

JUST ENERGY TRANSITION

Scenarios Brazil





Just Energy Transition / Scenarios Brazil

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Just Energy Transition

Scenarios Brazil

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List of abbreviations

AFOLU	agriculture, forestry, and other land use
AMI	advanced metering infrastructure
ANEEL	National Electricity Agency
ANP	National Oil, Natural Gas, and Biofuels Agency
BAU	Business as usual
CAGR	compound average growth rate
CAPEX	capital expenditures
CCUS	carbon capture, use, and storage
CDE	Energy development account
CEPAL	Economic Commission for Latin America and the Caribbean
CGIEE	Energy Efficiency Indicators Management Committee
CNG	compressed natural gas
CONPET	National Program for the Rationalization of the Use of Petroleum Products and Natural Gas Byproducts
EE	Energy efficiency
EEP	Energy Efficiency Program
ENCE	National Label for Energy Conservation
EPE	Energy Research Office
EV	electric vehicles
GCRI	global climate risk index
GDP	gross domestic product
GDPpc	gross domestic product per capita
GHG	greenhouse gases

HDI	human development index
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification
JET	just energy transition
LEAP	SEI's low emissions analysis platform
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MME	Ministry of Mines and Energy
MUSD	millions of US dollars
NCR	non-conventional renewable energy
NDC	nationally determined contributions
NSO	National System Operator
NZ	net zero
OLADE	Latin American Energy Development Organization
PNEf	National Energy Efficiency Plan
PPP	purchasing power parity
PROCEL	National Electricity Conservation Program
RJ	Rio de Janeiro
SEI	Stockholm Environment Institute
sieLAC	Energy Information System for Latin America and the Caribbean
SHW	sanitary hot water
SP	São Paulo
TJ	terajoules
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
WEC	World Energy Council



1. General objective

The general objective of the project was to develop a methodological approach to define the concept of just energy transition (JET) in a national context, with potential application in CAF – Development Bank for Latin America and the Caribbean – member countries and to evaluate the proposed approach in Brazil, Colombia, Mexico, Peru, and the Dominican Republic.



2. Specific objectives

The specific objectives of this report are the following:

1. to define a methodological approach to address the just energy transition in the region in a comprehensive way;
2. to diagnose the national (target countries) energy systems – in particular, the power systems – in the context of the energy transition process;
3. to define national scenarios for the low-carbon development model of the energy transition in the target countries, including those elements to be electrified in energy sectors that are currently not being served by the power sector, within the prospective requirements;
4. to model the viable energy transition alternatives in the previously defined context.

3. Organization of the Just Energy Transition series

The specific objectives of this report are:

1. Just Energy Transition / Conceptual framework for the region. Analysis in the national context
2. Just Energy Transition / Projection assumptions
3. Just Energy Transition / Scenarios for Brazil
4. Just Energy Transition / Scenarios for Colombia
5. Just Energy Transition / Scenarios for Mexico
6. Just Energy Transition / Scenarios for Peru
7. Just Energy Transition / Scenarios for the Dominican Republic

The reports were organized following the alphabetical order of their names.

4. Organizational aspects

This report has been financed by CAF and is published to communicate the results and conclusions obtained to the community interested in Latin American development. Therefore, the document has not been prepared following the procedures of an official document. Some of the sources cited in this report could be informal documents that are difficult to obtain.

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Edgar Salinas, Juan Ríos, and Walter Cont from CAF formed a working team that established the terms of reference and development of the abovementioned reports by GME consultants.

The GME team – in alphabetical order – was composed of Agustín Ghazarian, Coline Champetier, Darío Quiroga, Francisco Baqueriza, Nicolás Barros, Laura Souilla, Ramón Sanz, and Roberto Gomelsky.

5. Scenarios: Brazil

This report contains the analysis of the energy transition in Brazil and is organized into four chapters.

- **Diagnose and base line.** This chapter establishes the diagnose of the base line in terms of sources and uses, characteristics of the power sector, environmental aspects (greenhouse gas (GHG) inventories, commitments), and institutional, regulatory, and public policy aspects, among others. It allows us to present the starting point of the energy projections and to identify the main characteristics that may condition the just energy transition strategy.
- **Energy projection methodology.** This chapter summarizes the low-emissions analysis platform (LEAP) model and its use to model emissions in the energy sector¹.

Energy demand projection methodologies are presented by sector, subsector, uses, and sources, as well as the power generation modeling. It also describes the three projection scenarios contemplated and the main assumptions considered.
- **Transition scenarios.** This chapter presents the projections in terms of emissions and energy demand for the three scenarios previously defined (Business as Usual (BAU), Net Zero 2050 (NZ 2050), and Net Zero 2060 (NZ 2060)). It details the results by sector and the main explanatory assumptions, and presents the needs in terms of energy transition

¹ More specifically, the LEAP (Low Emissions Analysis Platform) model was used to model the emissions related to burning fuel.

investment related to the power sector and its end uses. It concludes with the starting point and the end point of the main transition indicators by scenario.

- **Proposal for a roadmap for a just energy transition.** The roadmap describes the public policies to be developed and the segments that require concessional finance or support to accompany the just energy transition scenarios previously presented.





Diagnosis
and base line

1. General characterization



Socio-economic aspects

Brazil, officially the Federative Republic of Brazil, is the largest country in Latin America, with an area of 8.5 million square kilometers. It is the fifth largest country in the world in terms of area and the sixth in the world in terms of population. Brazil borders most of the other countries in Latin America (except Ecuador and Chile), and covers 47 % of the continent’s land area.

Table 1

Socio-economic indicators

Indicator/Country	Brazil
Total population (2021, millions)	213.99
Population density (inhabitants/km²)	25
Urban population (%)	87 %
GDP per capita 2021 (USD at constant 2010 prices)	8,551
Extreme poverty index 2020	5.1 %

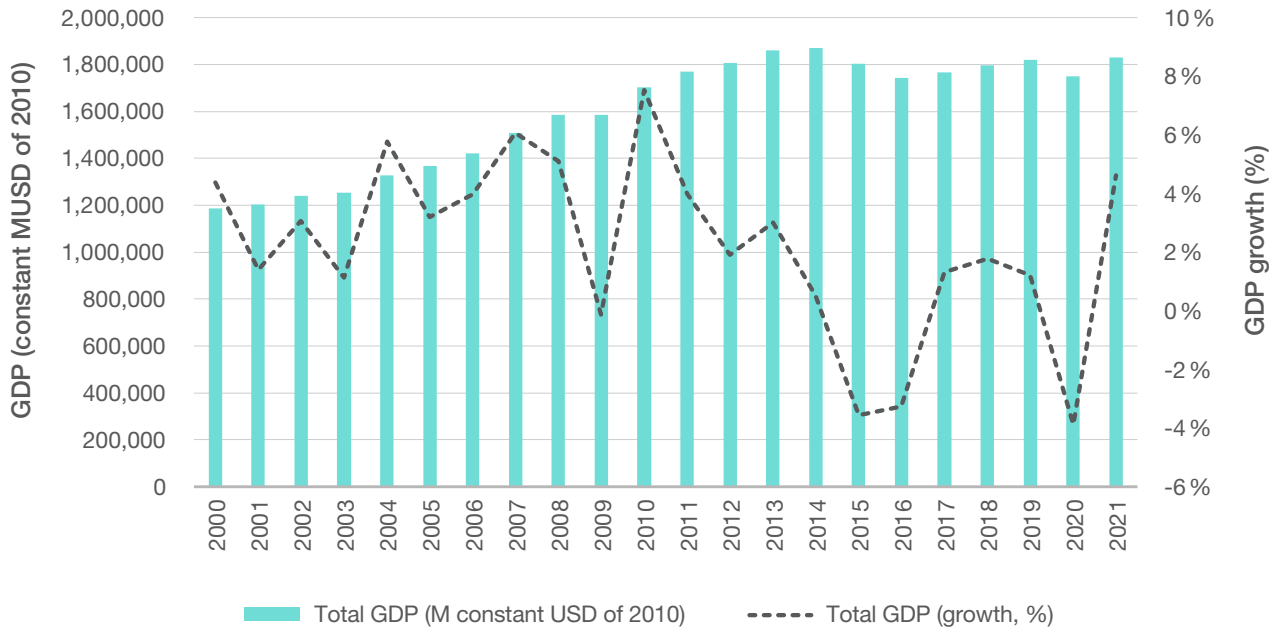
Source: Own preparation based on data from the World Bank and CEPALSTAT.

Population is estimated at 213.99 million (2021) with a density of 25 inhabitants/km². Most of the population lives in cities (87 %) and, more specifically, in cities with over one million inhabitants (42 %). Its capital is Brasilia and the most populated city is São Paulo.

Brazil has a mixed developing economy, the ninth in the world pursuant to its nominal gross domestic product (GDP) of 2020 and the first in Latin America. According to the World Bank, its gross domestic product per capita (GDPpc) at constant 2020 prices was USD 8,551 in 2021.

After years of instability, both political and economic, Brazil has managed to stabilize its economy and has experienced high economic growth. In 1994, the launch of the Plan Real was the first step towards greater economic stability and created a new currency (still used today), the real. From 2000 to 2013, Brazil benefited from the rise in the price of raw materials and was one of the fastest growing economies in the world (part of the BRICS), with an annual average GDP growth rate of around 4 % in constant US dollars (USD). However, Brazil's economic growth decelerated in 2014 and the country underwent a recession in 2015 and 2016. The economy started recovering in 2017, with a growth rate of 1.3 % in the last 3 years. In 2020, the impact of the COVID-19 pandemic on Brazil's economy was significant, like in most countries in the region, as it ended the year with a 4.1 % fall.

Graphic 1 ► GDP and annual growth rate, constant MUSD of 2010 and %

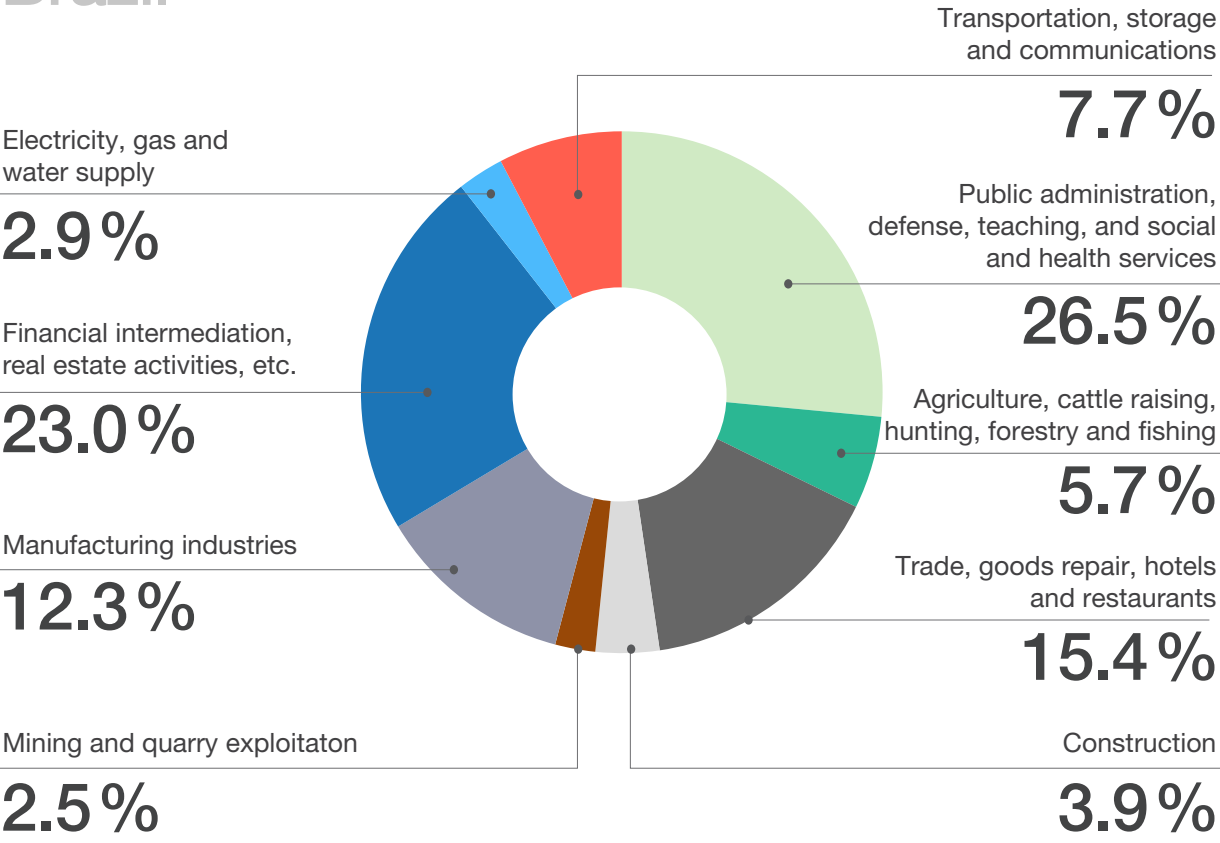


Source: Own preparation based on data from the World Bank.

Brazil has a diversified economy, in which the public administration, defense, teaching, social services, and health sectors accounted for 26.5 % of the GDP in 2021, followed by the financial (23 %), commercial (15.4 %) and manufacturing industries (12.3 %) sectors.

Graphic 2 ▶ GDP by sector, 2021, %

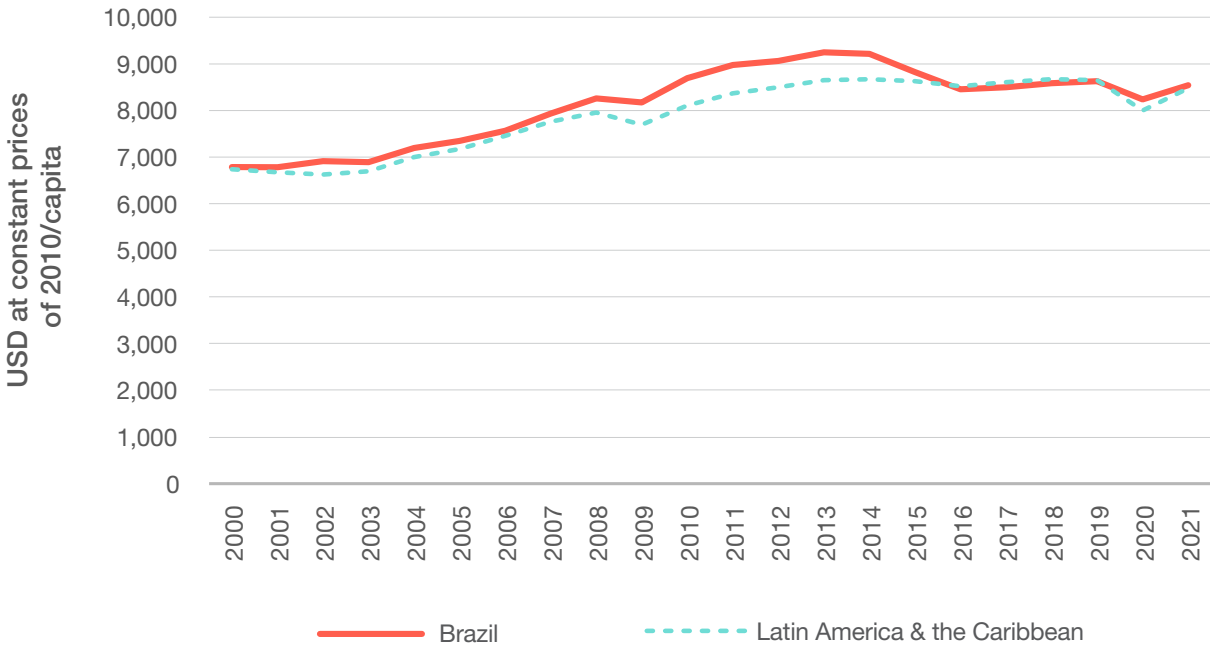
Brazil



Source: Own preparation based on data from CEPAL.

Except for certain particular years, the GDPpc has had an upward trend in the last 20 years.

Graphic 3 ▶ GDP per capita, constant 2010 USD

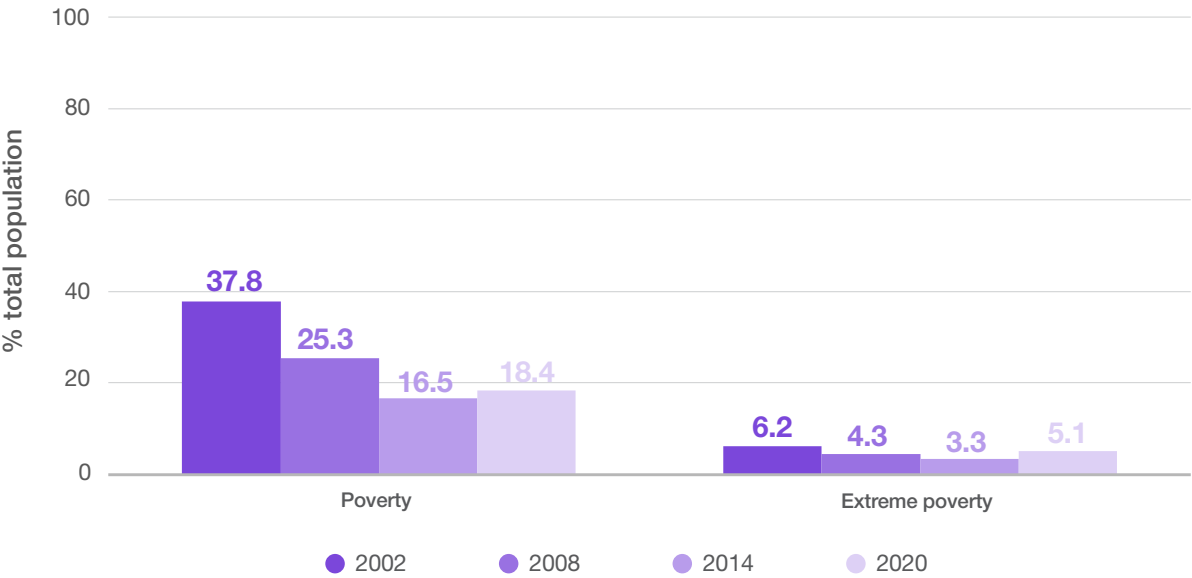


Source: Own preparation based on data from the World Bank.

In the last twenty years, we can see a strong reduction in poverty, except for 2020, when it rose as part of the social and economic consequences of COVID-19.

Graphic 4

► Incidence of poverty and extreme poverty per year, %



Source: Own preparation based on data from CEPALSTAT.



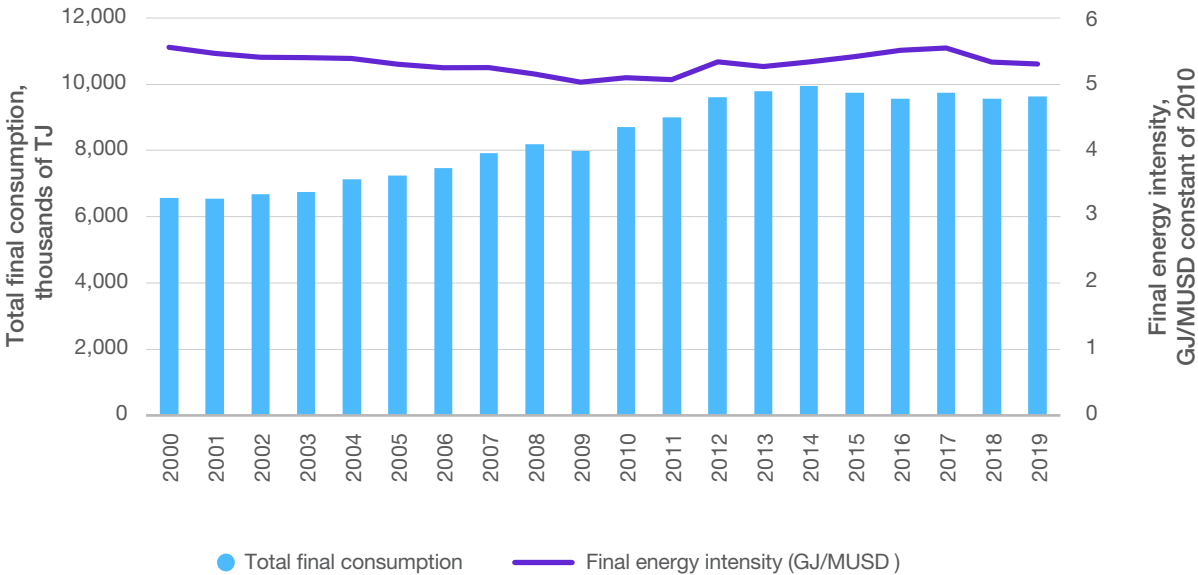
Socio-economic and energy indicators

Energy intensity in the economy

The final energy intensity² was slightly reduced in the period from 2000 to 2019 (cumulative -4.2 %) whereas total final consumption rose by an annual average 2.4 %.

Graphic 5

► Total final consumption versus final energy intensity, 10³ TJ and GJ/constant MUSD of 2010



Source: Own preparation based on data from sieLAC, OLADE³.

² It is defined as the relation between final energy consumption and GDP at constant USD of 2010.

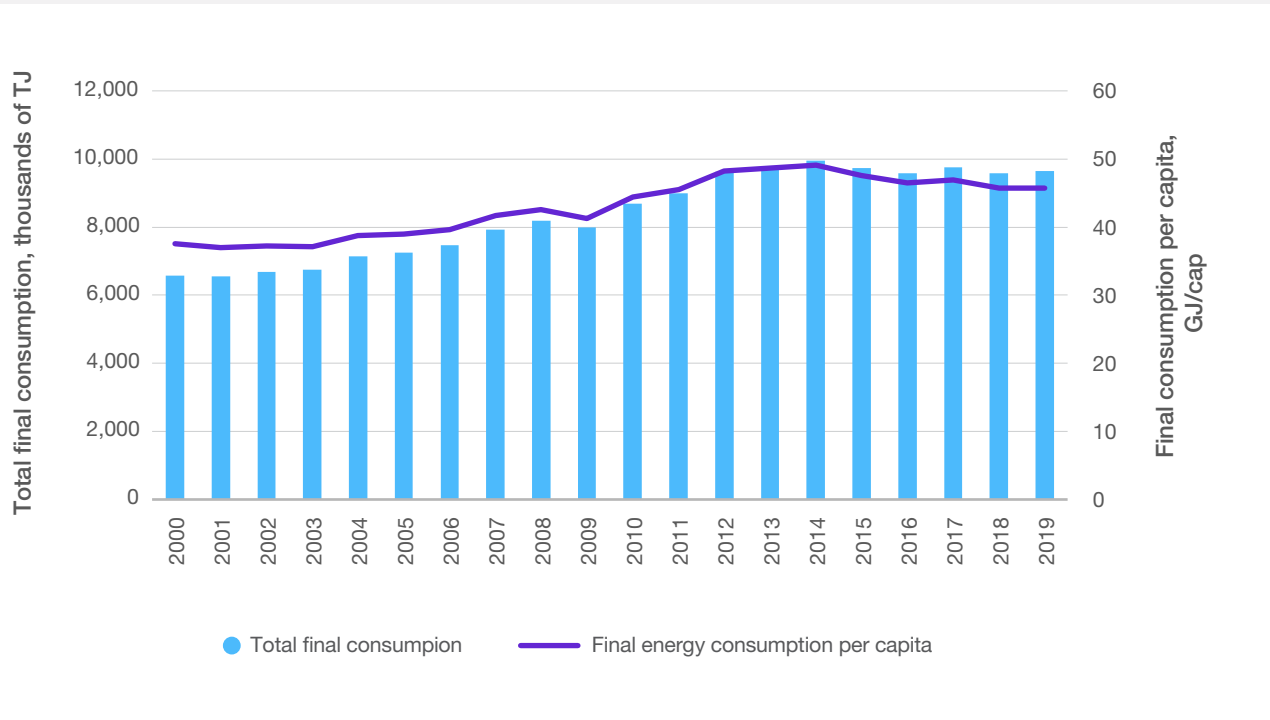
³ Data on energy intensities calculated internally in the system, with GDP data from the World Bank and energy consumptions from the national energy balances.

Consumption per capita

The growth in final energy consumption per capita was lower than the total final consumption in the period 2000-2019 (2.4 % vs. 1.1 %) and it has slowed down since 2014

Graphic 6

► Total final consumption versus final consumption per capita, 10³TJ and GJ per capita



Source: Own preparation based on data from sieLAC, OLADE.



Local prices

The following end user prices refer to Brazil. Both in the case of electricity and natural gas and other fuels, these prices are close to the average in the region, except for fuel oil, which – as in Peru – shows high prices compared to the rest of the region.

Table 2

► Prices of the main energy resources in Brazil, cut-off year 2018

Energy resource	VAT %	Special taxes ⁴	Price
Electricity (Residential)	-	Yes	187.0 USD/MWh
Electricity (Commercial)	-	Yes	169.1 USD/MWh
Electricity (industrial)	-	Yes	161.5 USD/MWh
LPG (Residential)	-	Yes	1.32 USD/kg
Gasoline	21 %	-	1.14 USD/l
Diesel	21 %	-	0.90 USD/l
FuelOil	-	Yes	0.66 USD/l

Source: OLADE - <https://www.olade.org/publicaciones/precios-de-la-energia-en-america-latina-y-el-caribe-informe-anual-abril-2021/>

⁴ The special tax with more significance is the Tax on the Circulation of Goods and on Providing Interstate and Intermunicipal Communications Transportation Services (*Impuesto a la Circulación de Mercancías y a las Prestaciones de Servicios de Transportación Interestatal e Intermunicipal de Comunicación*, ICMS) which, depending on the transportation goods and the state considered, may reach 25 %. The other special taxes applied on energetics add up less than 5 % of their value.



Energy aspects

Reserves and total fuel supply (production, imports and exports)

Brazil has significant energy resources, in particular, oil, uranium, and hydro power. Hydro power accounts for a considerable part of electricity production. By the end of 2021, Brazil was the second country in the world in terms of installed hydroelectric capacity. It also has great wind and solar potential.

As to its solar resources, according to the Global Solar Atlas platform, Brazil shows a value of 1,694 kWh/kWp in 10 % of the areas with greater photovoltaic production, and an average 1,606 kWh/kWp. As a reference, the global resource for 10 % of the areas with more irradiation has been established at 1,736 kWh/kWp and the average global resource is 1,576 kWh/kWp. The greatest concentration of solar resource is located in the central and northeastern regions in the country.

On the other hand, according to the Global Wind Atlas, Brazil's wind resource in 10% of the areas with more wind is equal to or greater than 326 W/m², where the mean wind speed at 100 meters is 7 m/s or more.

