 GW of total power capacity expansion undertaken during that period. This BNDES financing also helped in the roll out of 67 000 km of transmission lines (IRENA and BNDES, 2024).

When compared to its international peers, the substantial amounts of financing provided by the BNDES show the bank's key role in Brazil's renewable energy financing.[9] Indeed, according to BloombergNEF, the BNDES leads the world in total financing of new renewables (wind, solar, biofuels, biomass, *etc.*), providing more than USD 36 billion between 2004 and 2023 (see Figure 23).

Figure 23 Top clean energy project lenders, 2004-2023



Source: (BNEF, 2024).

BNDES' approach demonstrates the critical role of financial institutions in reducing investment risks and uncertainties. By providing stable financial conditions and supporting the supply chain for equipment manufacturers and service providers, the BNDES has facilitated investments in the renewable sector.

[9] *BNB – which is responsible for managing constitutional funds directed to regional development in the Northeast Region of Brazil, the north of Minas Gerais and Espirito Santo – also offers attractive financing conditions for renewable energy sources. This is particularly so with regard to solar energy and distributed generation in its area of operation. BNB is Latin America's largest regional development bank.*

4.7 ROBUST PHYSICAL INFRASTRUCTURE

Insufficient and unreliable grid infrastructure and high transmission and distribution losses pose a significant challenge in emerging markets and developing economies. High and unanticipated curtailment risks can also severely affect the financial sustainability of renewable energy projects, potentially delaying development until the grid is reinforced (IRENA and BNDES, 2024).

Brazil is addressing these challenges through strategic planning and risk mitigation strategies led by the electricity sector authorities – the MME, EPE, ONS and ANEEL. The EPE conducts critical studies to mitigate grid and transmission risks for generator entities. This work includes expanding system interconnections and installing substation hubs to integrate wind farms into the main grid, particularly in the Northeast Region. For its part, the ONS is responsible for short-term transmission planning. It also proposes adjustments to the specifications of transmission facilities based on situational aspects and specific operational requirements, aiming to reinforce and enhance operational security. The MME defines transmission network expansion — a process that determines which transmission facilities the ONS and EPE studies have recommended — and are then implemented by ANEEL (IRENA and BNDES, 2024).

These efforts ensure a robust infrastructure supporting the integration of significant amounts of renewable energy. The electricity sector authorities' proactive transmission planning enhances transparency and predictability regarding connection risks. This involves auctioning transmission grid infrastructure in advance, based on resource availability and clustering methodologies aligned with the renewable power projects that have been announced. To streamline grid connections, power auctions with shorter lead times include a preliminary phase to select feasible projects through competition at the same connection point. This prevents projects exceeding the connection capacity set by the bidding.

The capacity of Brazil's extensive grid system to transport electricity from generation sites in one region to consumers in others underscores the critical role of grid integration. Given the Brazilian grid's continental size and interconnected infrastructure, it offers a compelling example of the benefits of integration, such as the diversification of sources of energy. This integration is vital in harnessing the potential of unevenly distributed renewable energy resources. To ensure efficient and reliable energy delivery, proactive transmission planning, integrated with generation projects, is essential in minimising discrepancies between generation capacity and transmission infrastructure, particularly when planning for substantial renewable energy growth (IRENA and BNDES, 2024).

4.8 A DOMESTIC SUPPLY CHAIN FOR THE GREEN ECONOMY

Aligning financial mechanisms with long-term energy planning and environmental considerations can foster a supportive environment for renewable energy projects. This integrated approach, executed by domestic institutions with finance expertise, such as the BNDES, and energy planning knowledge, such as the EPE and MME, has increased renewable investments and improved the country's supply chain.

Long-term financing conditions in the local currency provided by BNDES are essential for project finance among power investors. While these investors can pursue funding internationally, BNDES financing necessitates the strengthening of the local energy industry's supply chain. The bank has played a crucial role in attracting global wind turbine manufacturers to Brazil, promoting the local production of technology-intensive components, developing a strong domestic supply chain, facilitating timely project development and mitigating the exchange-rate risk associated with imported equipment. This has lessened that risk, facilitated timely project development, created skilled job opportunities and stimulated local innovation (IRENA and BNDES, 2024).

5. LESSONS FROM BRAZIL

Among the world's emerging low-carbon economies, Brazil is a significant player with leadership potential. Renewable energy already accounts for a considerable proportion of the country's energy mix, with this the result of a number of factors from which lessons can be learnt, worldwide. These include: 1) the joint role of energy planners and domestic development finance institutions (DFIs) in de-risking renewable energy projects; 2) the need for appropriate institutional governance; and 3) recognition of the need for a skilled workforce to address the challenges associated with the acceleration of the energy transition.

5.1 THE JOINT ROLE OF INTEGRATED ENERGY PLANNING AND DOMESTIC DFIs IN RE-RISKING

Brazil has successfully integrated renewable energy into its national grid, mainly through the collaborative efforts of the MME, EPE and BNDES. These institutions have created a supportive environment for renewable energy projects by aligning financial mechanisms with strategic, long-term energy planning and environmental considerations.

Brazil's experience underscores the importance of a co-ordinated approach. This alignment expands renewable energy and infrastructure. It does this by designing long-term contracts with attractive risk-return profiles and scaling up private investments. This enhances the domestic industry supply chain and contributes to job creation, enabling energy transition projects to create positive local economic impacts.

5.2 APPROPRIATE GOVERNANCE

Appropriate governance is essential in ensuring that the energy sector operates efficiently and is aligned with national and international renewable energy and decarbonisation goals. Building on the lessons of the electricity crisis of 2001, Brazil developed an integrated governance approach, clearly defining the roles and responsibilities of the stakeholders and ensuring the co-ordination of efforts across different levels of government and sectors.

Brazil's emphasis on appropriate governance in the energy sector highlights the importance of adapting institutional structures to support the transition to renewable energy.

5.3 DEVELOPMENT OF THE NECESSARY HUMAN CAPITAL

Developing the human capital necessary for renewable energy expansion is crucial to Brazil's energy transition and to global decarbonisation efforts.

Building a skilled energy transition workforce requires measures to expand the talent pipeline and enhance the quality of education and training. As the experiences of the BNDES and EPE show, a skilled workforce is essential in developing sustainable renewable energy projects, but its creation takes time.

International collaboration through groups such as the Group of 20 (G20) is essential to mobilising support and fostering a skilled workforce for energy transition efforts, particularly in the Global South. In this regard, the ETP aims at international co-operation through platforms such as the BIP and Eco Invest Brasil, facilitating technology transfer and capacity building.

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