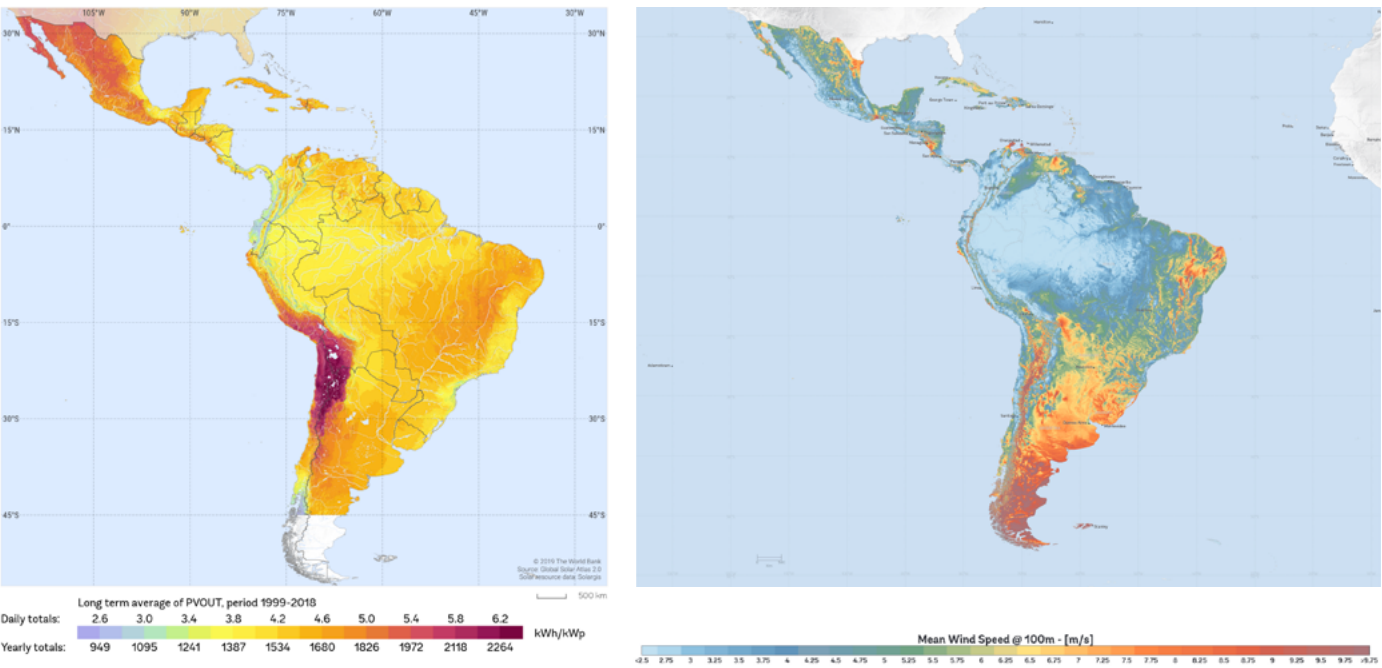
The Brazilian Eolic Energy Association (ABEEólica) estimated the gross potential of the land wind resource at 500 GW, with an average capacity factor of over 40 %, reaching values of around 60 % and 70 % in the northeastern region of the country. In addition, the Energy Research Office (EPE) estimates that, in the areas with wind speeds of over 7 m/s at an altitude of 100 m, there is a potential additional 697 GW from offshore resources in locations with depths of about 50 m⁵.

⁵ EPE, *Roadmap Eólica Offshore Brazil*, April 30, 2020 (<https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/roadmap-eolica-offshore-brasil>)

Graphic 7 illustrates the solar and wind resources in Latin America and the Caribbean.

Graphic 7

► Potential solar resource (kWh/kWp) and mean wind speed at 100 m (m/s)

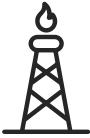


Source: Global Solar Atlas (World Bank)⁶ and Global Wind Atlas (World Bank)⁷.

Brazil's refining capacity allows it to supply most of its internal demand. Brazil is also considered an international leader in terms of biofuels and it is the second largest ethanol producer in the world.

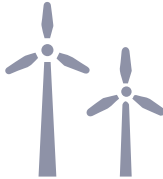
⁶ Global Solar Atlas, World Bank Group, <https://globalsolaratlas.info/download/latin-america-and-caribbean>
⁷ [ws_LAC.pdf](#)

Table 3 ▶ Fuel reserves, hydroelectric potential, and infrastructure, 2019, Brazil

Reserves				Potential	Installed capacity	
Oil	Natural gas	Coal	Uranium	Hydro power	Refining	Power generation
						
12,714	364	6,596	12,652	260.1	2,411	172.3
Mbbl	Gm³	Mt	10^6 bep	GW	kbbl/day	GW

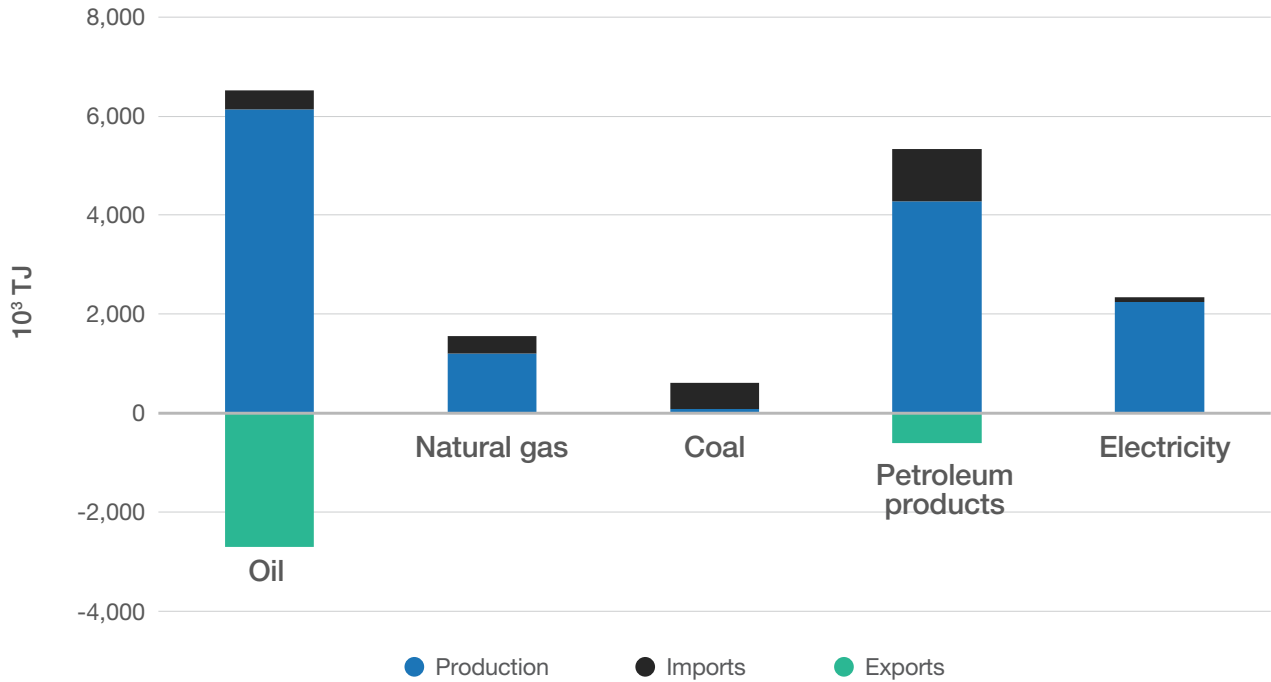
Source: sieLAC, OLADE.

Table 4 ▶ Wind and solar resources, Brazil

Recursos		
Wind (10% of the areas with more wind)	Solar (average)	Solar (10% largest production)
		
7.02	1,606	1,694
m/s	kWh/kWp	kWh/kWp

Source: Own preparation based on *PV Magazine - Latinoamérica*, ABEEólica, and EPE..

Graphic 8 ▶ Production, imports and exports by main source, 2019, 10³ TJ



Source: Own preparation based on data from sieLAC, OLADE.

Brazil is the first oil producer in Latin America (9th producer in the world in 2021). It exports slightly less than half its oil production. It locally consumes its natural gas production and imports the missing volume to supply its demand. Imports come from Bolivia and Argentina or more distant countries (LNG). Brazil has coal reserves but is mainly a coal importer. On the other hand, it has the sixth largest uranium reserves in the world.

In terms of electricity, most of the exchanges with neighboring countries with electrical infrastructure (Argentina, Bolivia, Paraguay, Uruguay and Venezuela⁸) are usually opportunity exchanges⁹, depending on the surpluses and deficits that each country shows and their prices. Exchange volumes through transmission lines are small compared to the size of the Brazilian generation system. Instead, there are exchanges through the binational power plants¹⁰.

Globally, Brazil has an energy import/export balance close to equilibrium. It is a slightly net energy exporter¹¹.

Its proven natural gas and oil reserves have remained stable in recent years whereas coal reserves decreased between 2000 and 2010 and later remained stable.

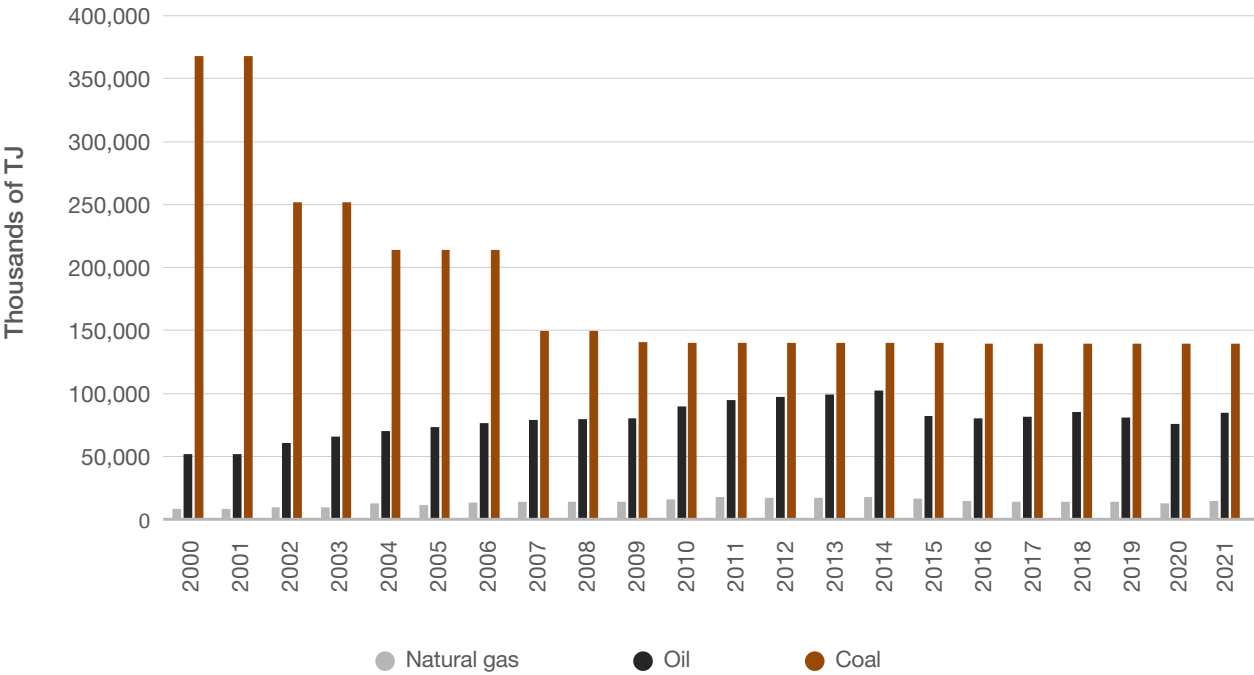
8 In the case of Venezuela, a 230 kV transmission line with a capacity of 200 MW connects the city of Boa Vista (Roraima, Brazil) with the city of Santa Elena (Venezuela). So far, Boa Vista has not been connected to the National Interconnection System (SIN). There is a supply contract with established prices and amounts.

9 Except for the exchanges between Paraguay and Brazil related to Itaipú hydro plant (50% of the plant total capacity) and the exchanges related to a contract whereby Brazil made the total investment in the plant and Paraguay delivers the energy as consideration for the capital loaned by Brazil.

10 Until 2022, 50% of Itaipú's electricity production belonging to Paraguay was dispatched to the Brazilian system as part of the payment for the investment made by Brazil. The plant produced 5 times Paraguay's energy demand; therefore, it is expected that the energy produced by the plant will be destined to the Brazilian market. This is the only relevant energy exchange between Brazil and any of its neighbors with electric power connections.

11 Since 2017, its energy foreign dependence index (relation between total energy imports less total exports divided by total energy supply) has been negative and approached -6 % in 2019.

Graphic 9 ► Evolution of proven oil, natural gas, and coal reserves, 10³ TJ



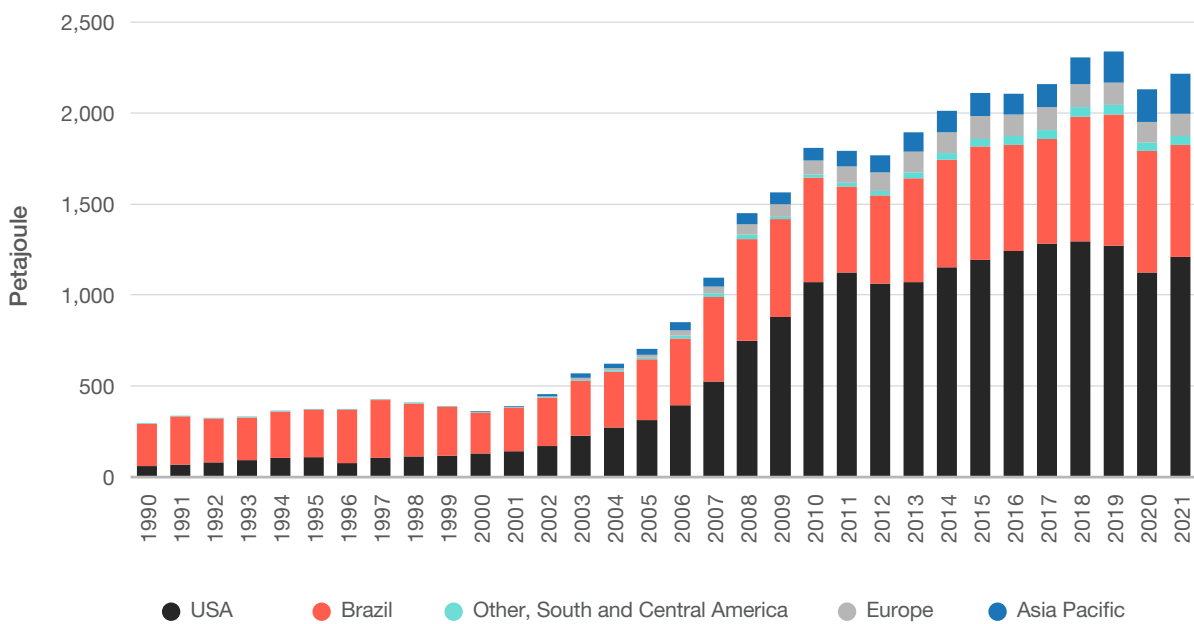
Source: sieLAC, OLADE.

Brazil is a global producer of biofuel, especially bioethanol. It is the second world producer after the United States, which produces it from corn whereas Brazil does so from sugar cane.

The development of bioethanol on a large scale was a joint and long-term development effort of the sugar or sucroalcohol industry and the car industry. This industry developed an Otto-cycle engine especially adapted (Flex engine) to run on hydrocarbon-based gasoline mixed with additional proportions of anhydrous or hydrated alcohol until completing 100 %, or 100 % of hydrated alcohol without mixing it with any kind of gasoline. Hydrocarbon-based gasoline can contain up to 25 % of anhydrous ethanol.

Graphic 10

► Brazil, second world producer of bioethanol fuel



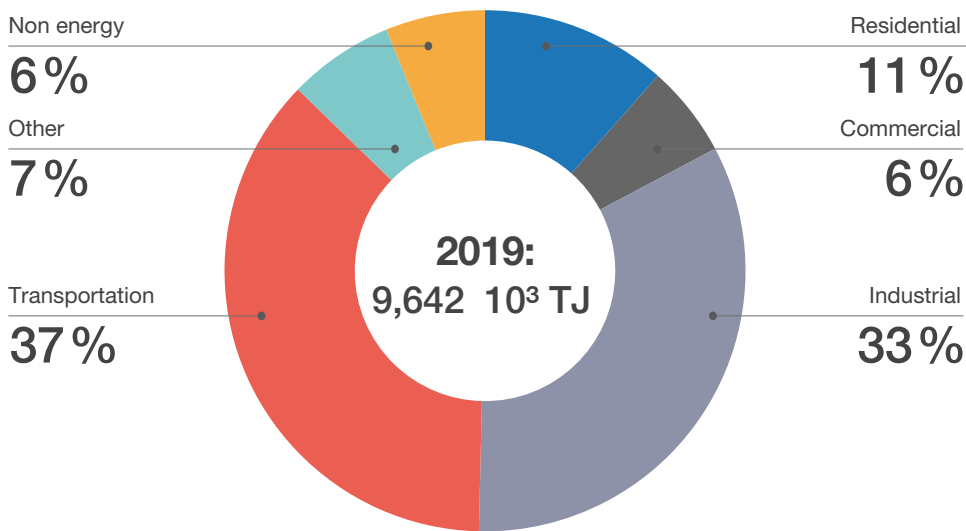
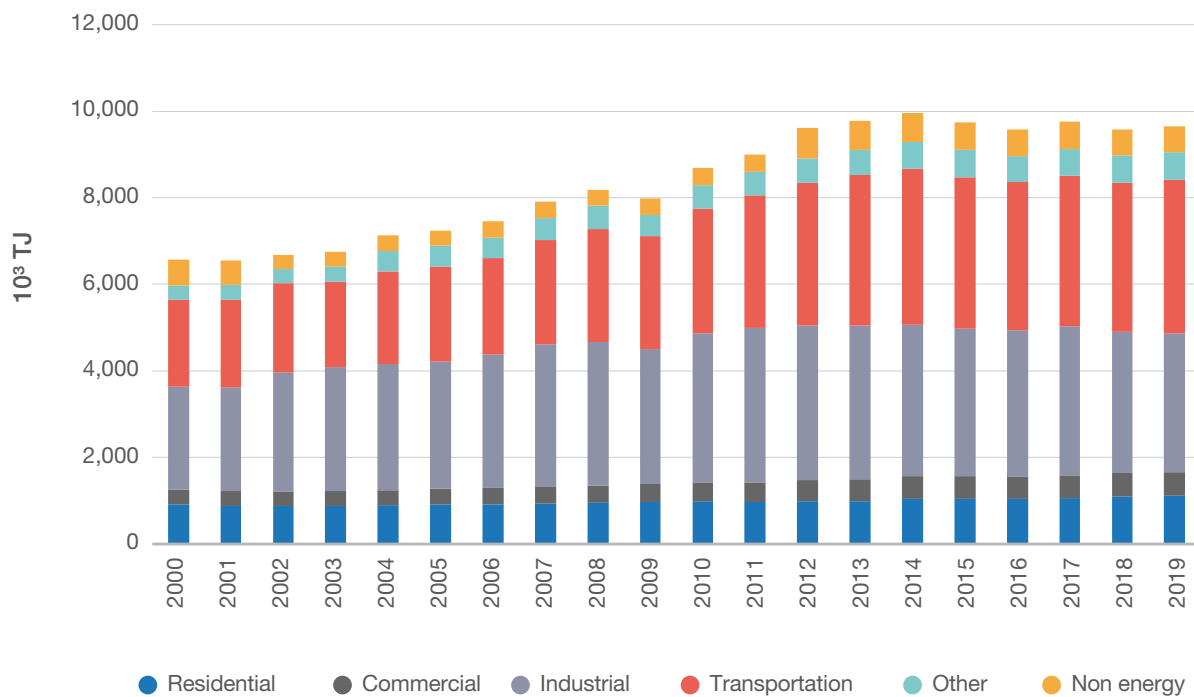
Source: Own preparation based on data from BP Statistical Review of World Energy 2022 and OPEC Annual Statistical Bulletin 2022.

Final consumption by sources and sectores

Transportation was the sector with the greatest consumption in 2019 and its relative weight has increased in the last 20 years from 31 % to 37 %. The industrial sector accounts for almost one third of final consumption; its relative weight has decreased slightly from 36 % to 33 %. The residential demand has much smaller incidence on total final consumption.

Graphic 11

► Final consumption by sector, 10³ TJ and %

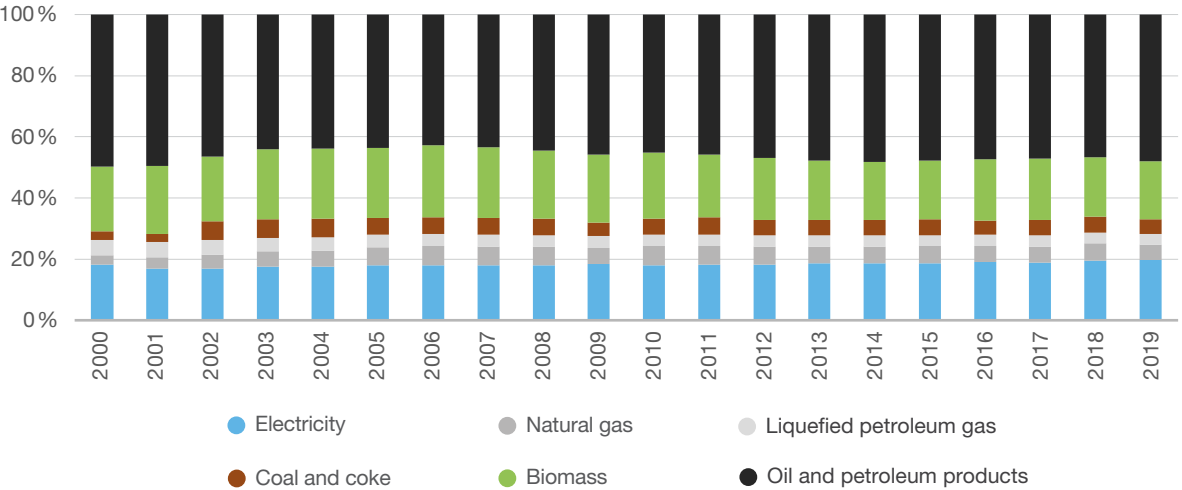


Source: Own preparation based on data from sieLAC, OLADE.

By source, the relative weight of each source remained quite stable in the period 2000-2019. Oil and petroleum products account for almost half of the total final consumption. Biomass¹² plays a more significant role compared to other countries in the region, whereas gas plays a minor role.

Graphic 12 A

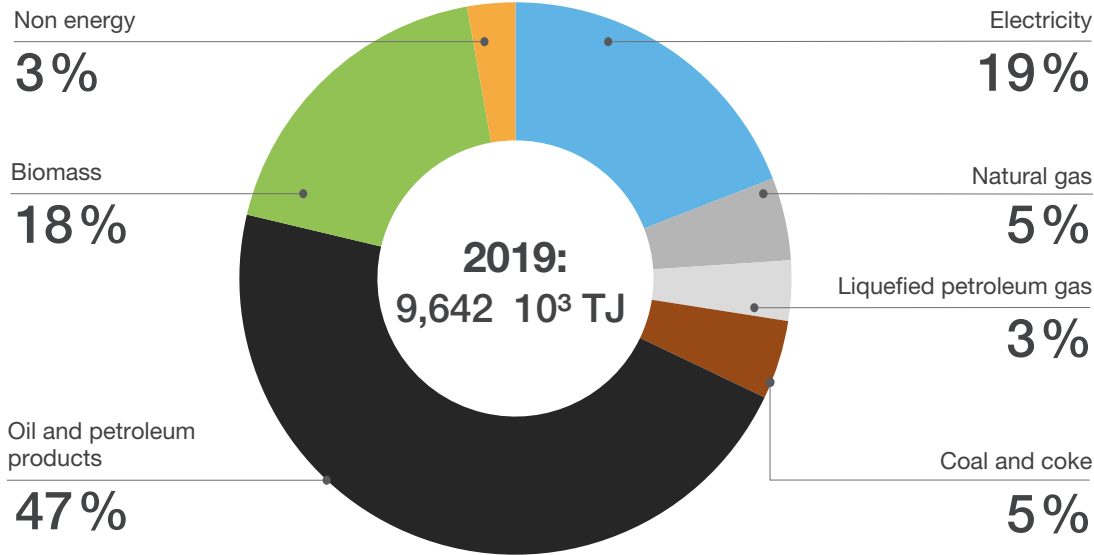
► Final consumption by source, 10³ TJ and %



Source: Own preparation based on data from sieLAC, OLADE. The 'non-energy' category is not included in the historical evolution. The 'Oil and derivatives' category includes gasoline/alcohol.

Graphic 12 B

► Final consumption by source, 10³ TJ and %



Source: Own preparation based on data from sieLAC, OLADE.



Climate profile

Climate changes scenarios and risks to the energy sector

Brazil is characterized by a mainly tropical climate (or subtropical in the southeast) and great hydrographic potential (mainly used to produce electricity, transportation, and irrigation).

¹² Unlike other countries in the region, in Brazil there are several industries that generate biomass for energy purposes, such as the forestry industry and the sugar industry.

Hydro plants are distributed in numerous hydrographic basins in different regions in the country. Some of the main rivers in Brazil include the Amazon, the second longest river in the world and the largest in terms of water volume; the Parana and its main tributary, the Iguazu, which includes the Iguazu Falls; the Rio Negro; the São Francisco, and the Xingu, Madeira and Tapajós rivers. Hydroelectric production has certain inertia in Brazil due to the presence of large reservoirs with multi annual optimization in a few cases¹³. However, in Brazil, global hydroelectric regulation capacity is lower than in previous decades because of the startup of large run-of-the-river plants and a more limited number of hydro plants with reservoirs¹⁴.

The global climate risk index (GCRI)¹⁵ indicates the level of exposure and vulnerability to extreme climate phenomena. In the period 2000-2019, Brazil occupied the 81st position among 180 countries (the first position is the position with the most exposure and vulnerability).

According to the study Índice de Vulnerabilidade a Desastres Naturais de Seca no Contexto da Mudança do Clima^{16,17}:

¹³ The largest reservoir in terms of useful volume is Serra da Mesa (around 43,250 hm³).

¹⁴ <https://www.sciencedirect.com/science/article/abs/pii/S0360544214011888>

¹⁵ The GCRI comprises four indicators: number of deaths, number of deaths per 100,000 inhabitants, sum of losses in USD at PPP, and losses by GDP unit. The final ranking considers these indicators with different weights and in a 20-year period. . <https://www.germanwatch.org/en/19777>

¹⁶ <https://www.wwf.org.br/?59423/IVDNS-ndice-de-Vulnerabilidade-a-Desastres-Naturais-de-Seca-no-Contexto-da-Mudana-do-Clima>

¹⁷ <https://www.ipcc.ch/report/ar6/wg2/>

[...] in a sub-basin of the Amazon River (one of the critical points for hydroelectric production in Brazil), hydroelectric potential in the dry season is expected to decrease by between -7.4 % and -5.4 % compared to the historical reference conditions according to scenario RCP4.5 (Arias et al., 2020). In the São Francisco basin in Brazil, it is expected that hydroelectric production will have fallen by -15 % to -20 % by 2100, according to the IPCC A1B scenario (Jong et al., 2018), which will affect hydroelectric production.

On the other hand, in the energy sector, other potential risks associated with climate change include a rise in energy demand for climate control, an eventual reduction in solar and wind production in some regions in the country, a decrease in the production of crops used to produce biofuels, and eventual risks to energy infrastructure related to extreme climate events (storms, floods, etc.), among others.

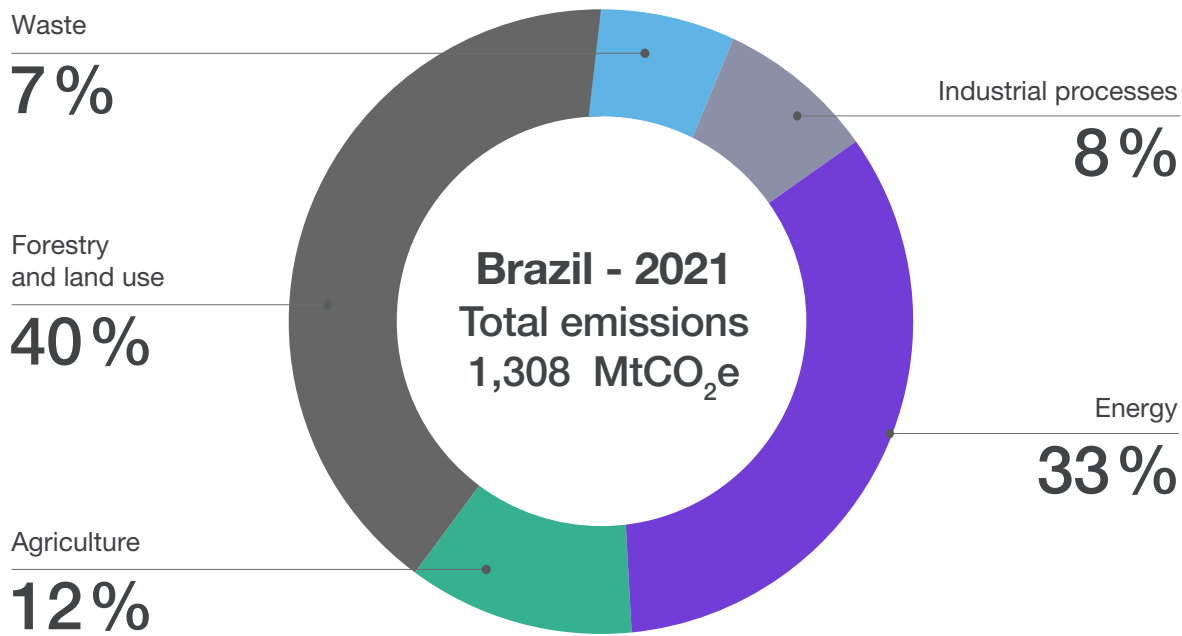
Given the climate profile of the country, and according to the climate scenario, it may be necessary to develop more renewable energy generation projects to compensate for the reduction in the estimated hydroelectric, solar, or wind production and guarantee future compliance with national commitments in terms of emission reduction.

GH contributions - base year

According to the latest National Inventory on Greenhouse Gases (INGEI, in Portuguese), total net emissions in 2021 were 1,308 MtCO₂e, 33 % of which were related to the energy sector (that is, emissions from burning fuels and fugitive emissions), 40 % to forestry and other land uses (deforestation, among other causes), and 12 % to the agricultural sector.

Graphic 13

► Total net emissions, MtCO₂e

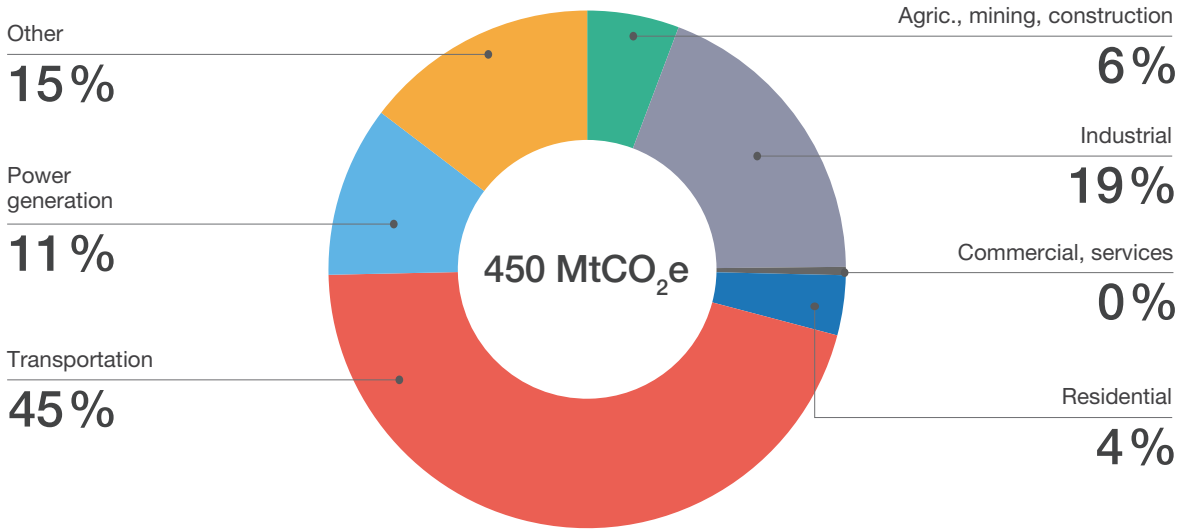


Source: Own preparation based on *Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa* (SEEG, 2021).

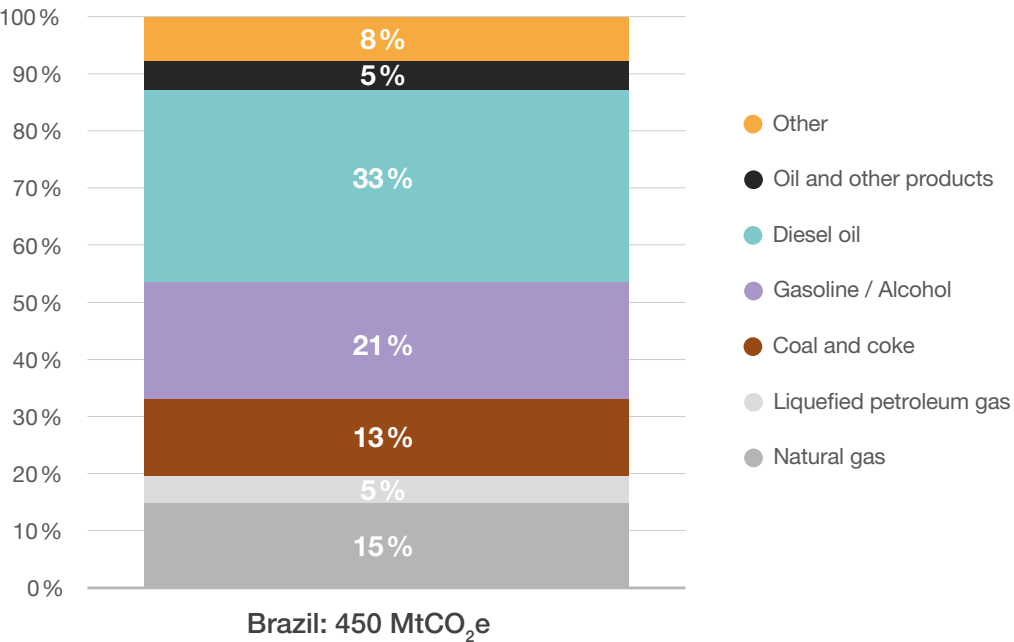
When specifically observing the energy sector (emissions resulting from burning fuels and fugitive emissions), it is possible to analyze the emissions by sector and by source. The data in Graphic 14 is based on the estimation of CO₂ emissions conducted by the Latin American Energy Organization (OLADE) (sieLAC).

Graphic 14

► Estimated emissions in the energy sector, by sector and by source, MtCO₂e, 2019



Emissions by source



Source: Own preparation based on data from sieLAC, OLADE.

The transportation sector comprises almost half the emissions from energy sources. Diesel and gasoline are the main fuels that the sector consumes. In the second place, industry explains 19% of the emissions in the sector, mainly from burning coal and petroleum products. The emissions from the power generation sector are limited due to their composition.

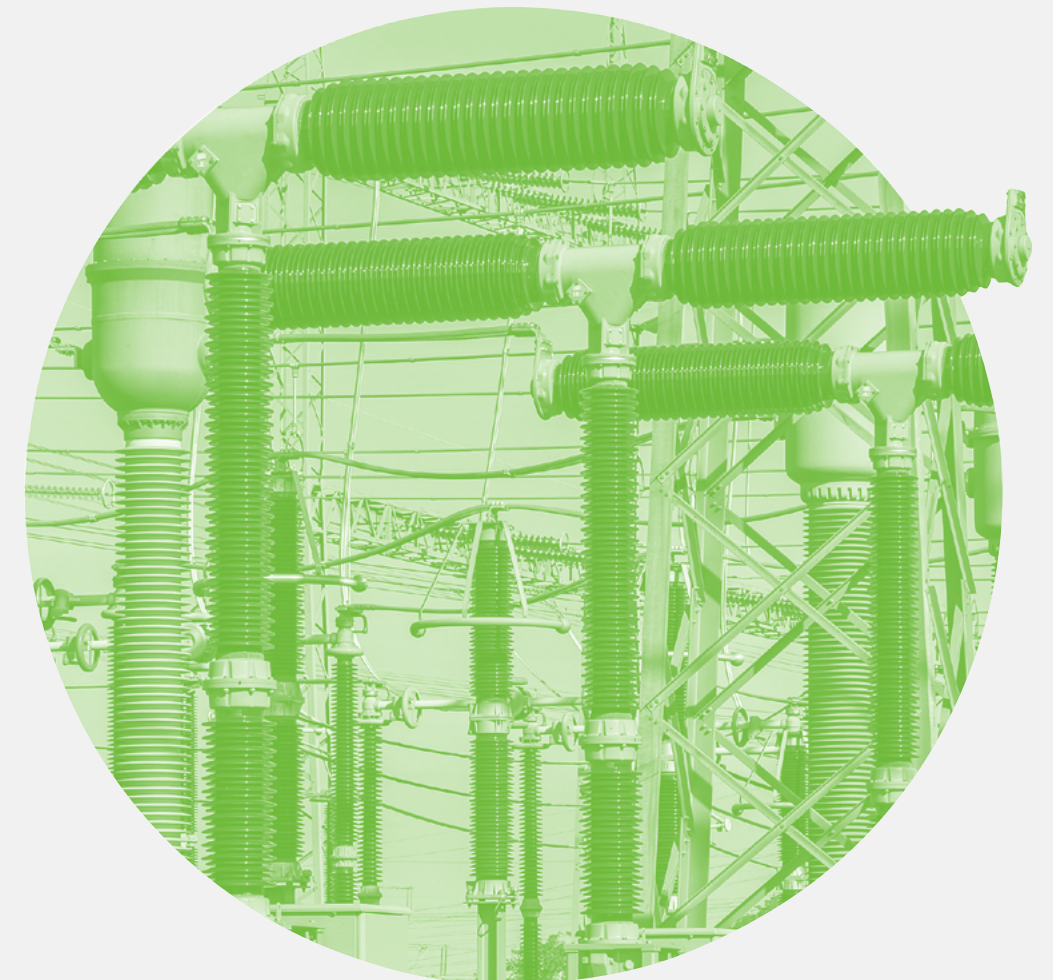
National commitments (NDC and Paris Agreement)

Regarding commitments to reduce CO₂ emissions, the following elements can be pointed out:

- Brazil presented a second update on nationally determined contributions (NDCs) in 2022; this update enhances the emissions targets compared to those presented in 2020. However, these contributions do not exceed the targets originally presented in 2016. According to the 2022 NDCs, Brazil is committed to:
 - o reducing the emission of greenhouse gases by 37% by 2025 compared to 2005; and
 - o reducing the emission of greenhouse gases by 50% by 2030 compared to 2005.
- National Adaptation Plan. This plan includes 55 types of governmental policies, plans, and programs for different sectors.
- Brazil signed the Paris Agreement; therefore, it is committed to “substantially reducing the greenhouse gas emissions to limit the increase

in global temperature in this century to 2 °C and make efforts to limit this increase to even more, only 1.5 °C”. In practice, it is committed to reaching carbon neutrality “by 2050”.

Law No. 12187 (2009) establishes the Climate Change National Policy in Brazil, and includes its principles, objectives, directions, and instruments. In addition, the Power Generation Expansion Plan contains the actions envisaged to comply with the emission target in the energy sector.



“The transportation sector accounts for nearly half of energy-related emissions. Diesel and gasoline are the main fuels consumed by the sector.”

2. Institutional, regulatory and public policy aspects



Sectoral government

Table 5 includes a list of the main institutions in the energy sector.

Table 5

► Map of the institutions in the energy sector

Institution	Function
Ministry of Mines and Energy (MME)	Definition of oil, gas, and electricity sector policies
Energy Research Office (EPE, in Portuguese)	Planning of the oil, gas, and electricity sectors
National Electricity Agency (ANEEL, in Portuguese)	Expansion and regulation of the power market
National Oil, Natural Gas, and Biofuel Agency (ANP, in Portuguese)	Expansion of the fuel market, oil and gas regulation
National System Operator (NSO)	Electricity market administrator

Source: Own preparation.



Main regulatory concepts

Table 6 indicates the existence of price regulation and of a competitive market with free access in each energy sector and segment.

Table 6

► Main regulatory concepts by sector and segment

Sector	Segment	Price regulation	Market
Electricity	Generation Distribution Transmission Commercialization	Transmission Distribution and retail commercialization	Competitive in generation and wholesale commercialization. Free access in all the segments of the chain.
Natural gas	Exploration and exploitation Transportation Distribution Commercialization	Reference prices established by ANP for oil and petroleum products in the transportation, distribution, and retail commercialization segments	Competitive in production and wholesale commercialization. Free access in all the segments of the chain.
Oil	Exploration and exploitation Transportation Refining Distribution and commercialization	Reference prices established by ANP for oil and petroleum products	Competitive, led by Petrobras. Refining strongly dominated by Petrobras.
Coal	Exploitation Commercialization		Free pricing

Source: Own preparation.



Public policy aspects

Energy efficiency policies

Brazil has been working on energy efficiency aspects for over 40 years. The Brazilian Labeling Program, created in 1984, establishes the National Energy Conservation Label (*Programa Nacional de Conservación de Energía*, ENCE), which can be voluntary or mandatory. This program is still effective and has the purpose of inducing the selection of more efficient products. Since 2003, the labeling program has extended to home appliances running on gas (ovens and water heaters).

In 1985, the National Electricity Conservation Program (*Programa Nacional de Conservación de Energía Eléctrica*, PROCEL) was introduced, managed by Electrobras, in order to conduct energy efficiency studies, training, and programs.

Regarding transportation, in 1991, the National Program for the Rationalization of the Use of Petroleum Products and Natural Gas Byproducts (*Programa Nacional de Racionalización del Uso de los Derivados del Petróleo y del Gas Natural*, CONPET) was developed; its main objective was to incentivize the use of fossil fuels.

Law No. 9991/2000, passed in 2000, created the Energy Efficiency Program (PEE, in Portuguese), managed by the National Electricity Agency (*Agencia Nacional de Energía Eléctrica*, ANEEL), and in 2001, the Energy Efficiency Act, Law No. 10295/2001, (*Ley de Eficiencia Energética*) was also passed, establishing minimum energy efficiency indices for equipment commercialized in Brazil and buildings. This law established the Energy Efficiency Indicators Management Committee (*Comité Gestor de Indicadores de Eficiencia Energética*, CGIEE), coordinated by the MME and composed by representatives of society and government institutions.

In 2011, Law No. 10295 regulated the National Policy on Conservation and Rational Use of Energy (*Política Nacional de Conservación y Uso Racional de Energía*).

All these policies are evidenced in the National Energy Efficiency Plan (*Plan Nacional de Eficiencia Energética*, PNEE), which indicates specific actions and directions aiming to promote energy efficiency. This program is in line with the NDCs.

The main energy efficiency policies, measures, and programs are briefly described in Table 7.

Table 7

► Energy efficiency in Brazil

Aspect	Concept	Country progress
Labeling regulation	Sector	Construction, commercial sector, and industry.
	Program	Brazilian Labeling Program, which includes home appliances, motors, and appliances running on gas.
	Minimum energy efficiency standards (MEPs)	Yes, there are laws that establish efficiency minimums in three-phase motors, fluorescent bulbs, and motors un general.
Sectoral policies	Public sector	✓
	Transportation	✓
	Residential	✓
	Commercial and industrial	✓
Energy efficiency fund	Type	
	Name	
	Other	Specific financial resources to implement energy efficiency policies.
Promotion and cultural change	Labeling	✓
	Training programs and workshops for the public and private sectors	
	Development of programs, and dissemination and demonstration campaigns	
	Social participation, consultations, and public access to information	✓
	Inclusion of energy efficiency in syllabuses	
	Energy efficiency awards, honors, and/or recognition.	

Source: Document *Leyes de Eficiencia Energética en Latinoamérica y el Caribe*, OLADE.

Pricing, subsidy, and incentive policies

Subsidies and taxes on fuel prices

Fuel taxes

The taxes applied on fuels are the following:

- a. Social Security Financing Tax (*Contribución para Financiamiento de Seguridad Social*, COFINS). The purpose of this tax is to finance social development in Brazil. The COFINS rate is 3 % (Section 8 of Law No. 9718 of 1998).
- b. Social Integration Program Tax (*Contribución para el Programa de Integración Social*, PIS) and Civil Servants’ Asset Formation Program Tax (*Contribución para el Programa de Formación del Patrimonio del Servidor Público*, PASEP). The rate for the PIS/PASEP (turnover tax) is 0.65 % (Law No. 9715, Section 8, subsection I, of November 25, 1998; Provisional Measure (MP, in Portuguese) No. 1807 of January 28, 1999).
- c. Provisional Tax on Financial Transactions (*Contribución Provisoria sobre el Movimiento Financiero*, CPMF). The provisional tax on transactions or transfers of securities, credit, and money of a financial nature has a 0.38 % rate imposed by Law No. 9311 of November 24, 1996, modified by Law No. 9539 of December 12, 1997 and amendments.
- d. Tax on the Circulation of Goods and the Provision of Interstate and Intermunicipal Communications Transportation Services (Tax on the Circulation of Goods and on Providing Interstate and Intermunicipal Communications Transportation Services, ICMS). This tax is a kind of value added tax. It is applied in Brazil on the circulation of goods and services, including imports and exports of goods. The ICMS rate imposed on energy products varies depending on the fuel considered and the Brazilian state where the end user is. In the case of gasoline, diesel, and ethanol imports, an 18% rate is applied in most Brazilian states. In the case of local fuel consumption, a general ICMS rate of 25 % is imposed in most states.

- e. Tax for Intervention in the Economic Domain (*Contribución de Intervención de Dominio Económico*, CIDE) is a tax on fuel, established under Law No. 10336 of December 19, 2001. Even though the tax is currently effective, its rate is 0%.

Subsidies

No subsidies are reported for fuel prices in Brazil. It is important to mention that there are waivers of collection of the COFINS, PIS, and CIDE taxes, which implies reductions in the general rates of these taxes¹⁸.

Subsidies and taxes on tariffs

The wholesale Brazilian market has an energy development account (CDE, in Portuguese)¹⁹ that ANEEL estimates on an annual basis and which works as a source of a series of explicit cross subsidy programs. Through this account, the following are financed:

- the cost of fuels for isolated areas;
- the cost of social and rural tariffs and potable water services irrigation tariffs;
- the cost of promoting distributed generation;
- support to small distributors.

¹⁸ In 2022, there were subsidies to LPG destined to the most destitute segments of the population; the Auxílio Combustível Brazil program, which grants subsidies specifically destined to single mothers and lower-income families for transportation services was also subsidized.e

¹⁹ https://app.powerbi.com/view?r=eyJrIjo1Y2Q1YjdlZTEtMzQ2ZS00OTIyLTU0ODctZDY2NTRhMD_-FhMmFjliwidCl6ljQwZDZmOWI4LWVjYTctNDZhMi05MmQ0LWVhNGU5YzAxNzBIMSIsImMiOiR9

Incentives for renewable energy

In recent years, renewable energy projects have benefited from different regulatory incentives to foster its development through specific programs (for example, Proinfa) or tariff discounts and specific energy auctions.

Distributed generation

Since April 17, 2012, when Regulatory Resolution No. 482/2012 (Resolución Normativa N°. 482/2012) was issued by ANEEL, Brazilian clients have been able to generate their own energy from renewable sources or qualified self-generation, and even sell the surplus to the local grid.

The rule aims to regulate the electricity produced by consumers through solar panels, self-generation, or other forms of supplying generation by residential or commercial clients. The regulation was prepared as a response to certain clients who had started to invest in photovoltaic panels or cogeneration.

Tariff discounts

The first discounts in renewable energy transmission and distribution tariffs were defined under Law No. 9427/1996. In 2015, Law No. 13203/2015 established new transmission and distribution tariff reduction targets for renewable energy facilities. These targets were again revised for solar plants in 2017.

In 2021, Law No. 14120/2021 defined new rules for discounts on the tariff for the use of the transmission system (TUST). The law gradually reduced the discount. This discount is granted to projects that obtained generation authorization prior to March 2022 and started operating in less than 48 months counted as from the grant.

In addition, a new category of free consumers was created, “special” consumers. These special consumers can buy energy in the free market if this energy is produced by small hydro plants (less than 5 MW) or solar, wind or biomass plants with a capacity of under 50 MW. This created a market dedicated to renewable energy.

Long-term auctions

Since 2004, some auctions have specifically focused on renewable energy, especially alternative sources auctions (LFA, in Portuguese), reserve energy auctions (LER, in Portuguese), and distributed generation auctions.

In 2007, 2010, and 2015, respectively, three alternative sources auctions were carried out – for the purpose of developing renewable sources and making them compete among them – as well as nine reserve energy auctions.

Renewable sources also proved to be successful in regular auctions, such as “new energy” auctions, where they compete with other technologies. The prices offered by wind and solar projects are currently more competitive than those of hydro and thermal projects.

Creation of a carbon market

In May 2022, the Federal Government enacted Decree No. 11075, which establishes the procedures to prepare the Climate Change Mitigation Sectoral Plans and creates the National Greenhouse Gas Emissions Reduction System (SINARE, in Portuguese). The decree establishes that the Ministries of Environment and Economy must develop sectoral climate change mitigation plans, including concrete emission targets; it also establishes a roadmap for such process.

The House of Deputies of Brazil has been analyzing Bill No. 412/2022 since 2022. The project has been granted preliminary approval. The objective is to regulate the Brazilian Greenhouse Gas Emissions Trading System (SBCE, in Portuguese), which focuses on large emissions and imposes a maximum emission limit of 10 thousand tCO₂e-year by activity.

Companies that emit more than 10,000 tCO₂e-year will be subject to SBCE control. Companies that emit between 10,000 tCO₂e-year and 25,000 tCO₂e-year will have to submit an emissions follow-up plan to the SBCE management authorities and an annual report on emissions and gas absorptions. Activities with emissions over 25,000 tCO₂e-year will be obliged, in addition, to send the SBCE management authorities an annual report on periodical reconciliation of obligations.

The Bill states that companies exceeding the limit of 10,000 tCO₂e-year must buy carbon credits to compensate for their emissions. On the other hand, companies that do not exceed the limits may sell credits in the market.

These emission levels may increase considering the impact of the regulation on profitability and compliance with Brazil’s commitments with the United Nations Framework Convention on Climate Change (UNFCCC).

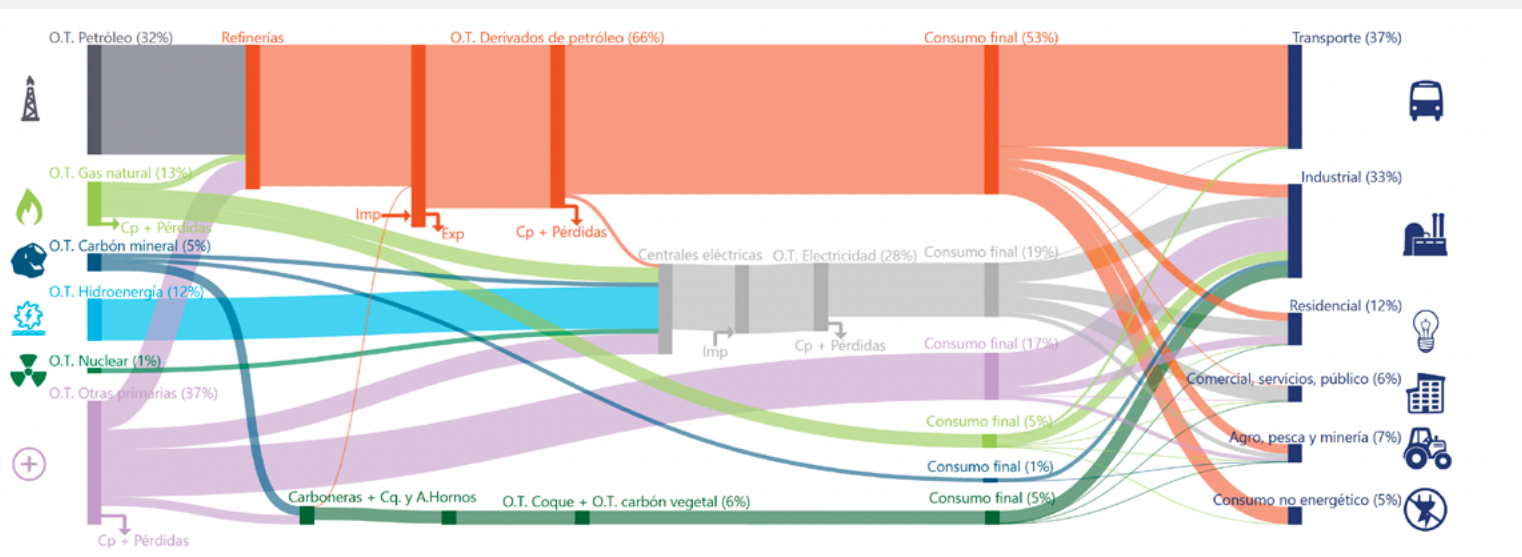
Moreover, the Bill establishes a carbon credit market and the generation of credits based on emission reduction.

3. Energy balance, 2019 and 2022

The energy balance records energy flows from production, energy imports and exports, and transformation to final consumption in the different socio-economic sectors for a certain period (one year). Graphic 15 is a graphic representation (Sankey diagram) of the year 2019, considered as the base year for this study.

Graphic 15

► Energy balance, 2019



Source: Panorama energético de América Latina y el Caribe 2020, OLADE, November 2020.

The energy balance allows us to summarize some of the main characteristics of the Brazilian energy sector:

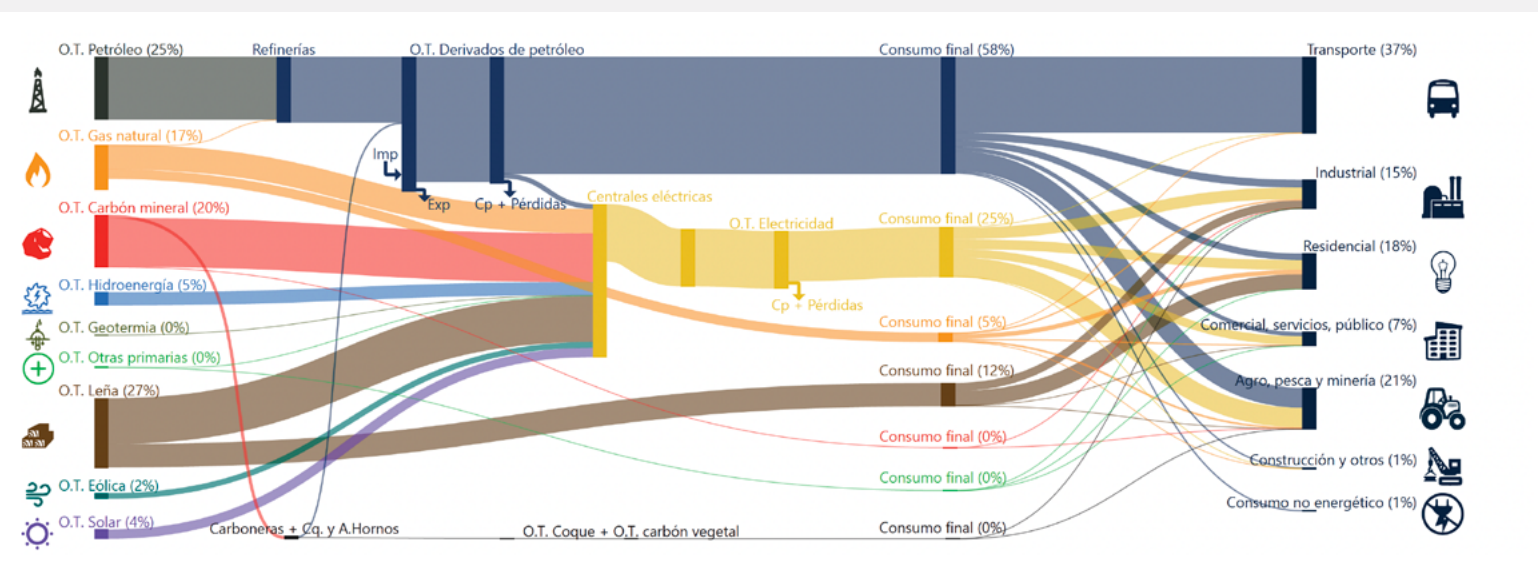
- The Brazilian energy matrix is much more renewable than the global one (49 % against 19 %) due to the major role of biomass (sugar cane byproducts), hydraulic energy, and other types of renewable energy;
- Coal and nuclear energy play a minor role in primary energy supply (Brazil is one of the few countries in the region with nuclear plants);
- There is a significant share of hydro production compared to total electricity;
- The role of electricity in final consumption is still limited (19%);
- The sectors with more final consumption (transportation with 37 % and industry with 33 %) are well above the other sectors.

The latest energy balance available (2022), which shows some slight differences with the energy balance of 2019, is also presented:

- Greater weight of oil (36%) and less weight of gas (10%) in terms of primary energy supply;
- Greater weight of the transportation sector (39%) and less weight of the industrial sector (30%) in terms of final consumption.

Graphic 16

► Energy balance, 2022



Source: *Panorama energético de América Latina y el Caribe 2020*, OLADE, December 2023.

4. Evolution of energy demand by sector and source

The national energy balance allows us to visualize the dynamics of the energy sector over time through the analysis of time series of the main variables that are part of the country's energy matrix and a comparison of the structures and indicators in different years of a historical period.

The following paragraphs include, in addition to the energy demand by source, additional data required to characterize this demand, such as the share of demand by energy use (useful energy balance), the description of the vehicle fleet, sectoral energy intensity, etc.



Residential sector

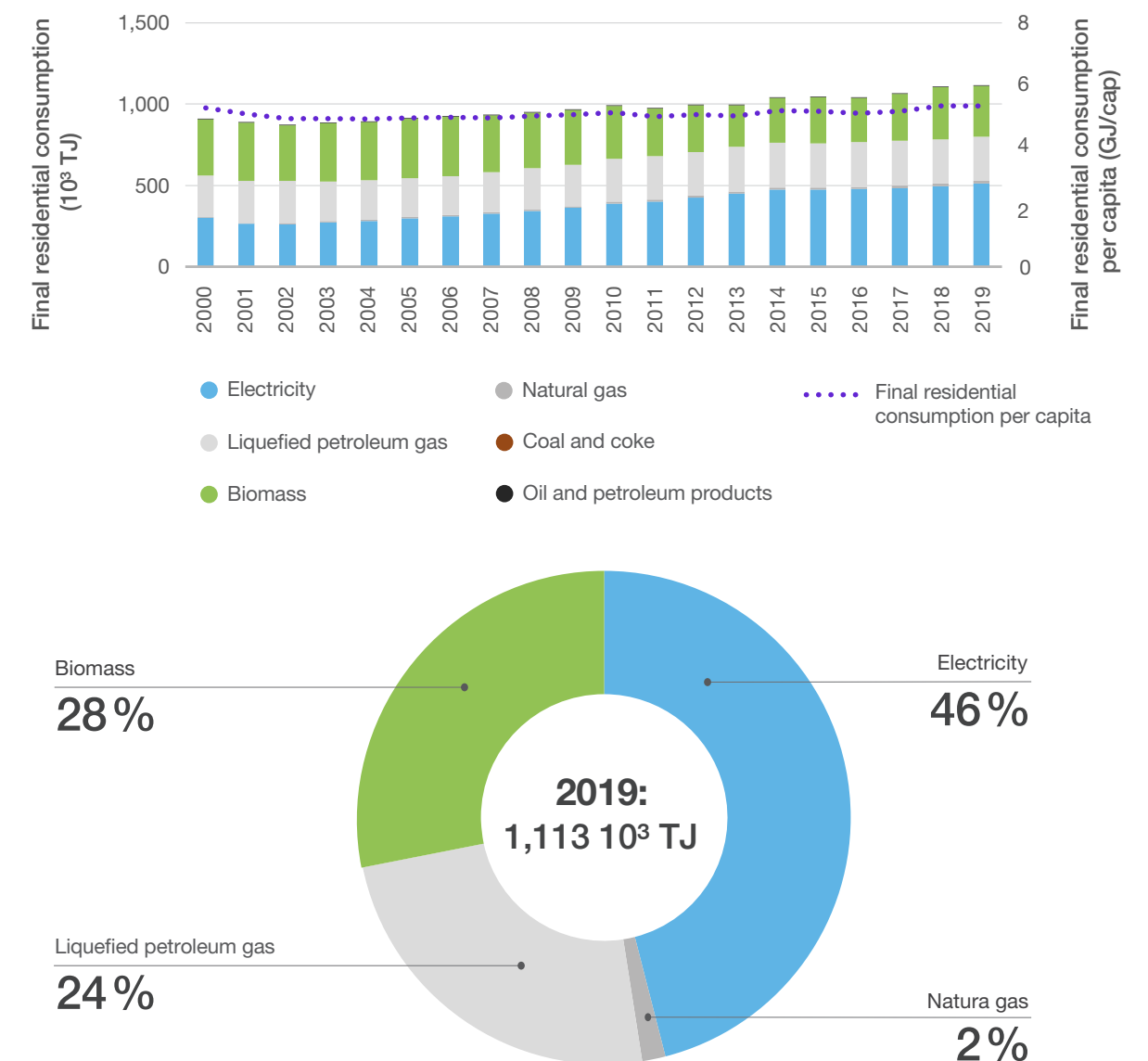
Final residential consumption has increased slightly in the last 20 years (from 909 10³ TJ in 2000 to 1,113 10³ TJ in 2019). By source, we can point out the following characteristics:

- a considerable increase in final electricity consumption, from 33 % to 46 % in the analyzed period; an interesting increase – though still marginal – of natural gas consumption, as gas quadrupled its share in final energy consumption (from 0.5% in 2000 to 2 % in 2019); however, it only reached 17 103 TJ in 2019;
- on the other hand, the share of biomass and petroleum products decreased in the sector.



Graphic 17

► Residential sector: evolution of final consumption by source (10³ TJ) and final residential consumption per capita (GJ/capita)

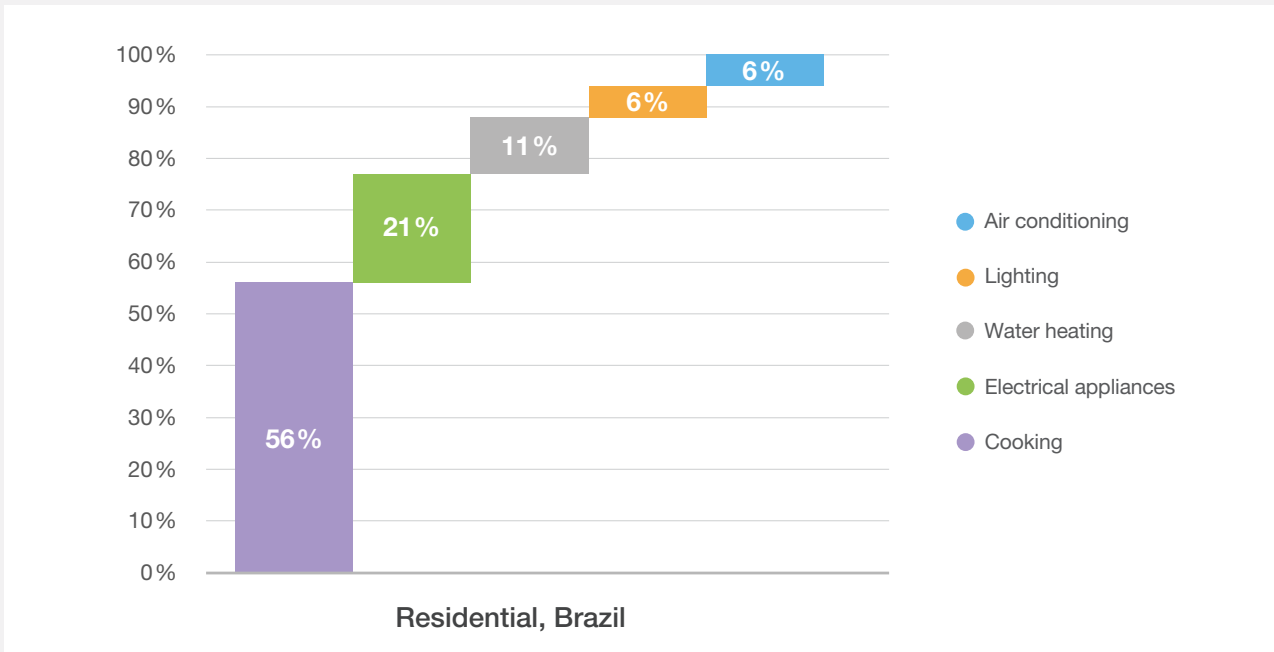


Source: Own preparation based on data from sieLAC, OLADE.

In terms of energy consumption for end uses, 68 % of the total refers to direct heat (that is, mainly cooking or space heating). The uses reserved to electricity are limited (lighting, refrigeration, electronics).

Graphic 18

► Residential sector: energy consumption for end uses, 2018



Source: (EPE, 2019).



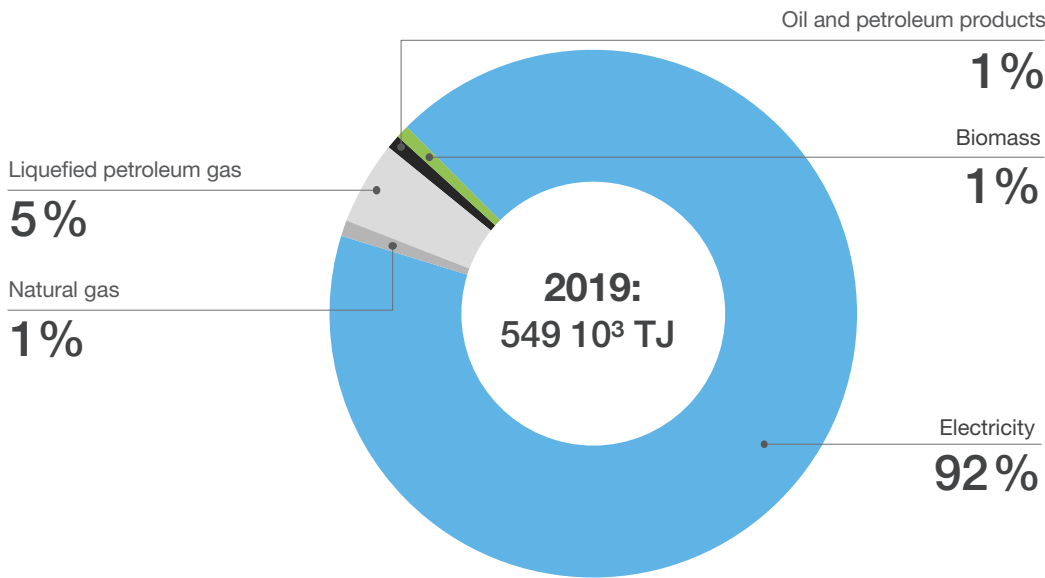
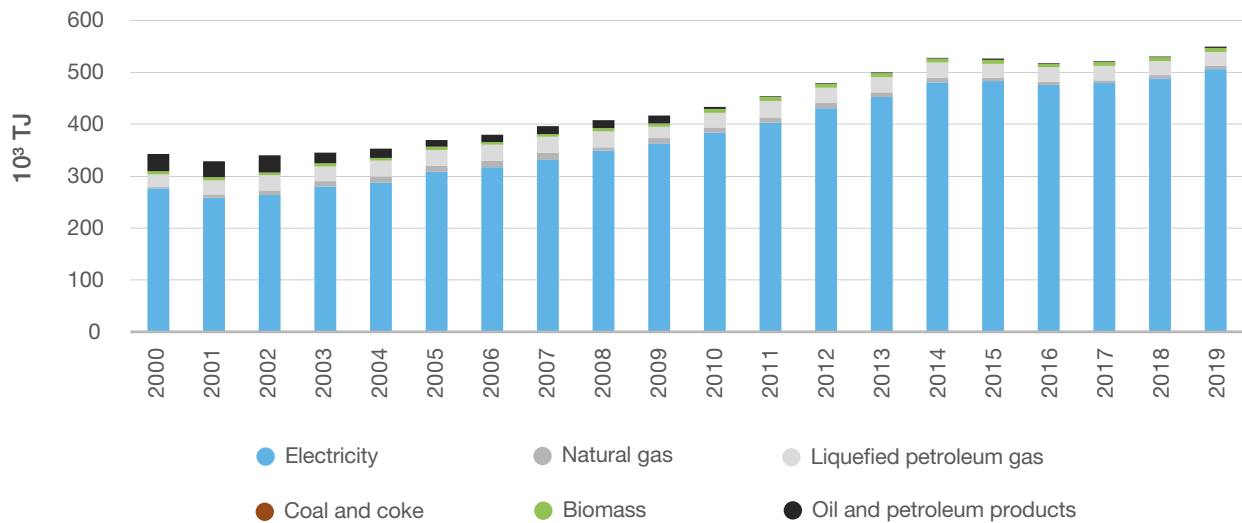
Commercial, services, and public sector

The final consumption of the commercial, services, and public sector has increased in the last 20 years (2.5 % annually). By source, the following characteristics can be pointed out:

- large participation of electricity in total consumption (92 % in 2019), and
- supply, mainly PLG, natural gas, and biomass, to cover the rest of the demand.

Graphic 19

► Commercial, services, and public sector: evolution of final consumption by source, 10³ TJ



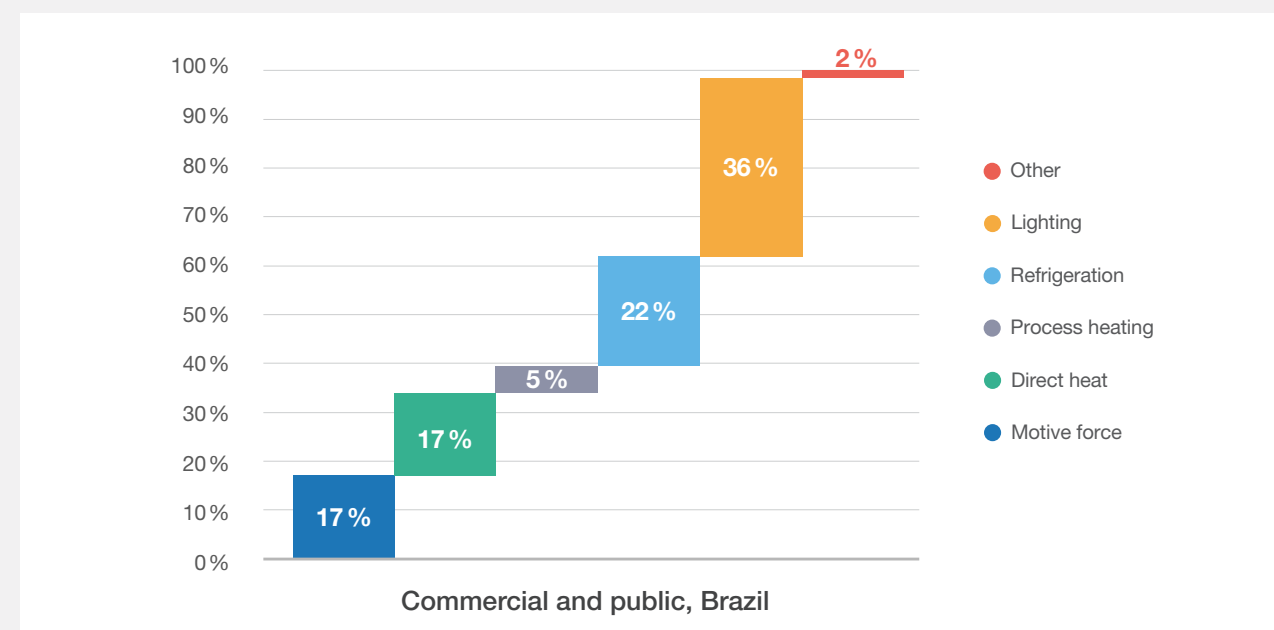
Source: Own preparation based on data from sieLAC, OLADE.

In terms of energy consumption for end uses, uses for refrigeration, lighting, and motive force, which have a large percentage of their energy demand by way of

electricity, are the ones with the most consumption. The share for end uses is very different from that of the residential sector.

Graphic 20

► Commercial and public sector: energy consumption by end use, 2004



Source: Own preparation based on data from the useful energy balance, 2004, Secretary of Energy's Office/Ministry of Mines and Energy.



Industrial sector

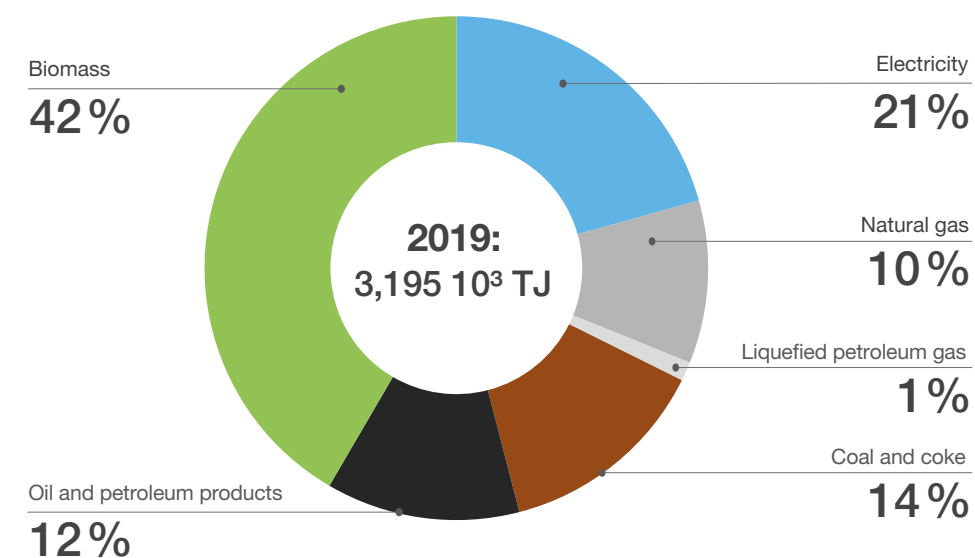
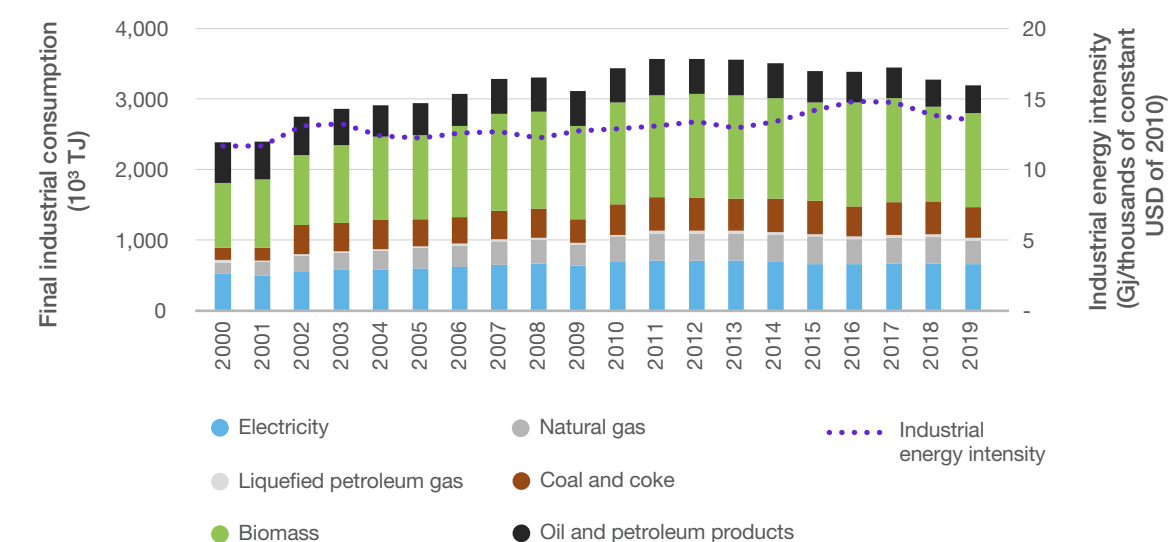
Final industrial consumption has increased in the last 20 years (1.6% annual average), but this growth has slowed down in recent years and has even recorded a slight fall between 2012 and 2019, in line with the fall in the country's economic activity. By GDP unit, the energy intensity of the industrial sector has tended to increase. By source, the following characteristics can be pointed out:

- biomass plays a fundamental role in final energy supply at the end of the period;
- natural gas consumption grew by 86% and accounted for a 10% share as final energy source;

- coal and coke consumption grew over 100% from 2001 to 2002 and has remained relatively constant since that date;
- the use of oil and petroleum products has decreased.

Graphic 21

► Industrial sector: evolution of final consumption by source (10³TJ) and industrial energy intensity (GJ/thousands of constant USD of 2010)

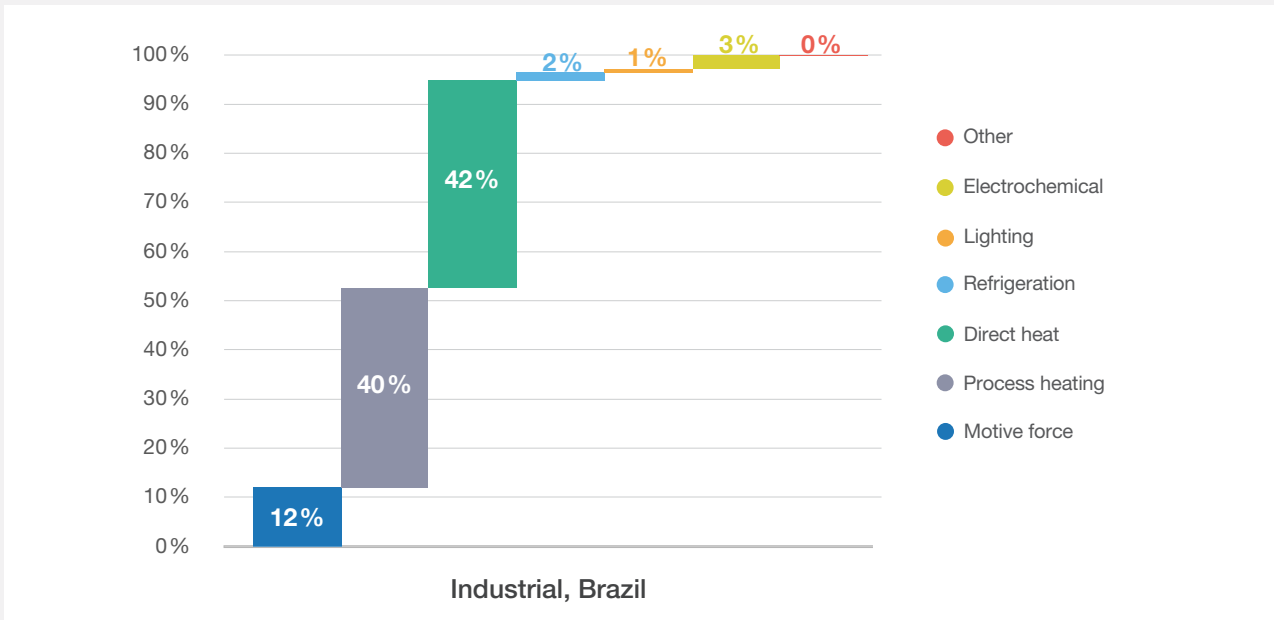


Source: Own preparation based on data from sieLAC, OLADE.

In terms of energy consumption by end use, process heating and direct heat are the uses with the most consumption and add up to 82 %.

Graphic 22

► Industrial sector: energy consumption by end use, 2004



Source: Own preparation based on data from the useful energy balance, 2004, Secretary of Energy's Office/Ministry of Mines and Energy.



Transportation sector

Demand by source

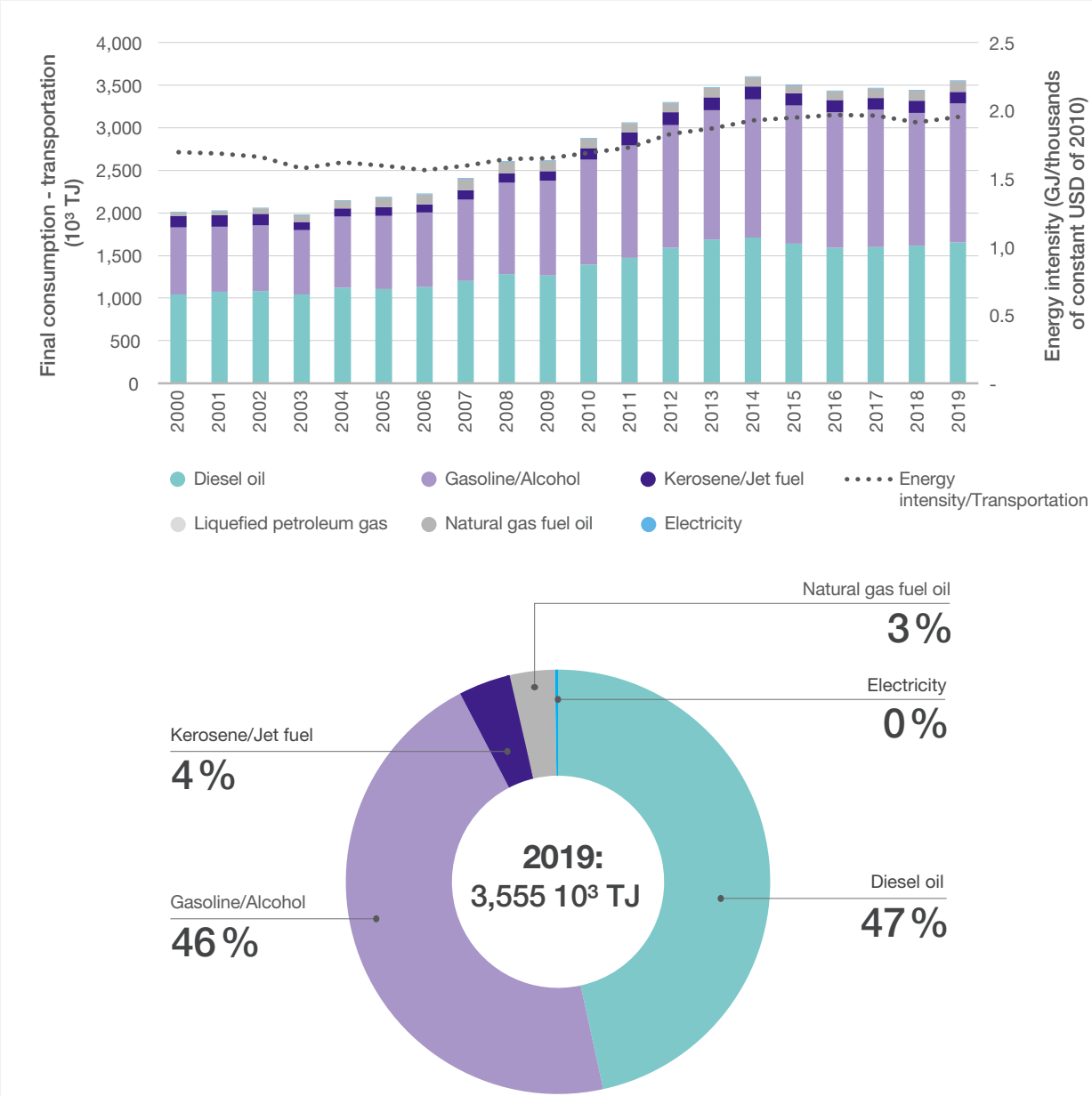
Final consumption for the transportation sector has increased steadily in the last 20 years (3.0% annual average). By GDP unit, the energy intensity of the transportation sector²⁰ has also increased in the sector although more slightly, to an average annual rate of 0.8%. By source, the following characteristics can be pointed out:

²⁰ The energy intensity of the transportation sector is calculated as transportation energy consumption/ total GDP. The GDP of the transportation sector alone is not considered. Transportation consumption is performed by all the economy.

- High diesel and gasoline/alcohol consumption; together they amount to 93 % of final consumption, and
- A very minor role of gas and electricity in the sector at present.

Graphic 23

► Transportation sector: evolution of final consumption by source and year 2019 (10³TJ) and energy intensity (GJ/thousands of constant 2010 USD)



Source: Own elaboration based on data from sieLAC, OLADE.

Vehicle fleet and consumption by type

Table 8 shows the total road vehicles and their breakdown by type. In Brazil, cars and light trucks account for 65 % of the road fleet, whereas motorcycles reach 27 %.

Table 8

► Number of road vehicles, total and by type, 2019, Brazil

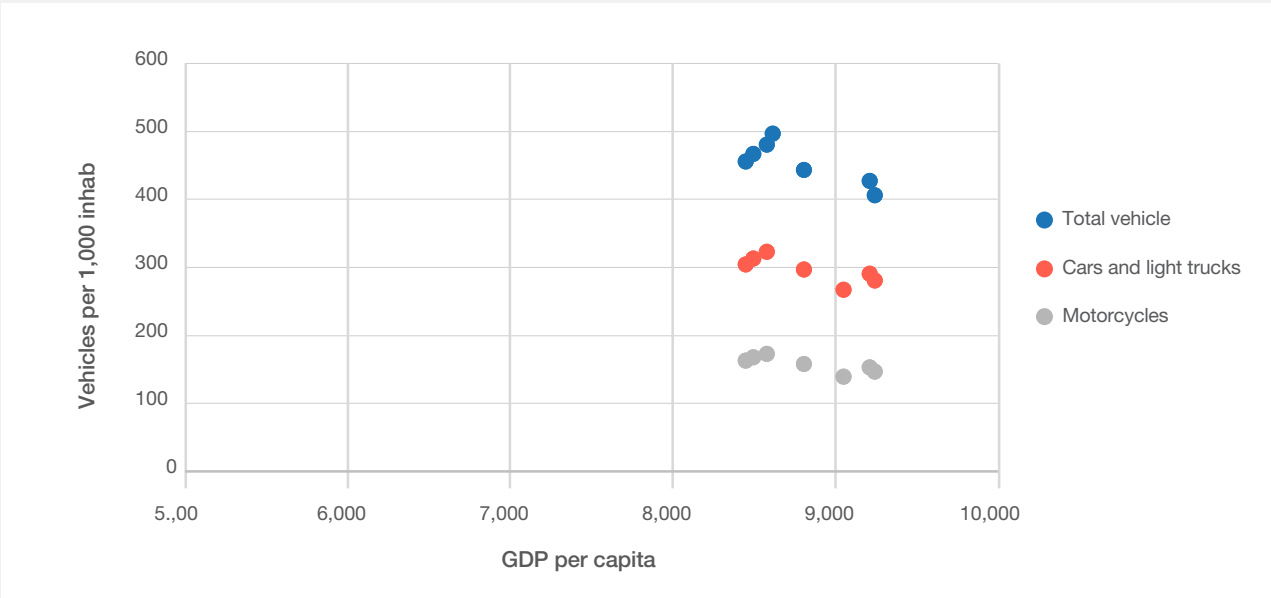
2019	
Cars	54 %
Light trucks	11 %
Motorcycles	27 %
Buses	1 %
Freight	3 %
Heavy machinery + dump trucks	3 %
Other	1 %
Total	104,784,375

Source: Own preparation based on data from Brazil's Ministry of Infrastructure.

In Brazil, it is difficult to detect a trend in the vehicle fleet compared to the GDP, as this indicator peaked in 2013 and then fell considerably; it is still at lower values than the ones in that year.

Graphic 24

► Vehicle fleet versus GDP/capita 2010-2019



Source: Own preparation based on data from Brazil's Ministry of Infrastructure and the World Bank.

Table 9 shows fuel consumption by transportation type and by fuel.

Table 9

► Consumption by transportation type and fuel type, 10³ TJ and %, 2019, Brazil

	Total consumption (10 ^{^3} TJ)	Diesel	Gasoline/ Alcohol	Jet fuel/ Gasoline for aviation	Fuel oil	Natural gas	Electricity	Biodiesel
Road	3,305	43%	49%	0%	0%	3%	0%	5%
Air	140	0%	0%	100%	0%	0%	0%	0%
Maritime/ River	49	31%	0%	0%	69%	0%	0%	0%
Railway	51	80%	0%	0%	0%	0%	11%	9%

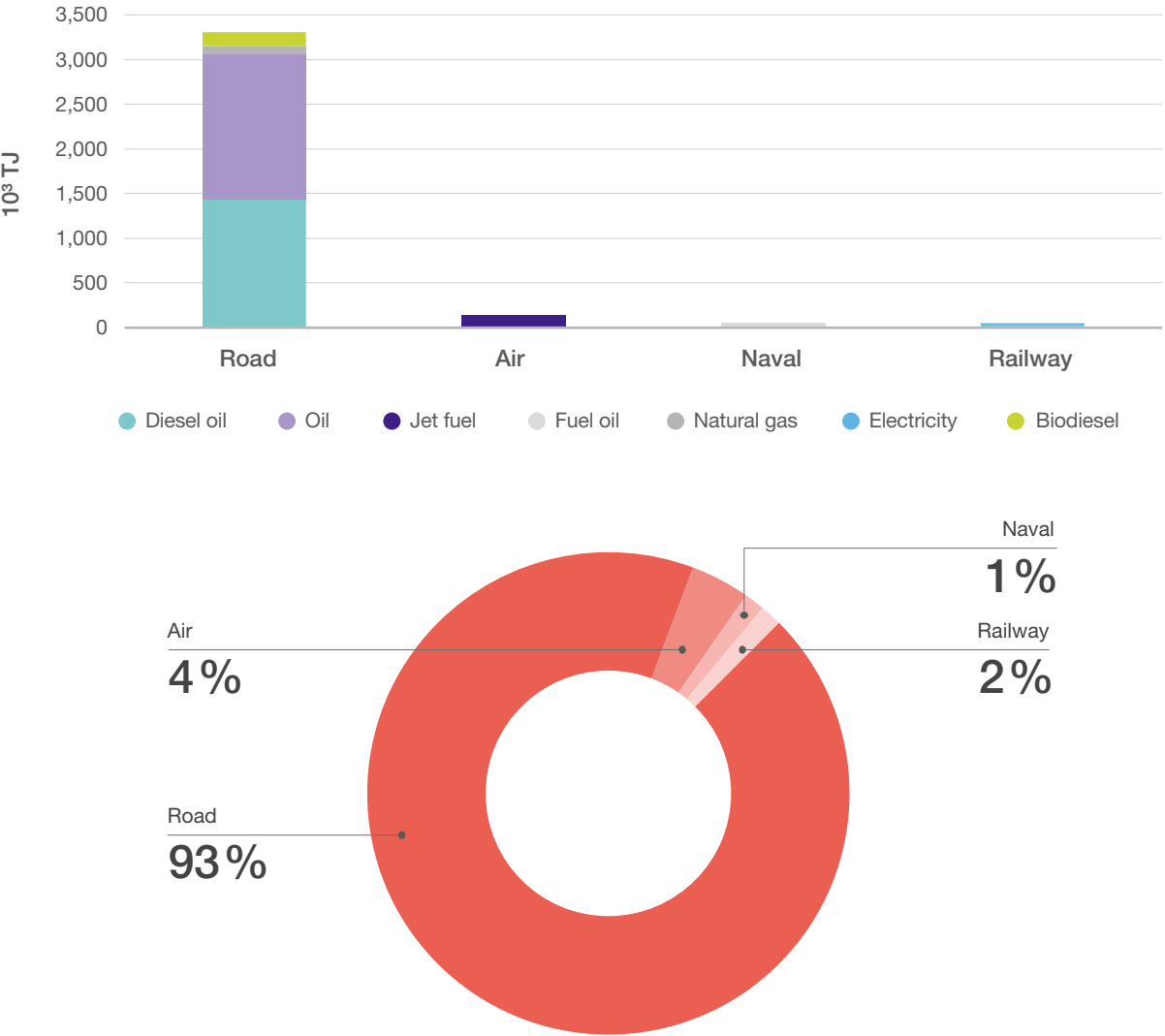
Source: Own preparation based on data from Brazil's energy balance²¹.

²¹ Due to differences in statistics sources, a difference of less than 0.3% is found in the data..

In terms of consumption by fuel, road transportation accounts for 93 % of total consumption, followed by air transportation with 4%, railway with 2 %, and maritime/river with the remaining 1 %.

Graphic 25

► Transportation sector: final consumption by type and by fuel, 10³ TJ



Source: Own preparation based on data from Brazil's energy balance.



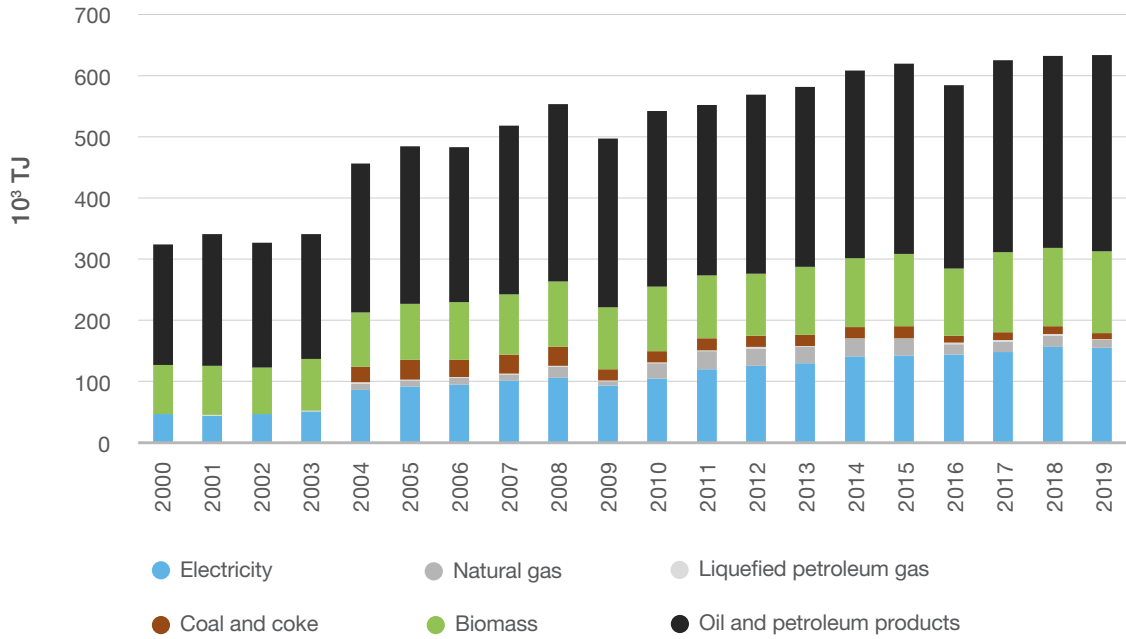
Agricultural, fishing, mining, and construction sector

The final consumption of the sector has increased irregularly in the last 20 years (3.6 % annual average), with an important growth from 2003 to 2004. By source, the following characteristics can be pointed out:

- oil and petroleum products share is close to half the total consumption in 2019 (51 %), and
- supply, mainly from electricity and biomass, followed, to a lesser extent, by natural gas, coal, and coke to cover the rest of the demand.

Graphic 26 A

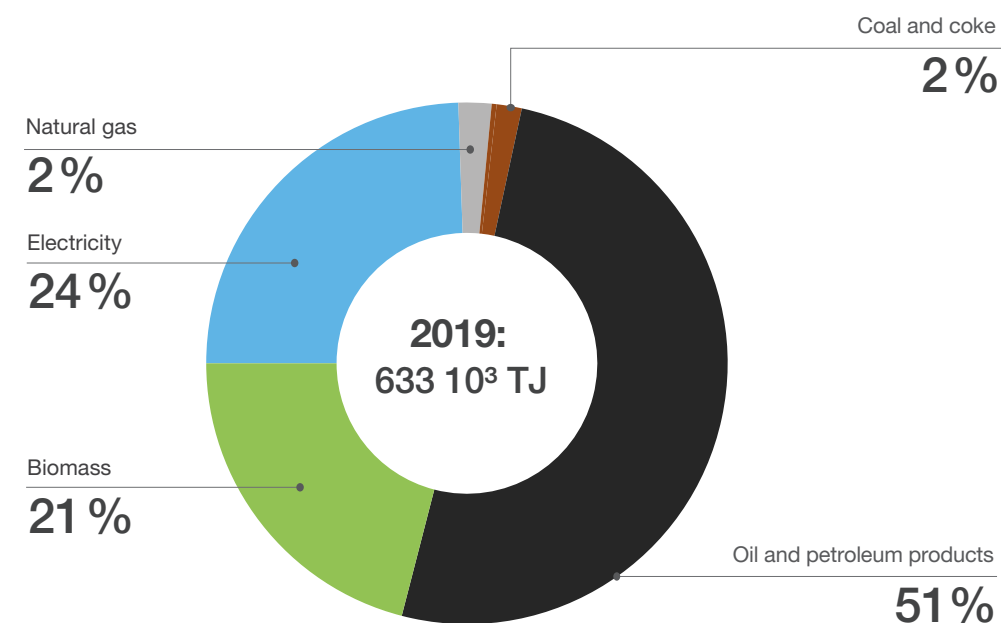
► Other sectors: evolution of consumption by source, 10³ TJ



Source: Own preparation based on data from sieLAC, OLADE..

Graphic 26 B

► Other sectors: evolution of consumption by source, 10³ TJ



Source: Own preparation based on data from sieLAC, OLADE..

By subsector, we can mention that the agricultural sector accounts for the most consumption (84 %) while mining represents 16 % of the demand.

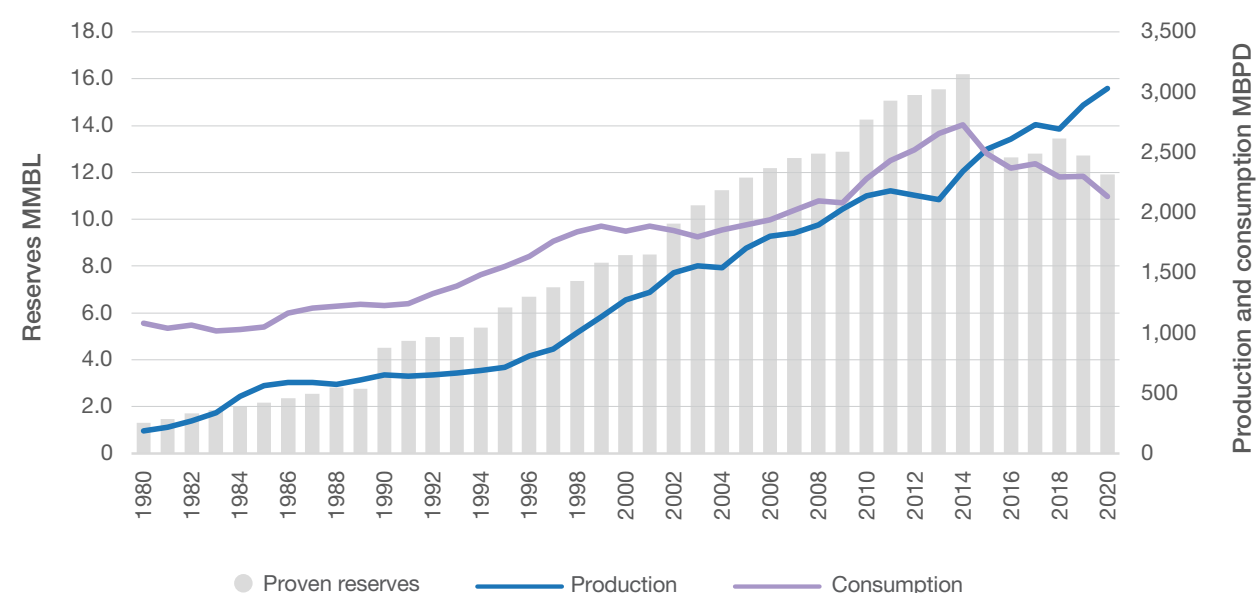
5. Inernational trade

Since over 30 years ago, Brazil has been making a systematic effort to invest in oil and gas exploration, including the development of its own technology for offshore drilling platforms. This effort has enabled the country to confirm very important reserves which have borne fruit in recent years, and the country has become a net oil exporter on a large global scale.



Graphic 27

► Brazil. Oil reserves, production and consumption



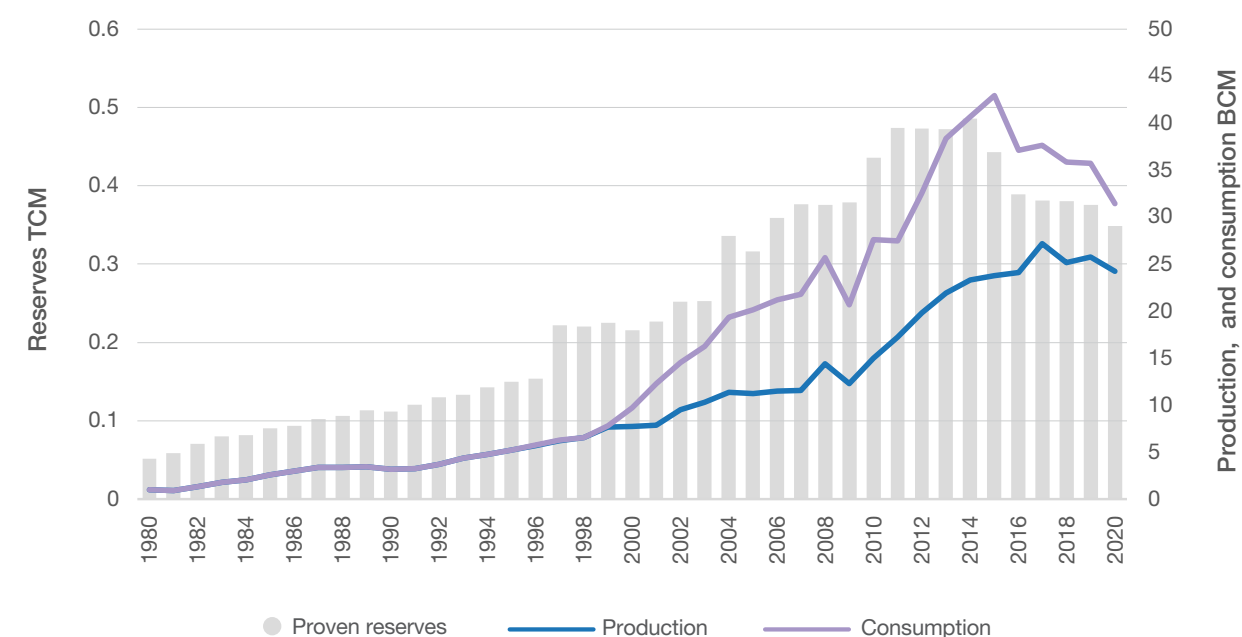
Source: Own preparation based on data from BP Statistical Review, 2022.

Additional oil and gas reserves were confirmed in what is known as pre-salt stratification (which means previous to salt); that is, under rocks with high saline concentration that are in deep submarine basins identified as probable in the Gulf of Mexico and in the Atlantic, in areas close to Brazil.

In this way, the country has become not only a net oil exporter but its imports have reduced and its dependence on purchases have diminished, especially from Bolivia, despite still being a net gas importer. This trend may affect the renegotiation of the supply contract with that country.

Graphic 28

► Brazil. Natural gas reserves, production and consumption



Source: Own preparation based on data from BP Statistical Review of World Energy 2022.

6. The power sector

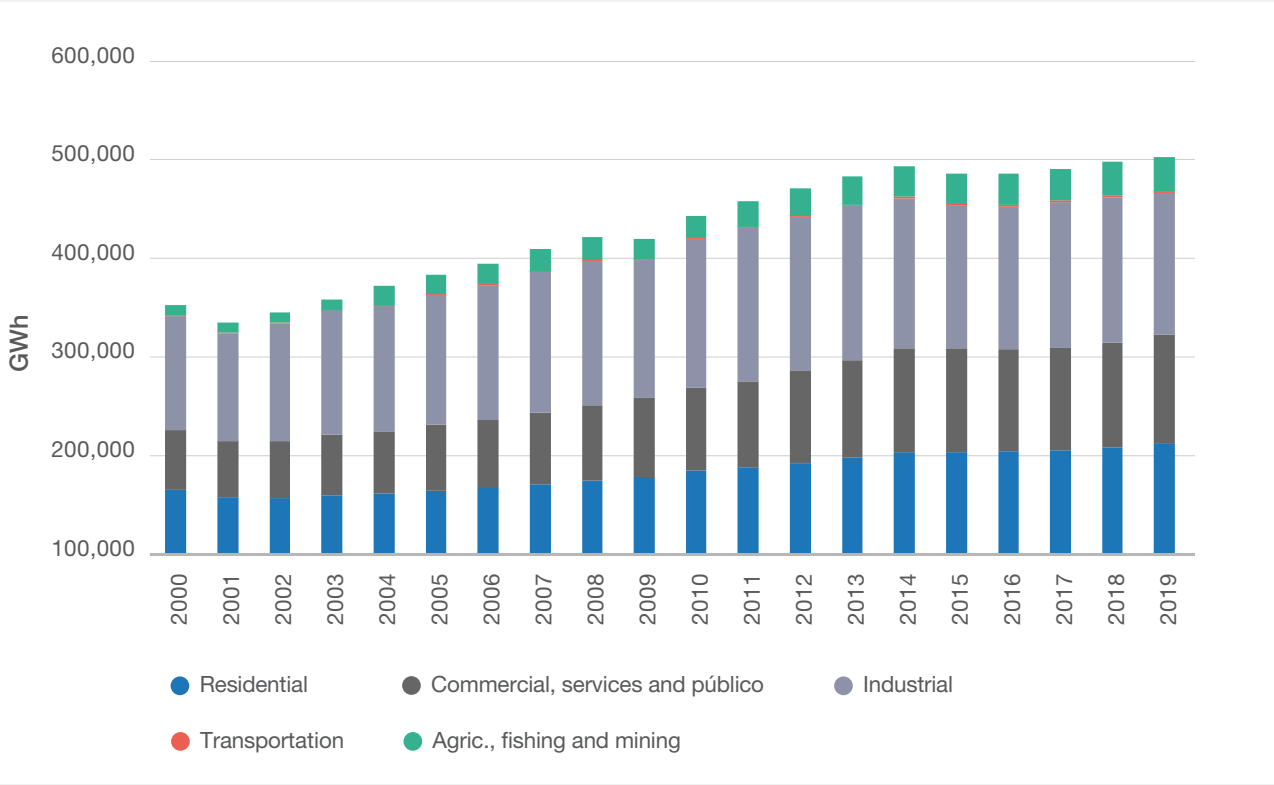


Power demand

Graphic 29 shows the final electricity consumption by economic sector.

Graphic 29 A

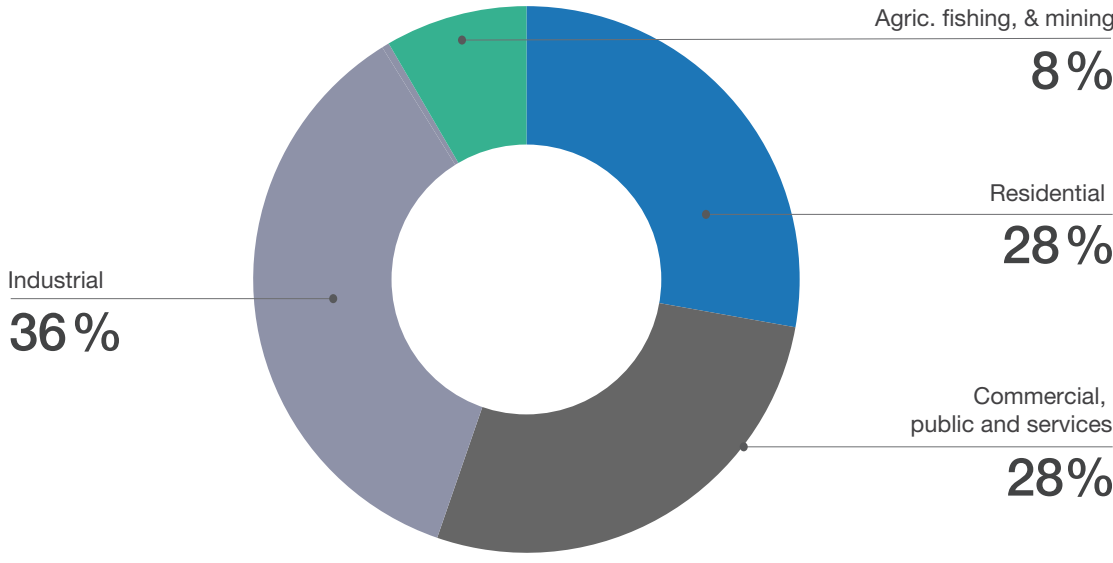
► Final electricity consumption by sector, between 2000 and 2019, and year 2019, GWh



Source: Own preparation based on data from sieLAC, OLADE.

Graphic 29 B

► Final electricity consumption by sector, between 2000 and 2019, and year 2019, GWh



Source: Own preparation based on data from sieLAC, OLADE.

Short and long-term growth trends are evidenced through the growth rates in the periods 2000-2019 and 2014-2019.

- Long term (2000-2019): 2.5 %
- Short term (2014-2019): 0.5 %

In the period between 2002 and 2014, we can see an important growth in power demand along with economic dynamism. However, the demand started a low-growth period from 2015 onwards.

In 2019, the average composition of power consumption in Brazil is represented,

in the first place, by the industrial sector (36%), followed by the residential sector and the commercial, services, and public sector (28% each). In the last 20 years, the share of the residential sector in the total electricity consumption has remained constant. On the other hand, the Brazilian economy has shifted towards a services economy.

In 2019, peak demand in the interconnected system reached 90.1 % GW.



Installed capacity

Installed generation capacity in Brazil (172.3 GW in 2019) is mainly composed of hydroelectric plants distributed in numerous hydrographic basins in different regions in the country. Some of the main rivers in Brazil include the Amazon (the second longest river in the world and the largest in terms of water volume), the Parana, and others.

Secondly, we can find the thermoelectric plants based on non-renewable energy, mainly natural gas, liquid fuels, and coal. These plants are dispatched according to the current and expected hydrological conditions; this allows them to manage the water stored in the reservoirs and ensure future service.

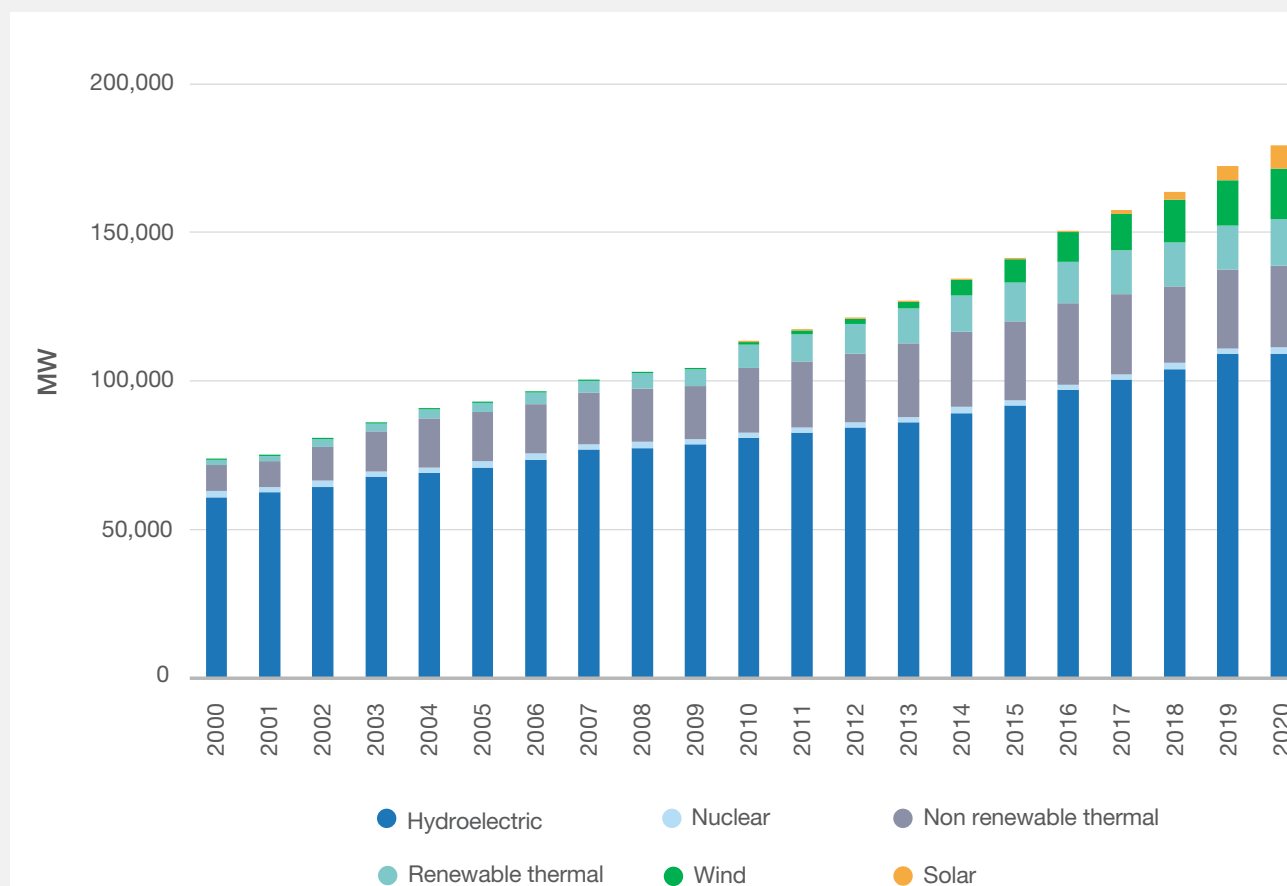
Brazil, together with Argentina and Mexico, is part of the group of countries with nuclear facilities in the region. In the case of Brazil, this kind of facility is in Angra dos Reis.

Thermal plants based on renewable energy (biomass and industrial residue) play a considerable role in the generation mix, especially cogeneration plants in the sugar/alcohol industry.

Finally, in recent years, the installation of wind and solar energy plants has grown thanks to the special attention received from the Government with specific incentives (long-term auctions, tariff discounts, and distributed generation, see section 2.3), financing from *Banco Nacional de Desenvolvimento Econômico y Social* (BNDES), and tax promotion mechanisms.

Graphic 30

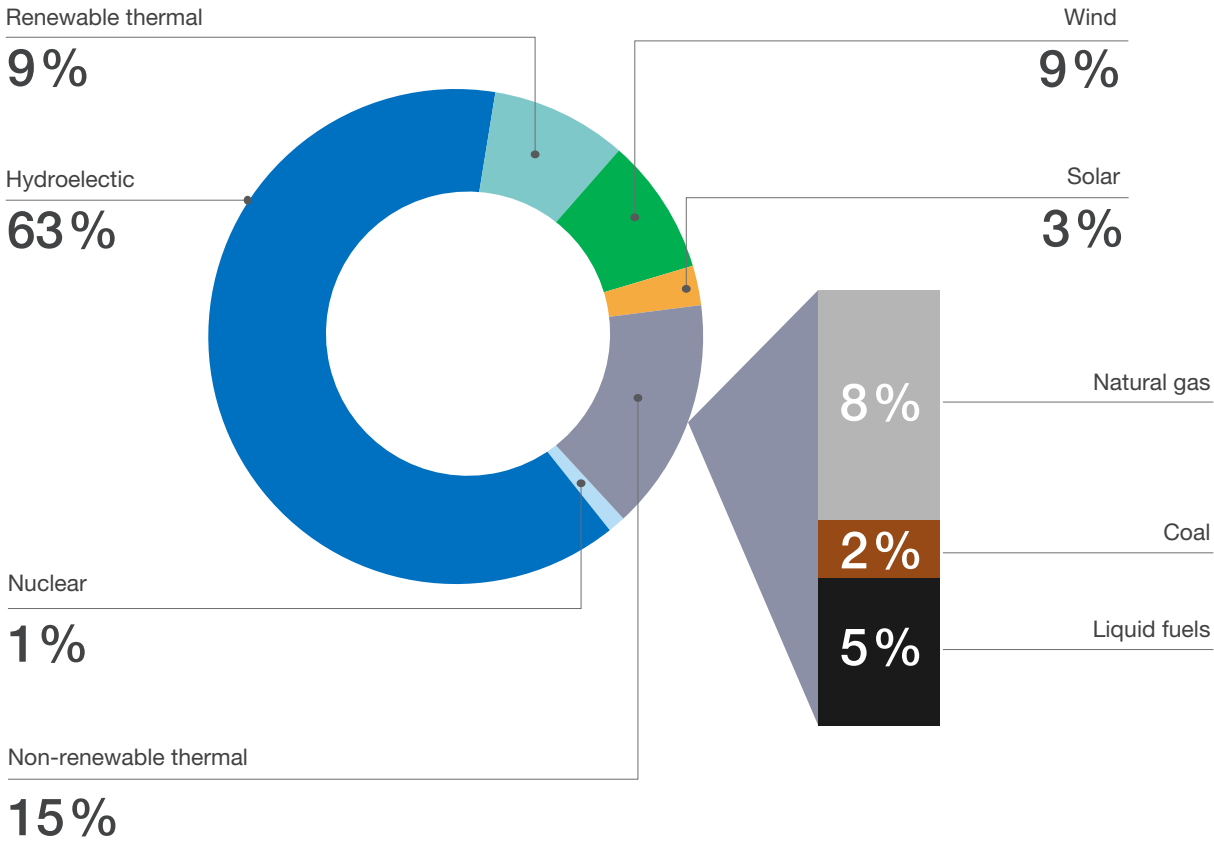
► Installed capacity between 2000 and 2020, MW



Source: Own preparation based on data from sieLAC, OLADE.

Graphic 31

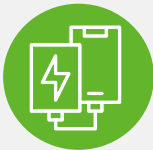
► Installed capacity by source, 2019, %



Source: Own preparation based on data from ANEEL.

In the last ten years, the expansion of the system has been very dynamic and has been dominated by the large hydroelectric plants, thermal plants, and renewable energy plants (especially wind, and more recently solar). The thermal share has remained relatively constant whereas renewables have grown significantly.

As to coal-fired plants, there is no official phase-out plan or a clear just transition mechanism. Even though the Brazilian Government has recently enacted Law No. 14299/22 or the so-called Just Energy Transition Act, this law guarantees that Brazil will continue using and subsidizing coal as an energy source until at least 2040. It is important to point out that coal-fired plants account for only 2 % of the total installed capacity and a similar order of magnitude in generation. Around two thirds of the coal-fired plants currently operating in Brazil were installed between 2010 and this date.



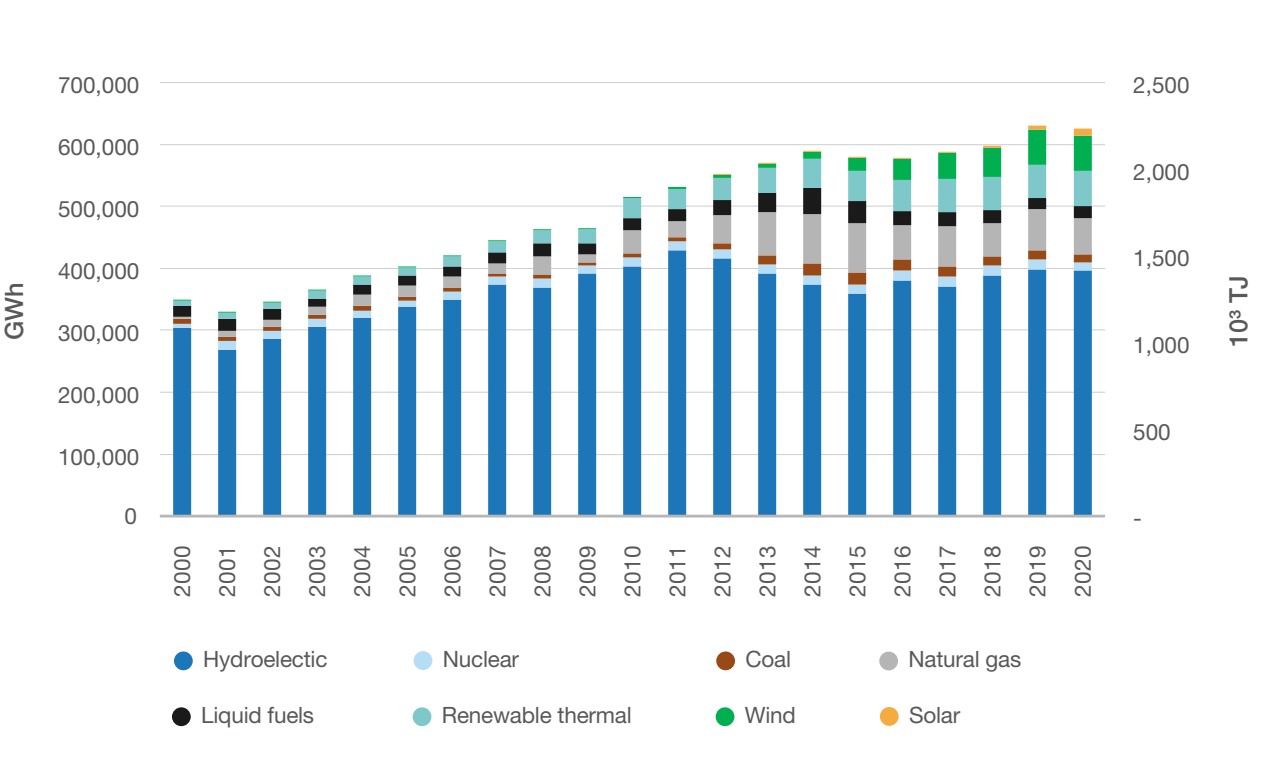
Power generation

Hydroelectric generation largely supplies Brazil's electricity demand. The participation of hydroelectric generation depends on the characteristics of the hydrology in a certain year (dry, medium, or rainy conditions) as well as the initial hydrological conditions (reservoir levels), since Brazil has a large number of reservoirs in multiple hydroelectric chains all over the country. Due to the country's great geographical extension, climate characteristics may vary depending on the regions considered in a specific year.

From 2000 to 2011, the share of hydro generation was an average 83 % of total generation, with a maximum of 87 % in 2000. In 2001, Brazil experienced an energy supply crisis and suffered from electricity rationing in a context of falling reservoir levels and growing demand for electricity. In 2014 and 2015, there was another power supply shortage situation and hydro participation reached a minimum (62 % in 2015) due to the lack of back-up generation capacity. In the period between 2016 and 2020, the hydro generation share was of around 64 %, with growing participation of wind and solar production (around 11 %) and a thermal quota of approximately 17 % (including nuclear generation).

Graphic 32

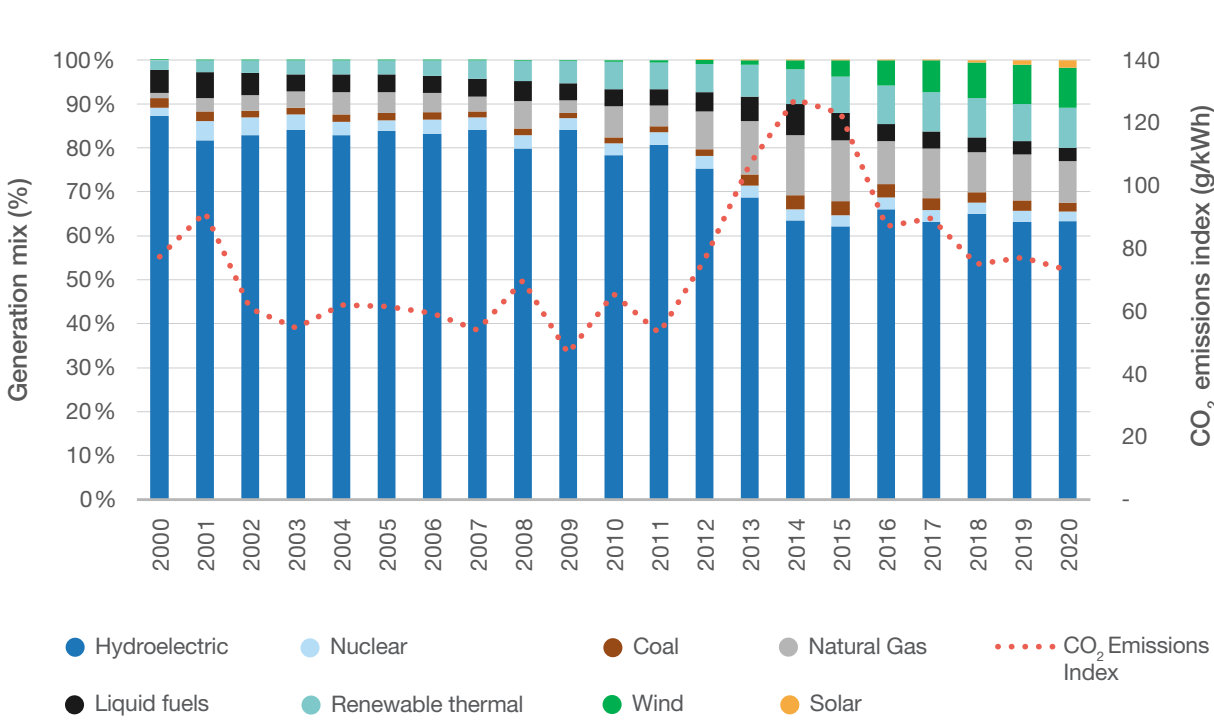
► Power generation by source between 2000 and 2020, GWh and 10³TJ



Source: Own preparation based on data from the Energy Research Office (EPE).

Graphic 33

► Power generation by source, 2000-2020, % and CO₂ emissions index of the power sector, g/kWh



Source: Own preparation based on data from the EPE and sieLAC-OLADE.

The annual generation mix has direct impact on the CO₂ emissions index, with higher values in the years when thermal generation participation increases.

Finally, due to the significant participation of hydro generation in the generation composition, the settlement prices for differences (PLD, in Portuguese) in Brazil's four electrical regions have high volatility.

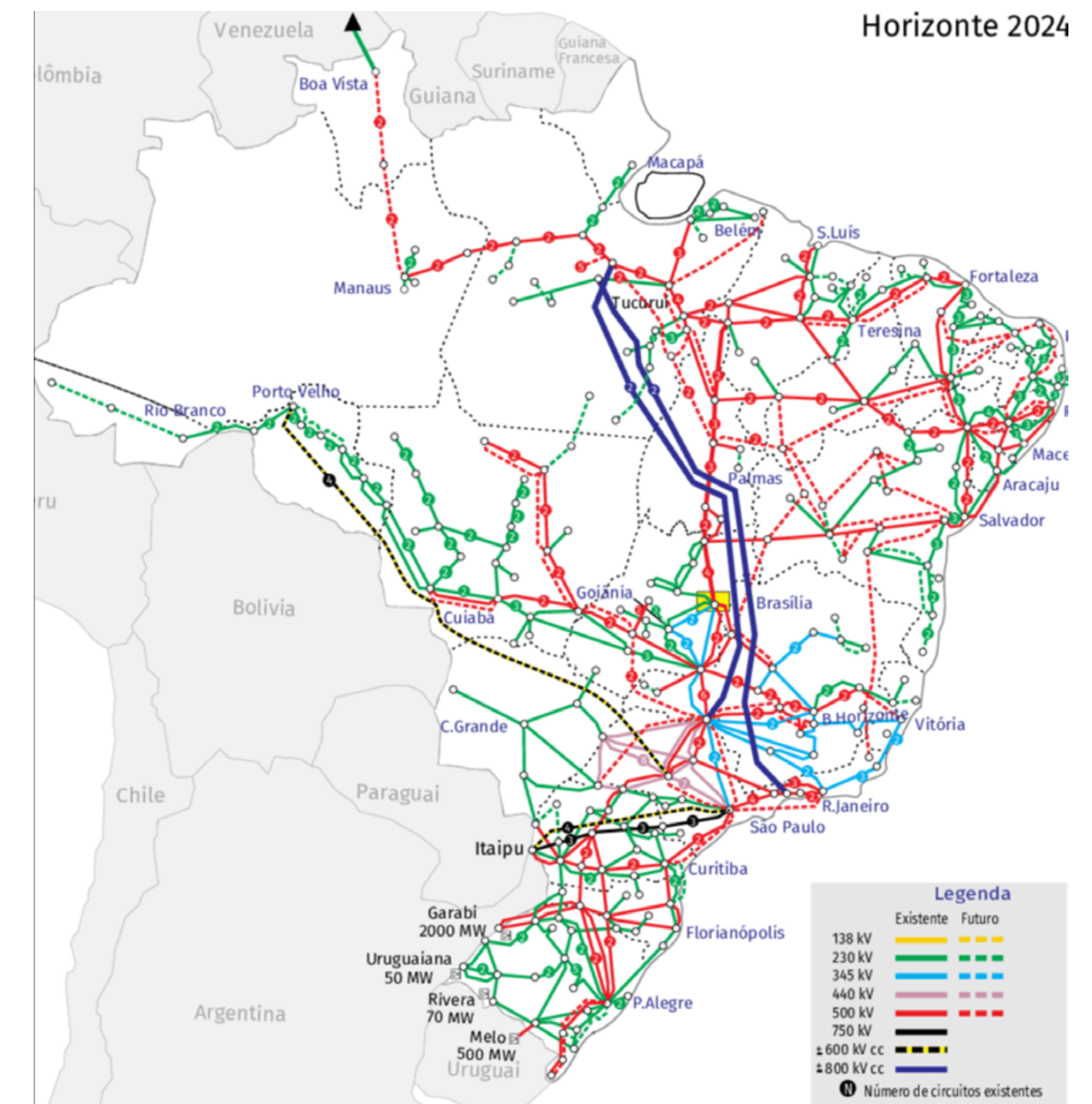
7. Existing power and gas pipeline networks

At present, Brazil has 149,000 km of power transmission lines (2020, EPE) and a 9,409-km gas transportation network (2019, EPE).

The interconnected system is divided into four electrical regions: southeast and central-west (SE/CO), south (S), northeast (NE), and north (N). The most important electrical region, in terms of its share of total demand, is the SE/CO. The electrification rate is close to 100%.

Graphic 34

► Existing (2020) and future (2024) National Interconnected System



Source: NSO (<http://www.ons.org.br/paginas/sobre-o-sin/mapas>).

8. Conclusions

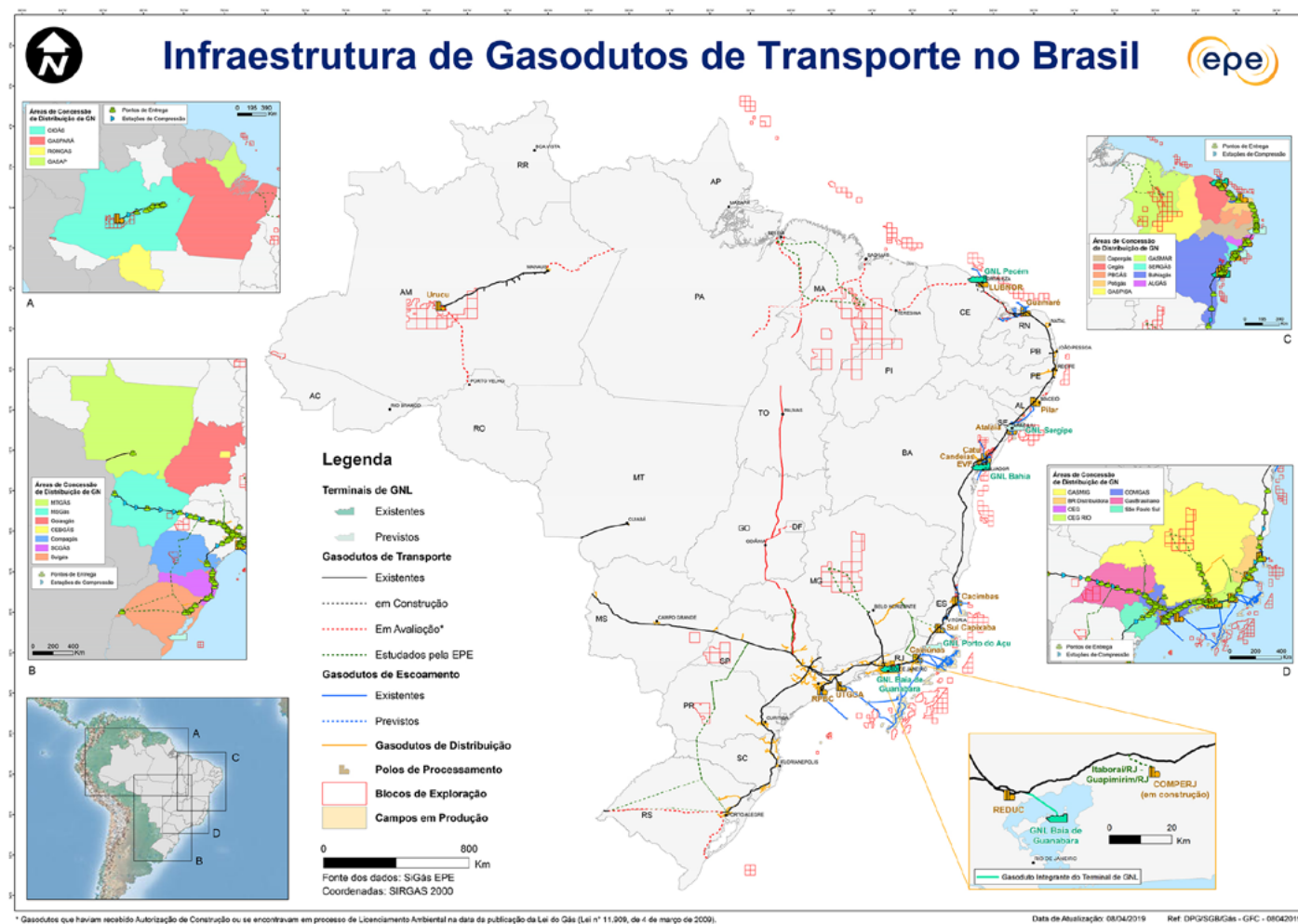
Brazil shows a series of very special characteristics in its economic and energy development that will largely condition its energy transition strategy.

General socio-economic context

- Economic growth has slowed down in recent years; this could prolong the energy transition process.
- The poverty level, as it is solved, will entail a rise in energy demand. This could represent an opportunity to make the introduction of new low-emission technologies viable through the increase in power demand.

Public policies and organization of the sector

- It has sound and stable regulatory agencies (ANEEL and ANH).
- It is one of the few countries in the region with a permanent, stable, and continuous energy planning system institutionally based on an agency with renowned technical capacity: the Energy Research Office (EPE).



Source: EPE.

From the point of view of taxes and subsidies

- Electricity and natural gas tariffs, as well as fuel tariffs, only have explicit subsidies.
- So far, there have been no taxes on carbon.

From the point of view of energy resources

- **Hydroelectric.** Brazil has a hydroelectric potential²² of 260 GW, and there is still 60% to be used, at least a relevant part of it.
- **Non-conventional renewable energy (NCRE).** Brazil has great onshore wind (247 GW), solar (307 GW), and biomass potential. It also has approximately 700 GW of offshore wind potential in locations less than 50 m deep²³. One of the sites with the most important wind potential in Latin America and with a high capacity factor, is in the state of Ceará, in the northeastern region of the country.
- **Oil and gas.** The abundant pre-salt reserves set a 20-to-30-year horizon to recover the investment in exports and development, and represent an important contribution to the economy and the generation of foreign currency from oil exports.
- **Biomass.** The sugar cane industry contributes cogeneration with the sale of surpluses in the public grid. Bioethanol has been highly developed; Brazil is the second largest world producer after the United States; together, they have 82 % of the world production (55 % the United States and 27 % Brazil, 2021).

²² It is important to remember that: a) hydroelectric potential should be updated due to major changes in elements such as the declaration of protected areas and restrictions to the construction of flow-regulation dams associated with power generation; b) part of the remaining potential is related to run-of-the-river plants with no regulation capacity beyond a few hours.

²³ According to the study *Roadmap Eólica Offshore Brasil* published by EPE.

- **Uranium.** The country has uranium reserves that might consist in an additional resource on an international scale. In terms of installed capacity, Angra I and II, in operation, total 1.9 GW, and 1 additional GW of nuclear capacity is included in the 10-Year Energy Plan 2031. Brazil is the only country in Latin America and the Caribbean with uranium reserves.

Energy demand

- Expected transition from the use of residential firewood to cleaner fuels.
- The energy demand for transportation is covered with a relevant portion of biofuels, in line with the solidly established ethanol industry.
- Mostly urban population, which may facilitate the development of a more efficient public transportation network.
- Historical energy intensity has not been significantly reduced, which offers a margin for enhancement and is somehow internalized within the technological change.

Power sector

- Dependence on the climate (hydrology) and on thermal plant backup in dry years, even though multi-annual reservoirs allow limiting this effect.
- Around 20% of the thermal plants (including coal-fired ones) have been built in the last 10 years, which may slow down the transition of the electric fleet; the economic impact of fossil fuels, however, will determine the pace and duration of the transition.
- About two thirds of the coal-fired plants in operation today in Brazil have been installed in the last 12 years.

- Generation mix with low CO₂ emissions on account of its high hydroelectric and wind – and recently solar – generation level.
- Several incentives to renewable energy: renewable energy auctions, transmission and distribution tariff reductions. Recently, there has been strong investment in renewable generation for the purpose of diversifying the generation mix.
- Potential to develop nuclear plants.

2

Energy projection methodology



1. Base year and planning horizon

The base year considered for the projection, and previously described in the chapter “Diagnosis and base line”, is 2019. The planning horizon starts in 2019 and ends in 2060.



2. Projection modeling



General description

In order to conduct the study, a low-emissions analysis platform (LEAP) model, developed by the Stockholm Environment Institute (SEI), was used. The LEAP model is a (software) tool used to analyze energy policies and assess climate change mitigation. In this case, it was used to model the emissions from the energy sector relating to fuel combustion in Brazil.

In terms of modeling methodologies, the LEAP model is particularly versatile.

- The LEAP model starts from the information of the energy balances, which guarantee the integrity of the data used.
- Energy demand can be projected by using methodologies:
 - o bottom-up, from specific detailed data to a total projection, or
 - o top-down.

In this study, bottom-up modeling was selected and the demand was divided into sectors (residential, industrial, transportation, etc.) which, in turn, were subdivided into subsectors and uses.

- Energy supply offers a wide range of simulation methodologies that allow us to estimate an annual power generation dispatch or incorporate the results of other more specialized optimization models.

The modeled demand sectors are projected according to an activity level and an explanatory variable, summarized in the following figure in a simplified manner.

Graphic 36

► Sectors, activity levels, and explanatory variables

Sector	Activity level	Explanatory variable
Residential	Population	Consumption per capita
Road transportation	Target variable, vehicle fleet	Average consumption per vehicle
Non-road transportation	Total GDP	Energy intensity
Industrial	Sectotal DGP	Energy intensity by subsector and use
Commercial, services, and public sector	Sectotal DGP	Energy intensity
Agricultural, fishing, mining, and construction	Sectotal DGP	Energy intensity

Source: Own preparation.

The sectoral gross domestic product (GDP) is one of the main drivers of energy demand growth, particularly for production sectors, while the evolution of the population plays an important role in the energy demand growth of the residential sector. The road transportation sector depends on the evolution of the number of vehicles which, in turn, is related to the GDP per capita

in the case of passenger transportation and the GDP in the case of freight transportation. Non-road transportation is projected on the basis of the global GDP.

The modeling adopted for this study is described below in more detail by demand sector and for the power sector. Given that the decarbonization strategy seeks to replace fossil fuels (coal, oil, and petroleum products, natural gas, etc.), the value chain associated with these fuels was not analyzed in detail, assuming that there will be enough supply.



Demand by sector

Residential sector

In order to analyze and project energy consumption in the residential sector, the **projection of the population and of unitary consumption** are estimated by use and by source per capita.

Residential consumption has two kinds of energy uses: heat uses (mostly cooking, sanitary hot water (SHW), space heating), which use different fuels with substitution potential, and electrical uses (lighting, refrigeration, etc.). The following analyses apply to each group.

- **Heat uses**
 - **Cooking.** The historical consumption trends, used for future projections, are analyzed in terms of useful energy²⁴ per 1,000 inhabitants. Fuel substitution assumptions by scenario (replacement of firewood with electric appliances or others running on natural gas) are presented.

²⁴ According to OLADE, IADB, 2017, final energy is “the amount of energy source consumed in each economic and social sector in the country”. On the other hand, useful energy is “the amount of energy actually used to perform the productive task of the consuming equipment or device, for example, the necessary heat that food must absorb to be cooked”.

- **SHW and space heating.** Given that these sectors are incipient and this type of consumption takes place with the increase in GDP per capita, a smaller portion of the current consumption observed in Spain and Portugal is extrapolated as target consumption²⁵. A broader implementation of energy efficiency measures and assumptions on the types of fuel to be used are also presented.
- **Other electrical uses.** Electrical uses (lighting, refrigeration, air conditioning, water pumping, electronics, etc.) are projected based on a historical regression against the GDPpc, which reflects the increase in electrical uses as the standard of living increases. In the particular case of air conditioning, the potential future temperature increase as a result of climate change could increase the need to use it. In addition, energy efficiency enhancements are considered.

Commercial, services, and public sector

In order to estimate the energy consumption of the commercial sector, we started from the consumption in 2019 and projected it **based on the GDP growth and energy intensity obtained for the base year**, by source, without making a difference by end use. Different assumptions are presented in terms of energy efficiency and fuel substitution.

²⁵ It is assumed that the increase in purchasing power (GDP per capita) entails an increase in the demand due to the higher levels of comfort enjoyed by the individuals. This implies an increase in current consumption to international levels compatible with a decent standard of living. Given that a large part of the Brazilian population lives in areas with warmer climate than those observed in Spain and Portugal, the target is a portion of the values observed in those countries.

Industrial sector

Industry was projected with information on energy consumption in 2019, broken down with an International Standard Industrial Classification (ISIC) digit, additional to that of the sector's GDP, **by activity subsector**. Seven subsectors were modeled; food and beverages; iron, alloys, and steel; paper and pulp; and cement and ceramic are those with more relevance in connection with energy consumption. In turn, for each industrial subsector, consumption is broken down by energy end use (direct heat, indirect heat, motive force, etc.) and by source.

Expected GDP growth, together with energy intensity by subsector and use obtained for 2019 are used for the energy consumption **projection**, mainly based on the final and useful energy balances available. The assumption was that the subsectors will maintain their share of the total industrial GDP during the planning horizon²⁶. Energy efficiency is modeled through a reduction in energy intensity while fuel substitutions are performed in terms of useful energy, with annual rates of participation.

Transportation sector

The transportation sector is projected pursuant to the following structure to reflect the main drivers that vary in each segment:

- road passenger transportation (cars, motorcycles, buses, etc.);
- road freight transportation (trucks, truck tractors);
- other (air, maritime/river, railway).

²⁶ This assumption implies that no structural changes are modeled within the industrial sector and the same GDP growth rate is applied to all the subsectors.

Road passenger transportation

To estimate the energy consumption level or the activity level of road passenger transportation, the following were estimated:

- **evolution of the vehicle fleet** (number of motorcycles, cars, light trucks, buses, etc);
- **average consumption by vehicle** calculated as the average annual distance traveled, divided by performance in km by energy unit.

Projection of the passenger vehicle fleet

- Private transportation (motorcycles, cars, light trucks)

In the first place, the countries with high development levels were identified and the average number of cars and motorcycles per 1,000 inhabitants in these countries was estimated. Such average was used as a long-term **saturation point** (2060), and projections were made using a logit function²⁷ to estimate the number of future private transportation vehicles.

In addition, to calculate the number of vehicles by type (motorcycles/ cars), Law’s conclusions (Law, 2015) on the relation between the **number of motorcycles per 1,000 inhabitants and GDP per capita** shaped like an **inverted “U”**²⁸, were used. This implies that, at first, the number of motorcycles per 1,000 inhabitants has a positive relation to GDP per capita until it peaks; from there on, as the development level of the countries increases, the number of motorcycles starts to fall and the number of cars increases.

- Public transportation (bus)

²⁷ The logit function or logistic curve or S-shaped curve is a mathematical function used in population growth models, product introductions, etc. Such function is a refinement of the exponential model for magnitude growth. In product introduction, growth is initially exponential; after some time, the growth rate decreases; finally, at maturity, growth stops.

²⁸ Law, Hamid & Goh (2015), *The motorcycle to passenger car ownership ratio and economic growth: A cross-country analysis*.

Similarly to private transportation, the average number of passenger vehicles per 1,000 inhabitants in developed countries was considered as an expected saturation point for developing countries in the long term. A logistic function was also used.

Road freight transportation

To estimate the energy consumption level or the activity level of the freight transportation sector, the following were estimated:

- evolution of the vehicle fleet (number of trucks + truck tractors), and
- **average consumption per vehicle** calculated as the annual average distance traveled divided by performance in km per energy unit.

Projection of the freight vehicle fleet

In order to estimate the future evolution of the freight vehicle fleet, the freight transportation fleets were projected with the linear regression method using the total GDP (measured at PPP of 2017) as an independent variable.

Freight transportation is segmented into two types of trucks: trucks and truck tractors; the latter are heavy duty trucks with trailers. The shares of each type of truck were projected as constant.

Air, maritime/river, and railway sector

Energy consumption for the sector was projected based on the **global GDP growth and the energy intensity** obtained for 2019, for each type of transportation, by source and without making a difference by end use.

“The detailed modeling of energy demand, divided into sectors, subsectors, end uses, and types of fuels, along with the projection of energy supply by technologies, allows for a precise analysis of the different emission profiles and substitution opportunities.”

Agricultural, fishing, mining, and construction sector

Energy consumption for this sector was **projected based on the GDP growth and energy intensity** obtained for 2019, by source and without distinguishing it by end use. The transition measures considered were enhancements in terms of energy efficiency and fuel substitution.



Power sector

The starting point was the current composition of installed capacity and generation. To cover the growth of the sector in the short and medium terms, the development of the power sector considers the projects under construction or the winners of auctions with a high degree of certainty and progress.

In the future, the expansion of the generation fleet will depend on:

- the relative competitiveness of the expansion options (renewable projects, particularly solar and wind, are believed to become more and more competitive due to the projected reduction in construction and development costs);
- the maximum project development potential by technology, as published at national level. This potential is considered a maximum limit;
- energy policy decisions included in the generation expansion plan;
- the local context regarding the development of projects by type.

The expansion of the generation fleet considers aspects such as:

- the average production factor, by technology and by country, for renewable projects;
- the firm energy or capacity that each technology can provide;
- the minimum production factor from which new thermal projects are developed;
- the estimation of power demand²⁹, including losses and own consumption.

The analysis is carried out on an annual basis (that is, it is not a detailed hourly simulation exercise but a high level estimation, as a first estimation in the context of a long-term energy transition analysis).

Even though most countries will need flexibility means (storage, demand management) to accompany the development of non conventional renewable energy (NCRE), a high level estimation was carried out in the chapter on financing³⁰.

²⁹ The projections presented in this report do not include the power demand associated with the electrolysis process to produce green hydrogen for local consumption and/or export, or the related electrical capacity.

³⁰ Current technologies are not competitive and productivity enhancements are expected, which prevents us from establishing with certainty the degree of penetration they could reach.

3. Scenarios and global framework



Definition of scenarios

Three scenarios were studied to characterize different pathways towards a just energy transition. See the detailed description in the chapter “Methodological section and assumptions”, *Just Energy Transition / Projection Assumptions report*.

The **Business as Usual (BAU)** scenario represents the expected evolution **following national public policy guidelines and the current trends**. The assumptions are based on the analysis of recent historical trends in terms of energy transition in each analyzed country, as well as on the paths traveled by more developed countries, to identify mitigation measures that can be rapidly implemented. Even though no disruptive changes are expected in this scenario and it is not possible to meet the net zero emissions commitment during the planning horizon, investment is required to continue with the energy transition policies that are being carried out in Brazil.

On the other hand, the **Net Zero 2050 (NZ 2050) and Net Zero 2060 (NZ 2060) scenarios** are based on the terms established in Article 4 of the Paris Agreement³¹.

³¹ Paris Agreement, paragraph 4.1: “achieve a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of the century”.

Both scenarios focus on reducing GHG emissions from the energy sector³² to a permissible minimum³³, so that the country can manage the absorption of CO₂ in the general balance of the national GHG inventory³⁴.

These scenarios require major investment and addressing different topics to transform the current energy sector deeply. Such topics include, for example, strengthening the technological bases, training human resources, energy planning, regulatory commissioning, infrastructure expansion, and instruments to develop the market for the new energy resources, as well as changes – in some cases disruptive – in the energy matrix, among others.



Projections of the socio-economics variables

GDP per capita and GDP

In line with the grounds for a **just energy transition (JET)**, the scenarios presented are accompanied by similar socio-economic development in the region, **reaching sufficient GDP per capita levels to be considered high-income countries**. In the case of Brazil, the GDP per capita will reach USD 37,000 per capita at PPP in 2060, with a 2.3% annual growth rate during the period.

³² The analysis performed focuses on the emissions related to burning fuel, both in energy demand processes by sector and in power generation. GHG emissions from other sectors (e.g., industrial processes, waste, fugitive emissions, etc.) are not detailed in this study, but are broadly estimated and are subtracted to estimate the national reduction potential.

³³ It is assumed that emission reduction must be achieved through an effective combination of regulatory measures, market efficiency promotion, technology transfer, and investment.

³⁴ It is assumed that CO₂ absorptions will result from measures implemented in the agricultural, cattle-raising, forestry, and other land uses (AFOLU) sectors or via the adoption of CO₂ capture, use, and storage technologies (CCUS).

Table 10

► Socio-economic indicators and CAGR between 2019 and 2060, %

		2019	2030	2040	2050	2060	CAGR
GDP per capita	USD per capita	14,685	16,882	21,713	29,179	37,275	2.3%
Total GDP	MUSD	3,110,059	3,779,951	4,996,912	6,736,951	8,460,524	2.5%
Population	1,000 inhabitants	211,783	223,909	230,132	230,886	226,977	0.2%

Source: Own preparation.

The GDP by sector is projected assuming that the share of each sector is maintained pursuant to 2021 values. This results in a GDP growth rate by sector equal to the total GDP growth rate.

Population

As to the projection of the population, the information from CEPALSTAT³⁵ was used. A deceleration in population growth is expected in Brazil in the future, with long-term negative growth.

³⁵ <https://statistics.cepal.org/portal/cepalstat/dashboard.html?theme=1&lang=es>

4. Main assumptions of the energy sector

The general framework of the study covers the definition of assumptions for **five target countries**. Even though each country has its own characteristics, the study **standardizes, whenever possible, the assumptions used** and assumes that the countries will undergo similar processes for the just energy transition. The particularities inherent in each country were considered, such as the coal industry in Colombia, biofuels in Brazil, natural gas at very competitive prices in Mexico, gas in Peru, and fossil natural resource shortage in the Dominican Republic, among others.

In order to meet the decarbonization targets set in each scenario, the assumptions considered were more ambitious in the case of the net zero (NZ) scenarios. The main assumptions are based on the measures described below.

- **Energy efficiency enhancements.** This is applied in all sectors, with equipment replacements, more thermal efficiency in households, optimization of the use of energy in industrial processes, and technological replacements towards more efficient devices and facilities, more efficiency in transportation vehicles, etc.
- **Behavior changes.** This refers, in particular, to the reduction in average distances traveled by vehicle (km/vehicle) as a result of digitalization in society (remote work, etc.), the development of public transportation, logistics enhancements, and the shift from freight transportation by truck to the railway system.

- **Fuel substitution.** In most of the sectors, there is a trend towards further electrification of energy uses, except for industrial uses or subsectors where there are low electrification possibilities. In these cases, the replacement of fuels with more CO₂ emissions by natural gas or the use of CO₂ capture and storage technologies are the projected options. Hydrogen and low-emission byproducts may also contribute to the decarbonization of the industrial sector (fertilizers, refining) and of heavy road, maritime, and air transportation (synthetic fuels).
- **Power generation matrix with non fossil technologies.** A very significant development of renewable energy and, in some cases, nuclear energy, is incentivized, as well as the phase-out of coal-fired plants and plants running on liquid fuel. It is important to remember that power generation composition is a key element in scenarios where a strong electrification of the consumption matrix is proposed to guarantee that this substitution will have the expected effect in terms of GHG reduction. This integration of renewable energy must be accompanied by the development of grid infrastructure, smart grids, and batteries to facilitate the integration of variable power generation.

The assumptions detailed by sector are presented in the chapter “Results and assumptions by sector”. It is important to point out that the sectors with the most emission reduction potential in absolute values are the transportation and industrial sectors, which nowadays are responsible for around two thirds of the emissions from the energy sector.

1. Global results

The global results presented below reflect the sum of the assumptions adopted by each sector.

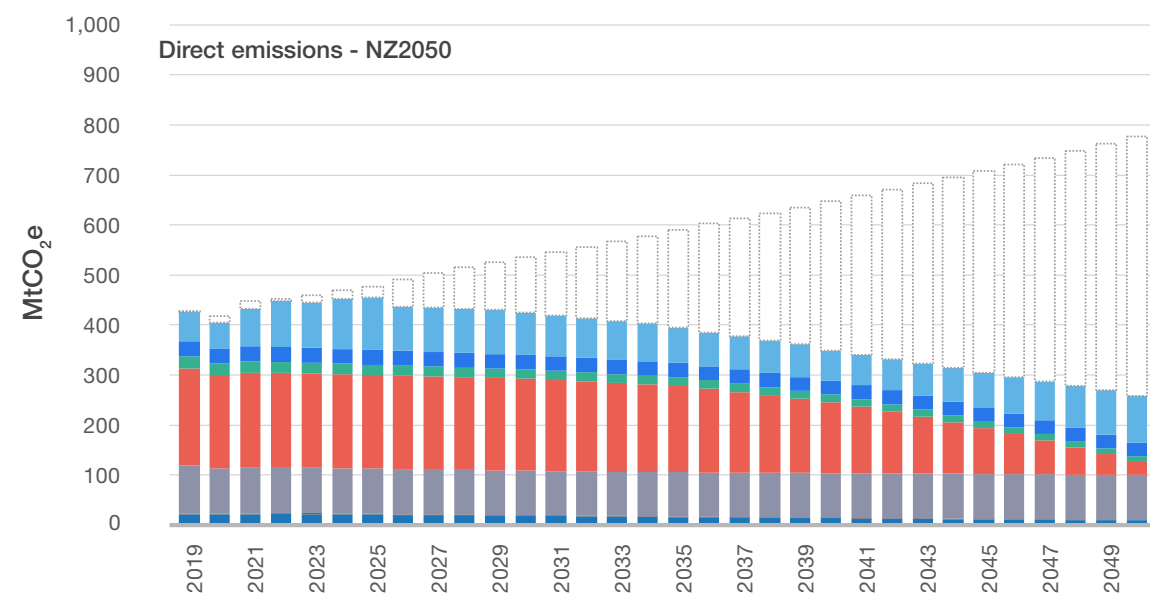
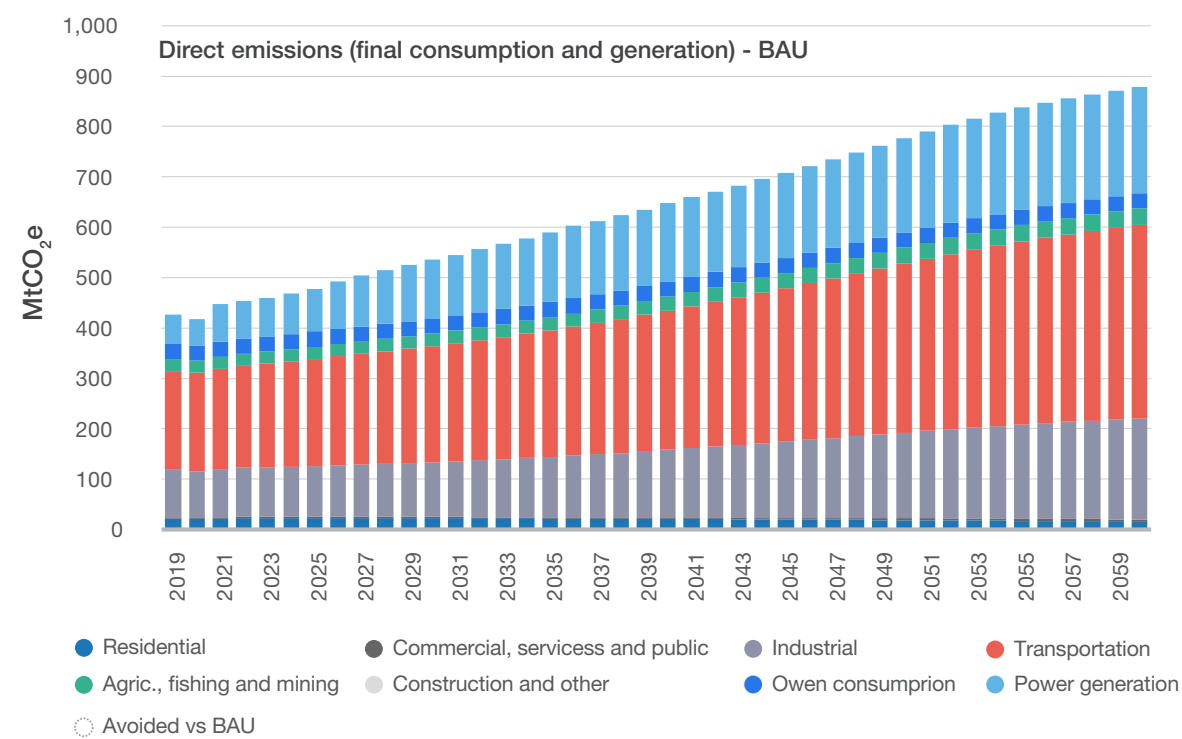


Emissions by sector

In the **BAU scenario**, the emissions related to burning fuels grow at an average annual rate of 1.8%, from 426 MtCO₂e in 2019 to 879 MtCO₂e in 2060. Even though this **increase** is sustained, it is **lower than the expected GDP growth**, which shows a certain environmental improvement in the economy. This scenario is well above the country's CO₂ absorption capacity, estimated at 300 MtCO₂e per year³⁶.

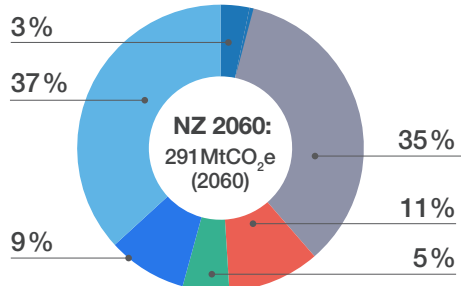
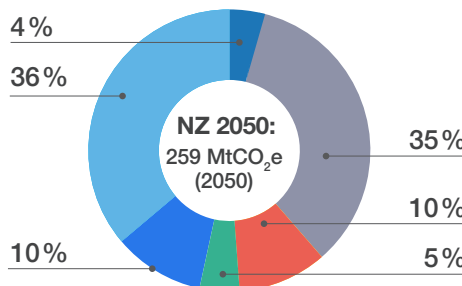
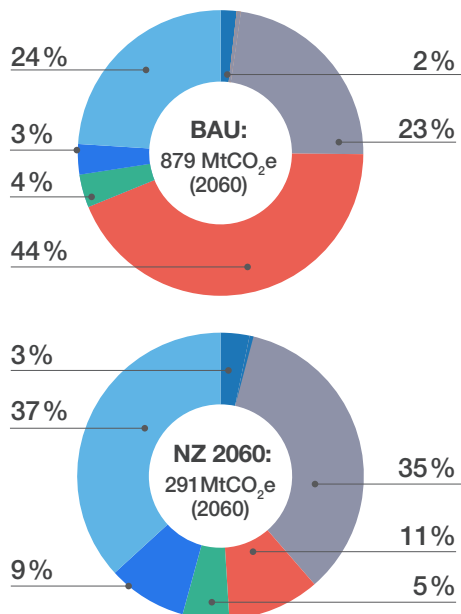
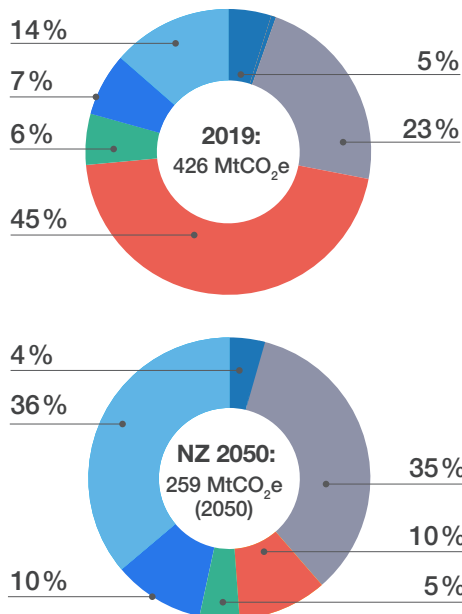
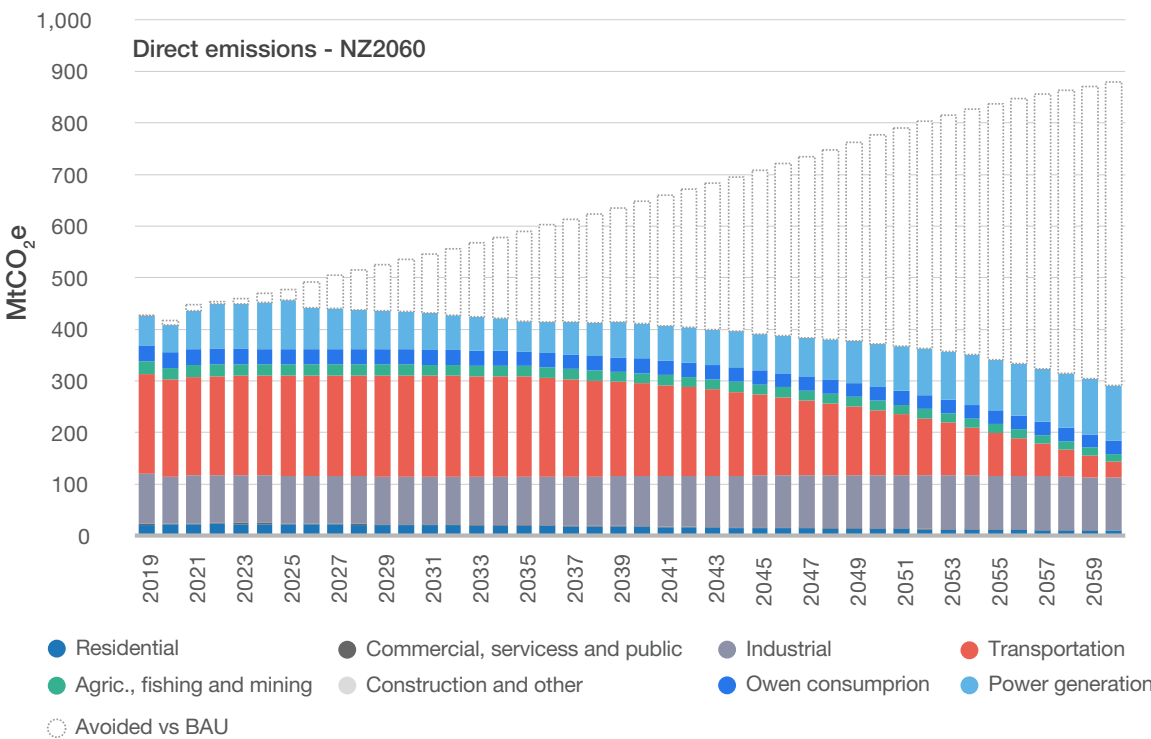
³⁶ <https://climateactiontracker.org/countries/brazil/>. Absorptions must cover not only the energy sector but also the industrial processes sector and the product use (IPPU), residues, etc. It is estimated that emissions should be lower than 250 MtCO₂e in the energy sector.

Graphic 37 A ▶ Direct emissions (final consumption and generation) by sector (MtCO₂e)



Source: Own preparation. Direct emissions do not reflect the absorption potential by carbon capture.

Graphic 37 B ▶ Direct emissions (final consumption and generation) by sector (MtCO₂e)



Source: Own preparation. Direct emissions do not reflect the absorption potential by carbon capture.

In the **NZ scenarios**, direct emissions fall to 259 MtCO₂e in 2050 (NZ scenario 2050) and to 291 MtCO₂e in 2060 (NZ scenario 2060). If we consider the annual carbon capture of 20 MtCO₂ (NZ scenario 2050) and 50 MtCO₂ (NZ scenario 2060), the resulting emissions fall to 239 MtCO₂e in 2050 (NZ scenario 2050) and 241 MtCO₂e in 2060 (NZ scenario 2060). Carbon capture and storage (CCS) will allow reducing the direct emissions from the industrial sector and from power generation, thus meeting **the net zero emissions target**. The average annual emission reduction pace is -1.9% (for the NZ scenario 2050) and -1.4% (NZ scenario 2060), considering the CCS potential.

To meet the net zero emission target, **total emissions should reduce by half during the planning horizon**, compared to current emissions.

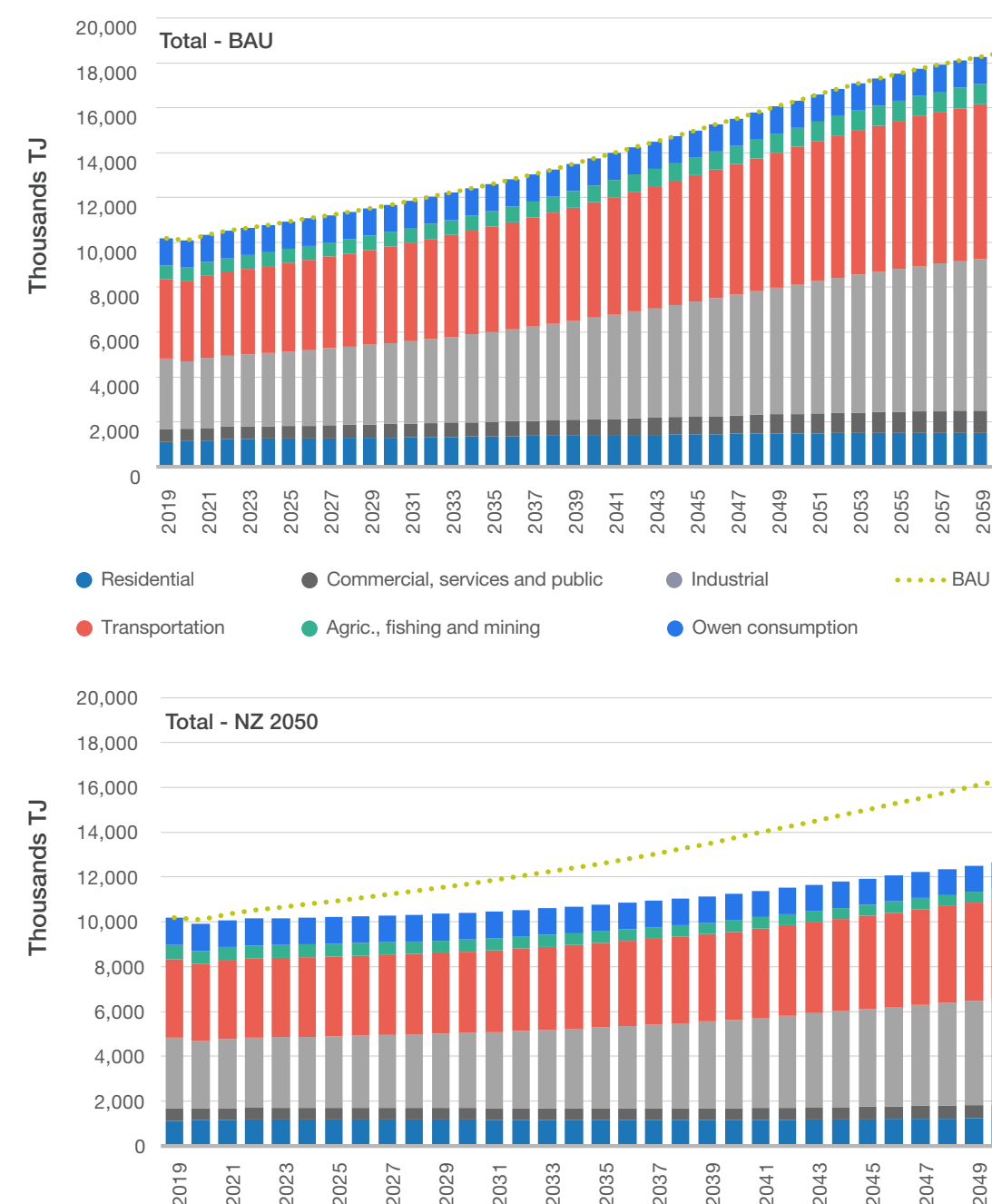


Energy demand by sector

In the BAU scenario, the demand almost doubles during the analyzed period and reaches around 18,500 thousand TJ in 2060. In the NZ scenarios, the demand grows slightly due to the stronger effects of efficiency and fuel substitution. In all the scenarios, **demand growth is higher than that of GHG emissions**.

Graphic 38 A

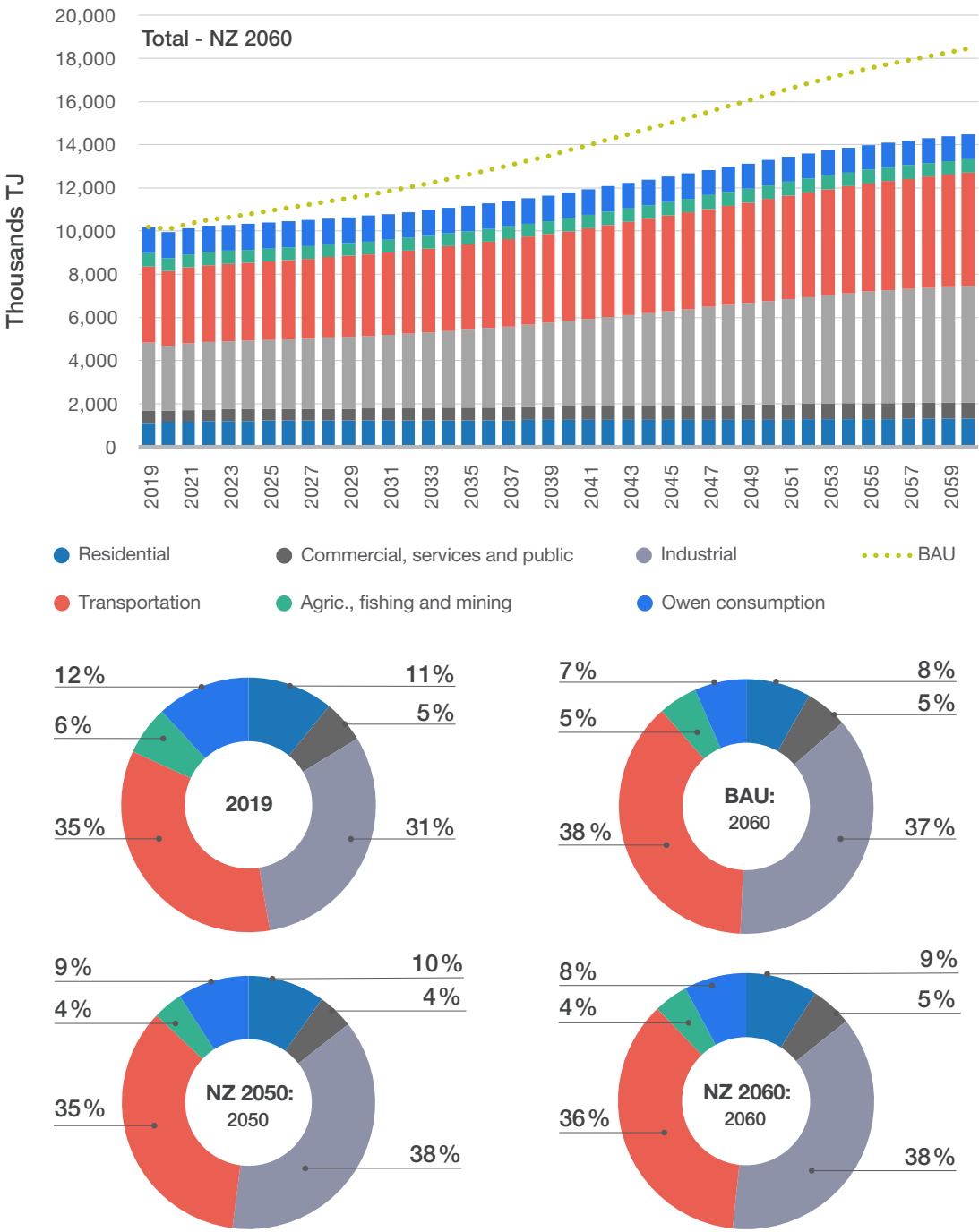
► Final consumption by sector and own consumption, by scenario (thousands of TJ)



Source: Own preparation. Non-energy consumption is not included

Graphic 38 B

► Final consumption by sector and own consumption, by scenario (thousands of TJ)



Source: Own preparation. Non-energy consumption is not included

Table 11

► Total demand by scenario, thousands of TJ and CAGR (%)

Demand (thousands of TJ)	2019	2030	2040	2050	2060	CAGR (%)
BAU	10,194	11,680	13,735	16,327	18,456	1.5%
NZ 2050	10,194	10,405	11,248	12,661		0.7%
NZ 2060	10,194	10,710	11,779	13,283	14,465	0.9%

Source: Own preparation. Non energy consumption is not included.

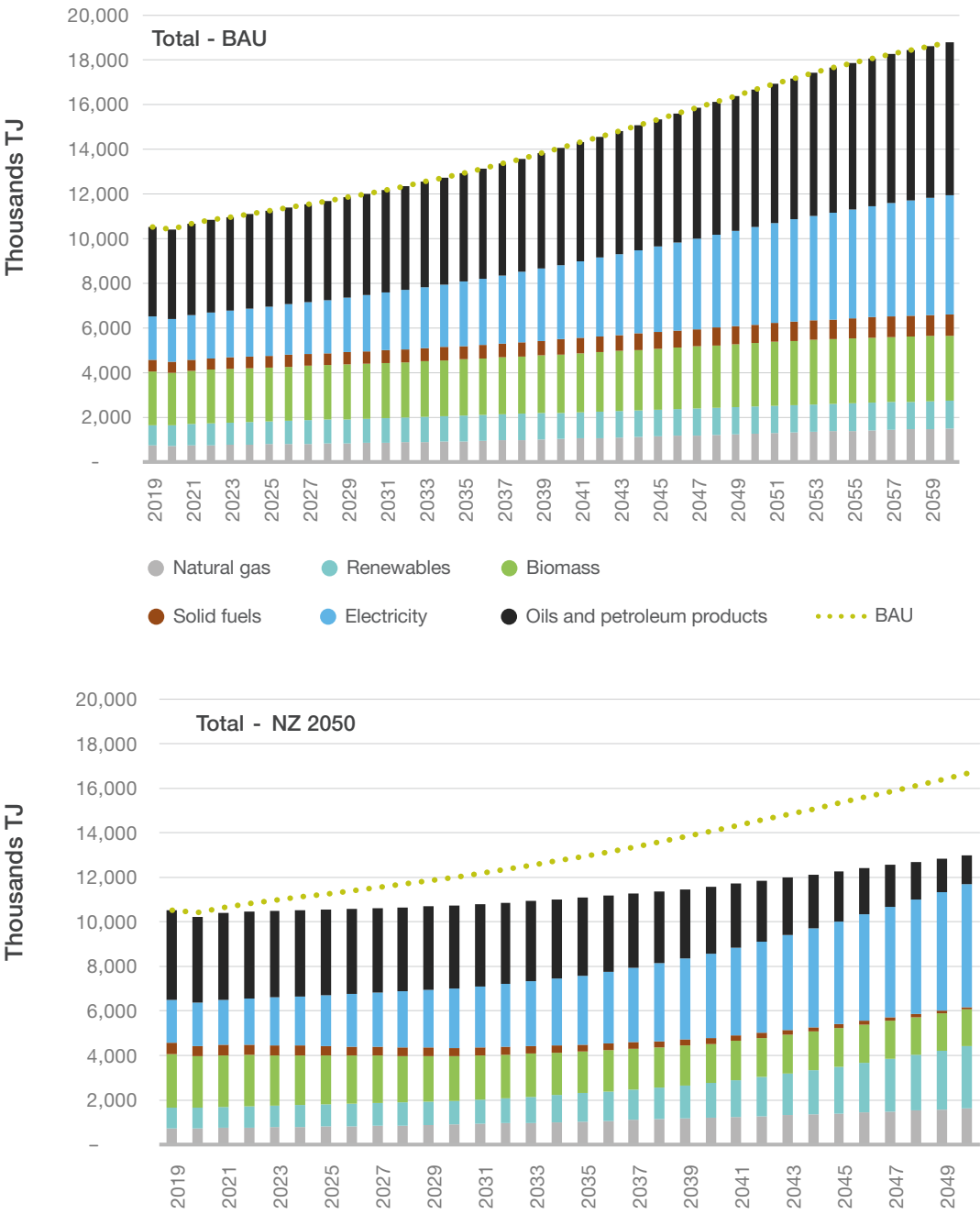
In all the scenarios, the relative participation of the demand by sector does not change very significantly and the transportation and industry sectors add up to around 70 % of the demand. Most of the sectors have similar growth rates, which evidences that **all the sectors participate in the transition efforts**.



Energy demand by source

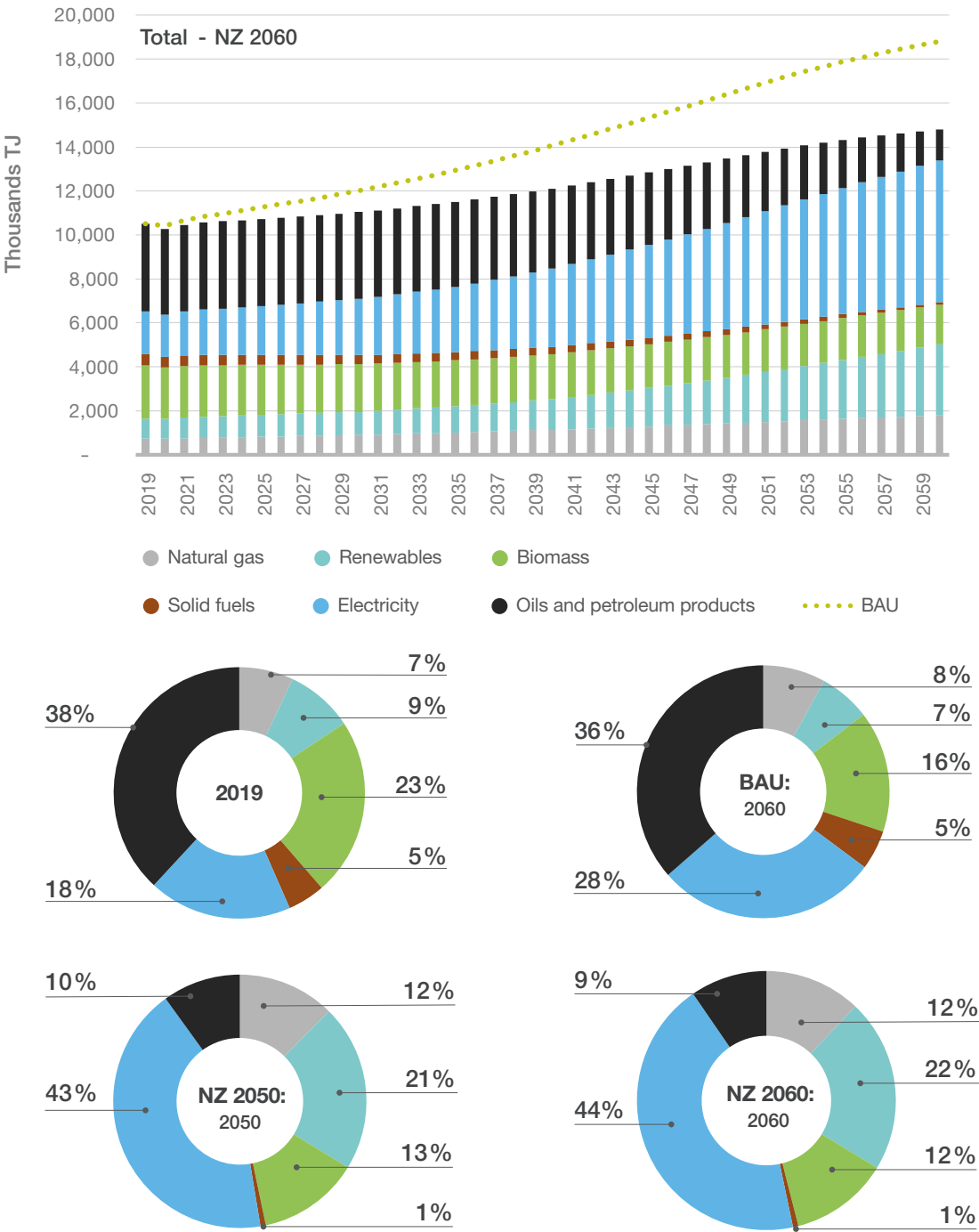
By fuel, a **strong trend towards electrification and the use of green fuels** can be observed. The BAU scenario reflects a slight increase in coal, biomass, and fossil fuel consumption and a stronger increase in natural gas and electricity (measured in growth rates). The NZ scenarios present stronger electrification hypotheses (approximately 45 % of total final consumption) and partial replacement of coal and firewood as well as liquid fuels. Green and synthetic fuels and solar thermal energy are developing in the long term. The use of sustainable biomass grows slightly.

Graphic 39 A ► Final consumption and own consumption by source and scenario, thousands of TJ



Source: Own preparation. Note: The renewables category refers to solar thermal energy, bioethanol, biodiesel, green diesel, and synthetic fuels. The oil and petroleum products category includes LPG.

Graphic 39 B ► Final consumption and own consumption by source and scenario, thousands of TJ



Source: Own preparation. Note: The renewables category refers to solar thermal energy, bioethanol, biodiesel, green diesel, and synthetic fuels. The oil and petroleum products category includes LPG.



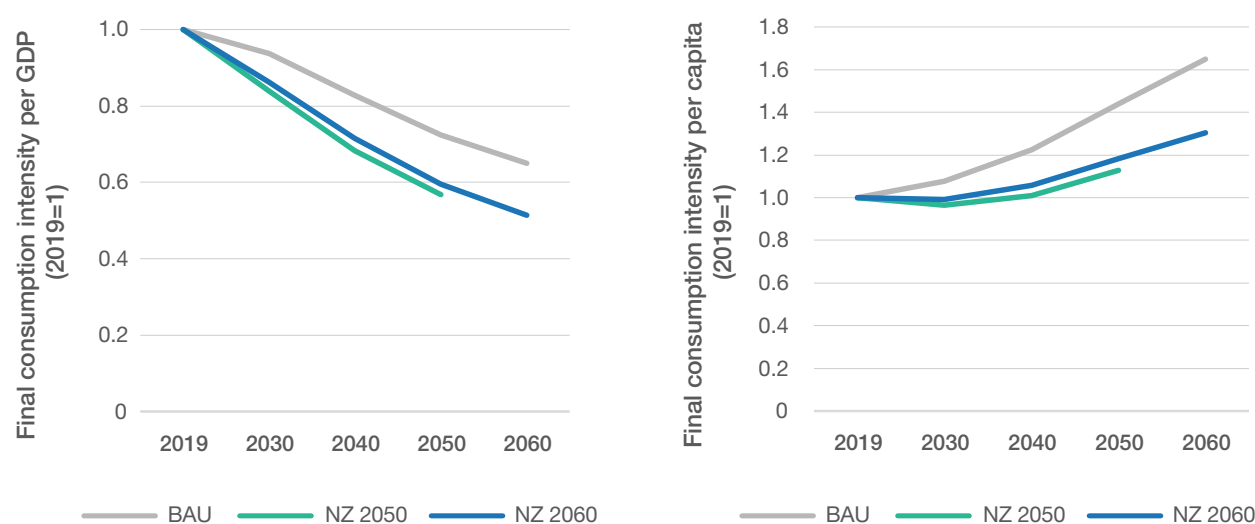
Energy and environmental intensity

In the BAU scenario, energy intensity measured in economic terms (final consumption/total GDP) is reduced by around 35% over the period (-1.0% annually), whereas in the NZ 2050 and NZ 2060 scenarios, it is reduced by nearly 50% (-1.8% and -1.6% annually, respectively).

Measured in terms of population (final consumption per capita), total unitary consumption grows by around 65% in the BAU scenario, while in the NZ 2050 and NZ 2060 scenarios, it grows by 13% and 30%, respectively. These values reflect the necessary evolution of final consumption to comply with the country's economic development and cover current consumption gaps.

Graphic 40

► Unitary energy intensity (2019=1), thousands of TJ/MUSD PPP 2017 (left) and thousands of TJ per capita (right)

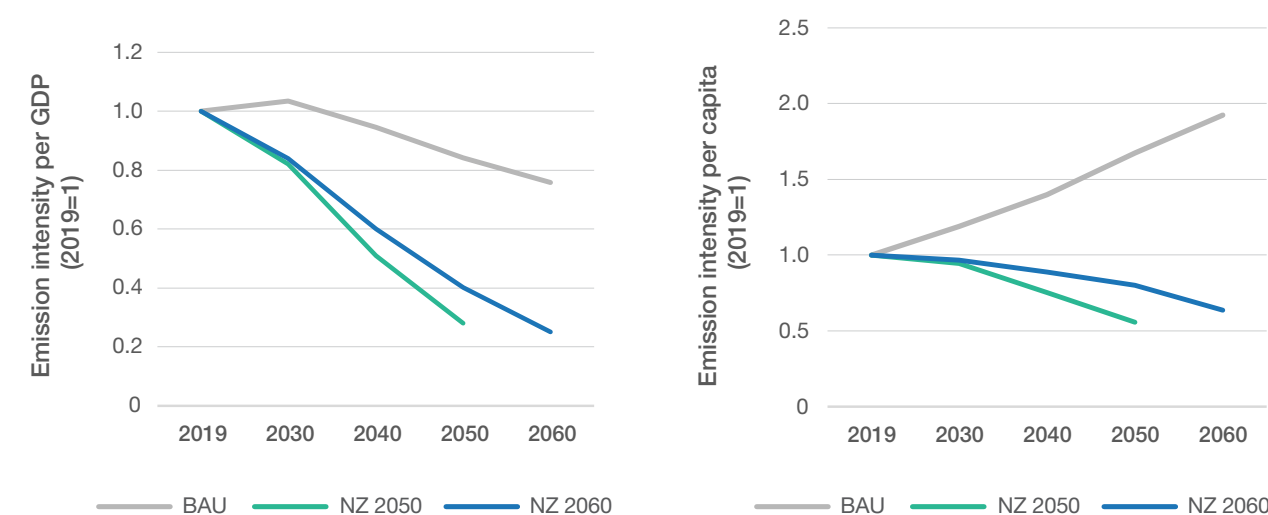


Source: Own preparation.

A significant reduction in energy intensity is required to meet the Paris Agreement targets. This reduction reflects the **decoupling between economic development and energy consumption**. The assumptions adopted to implement the proposed solutions (see *Just Energy Transition / Projection Assumptions report*) for energy transition in Brazil aim to reach a high future decarbonization level and **to promote a more developed and efficient economy**.

Graphic 41

► Unitary environmental intensity (2019=1), tCO₂e/thousands USD PPP 2017 (left) and tCO₂e per capita (right)



Source: Own preparation.

Unitary environmental intensity, measured in terms of economy (GHG emissions/total GDP) and population (GHG emissions per capita), is more significantly reduced than energy intensity for all the scenarios and reflects the emission reduction by energy unit consumed. To achieve net zero emissions, the emissions by GDP unit of the base year should be reduced by between 70% and 75%.

2. Results and assumptions by sector



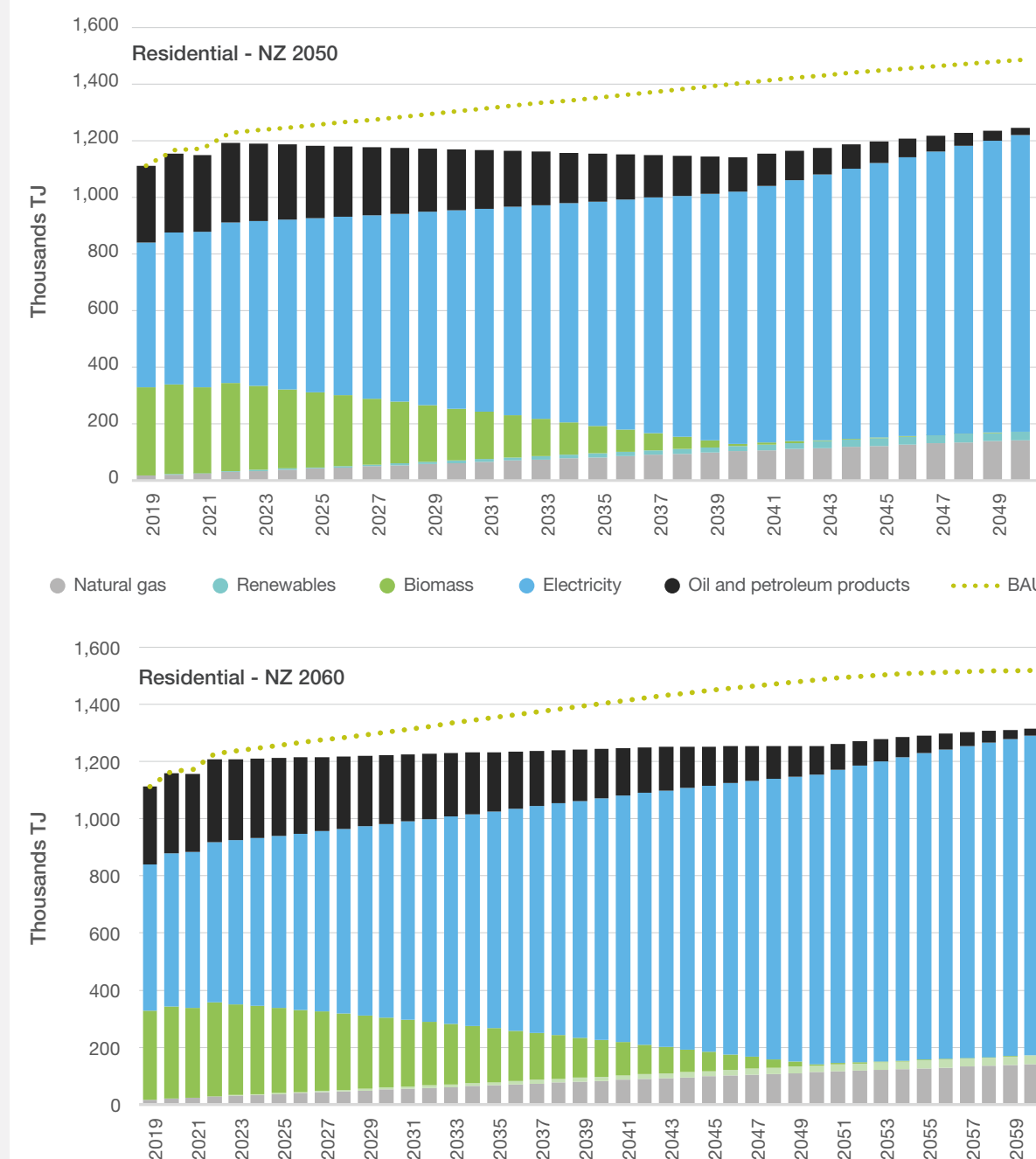
Residential sector

The residential sector is the fourth sector in terms of energy demand (11 % in 2019). It is responsible for a limited number of emissions (21 MtCO₂e), but there is potential to reduce them even further with energy transition measures. This sector is characterized by:

- high firewood consumption, with great electrification potential (and, in turn, large efficiency gains³⁷). This firewood consumption (28 % of the sector's final consumption) relates to the most vulnerable segments of the population; that is, its replacement is possible in a context of higher standards of living and support programs for the sector. Cooking end uses account for 56 % of the sector's final consumption;
- other uses (SHW, home appliances, air conditioning, etc.) with growth potential, as the standard of living improves, in line with what was observed in developed countries.

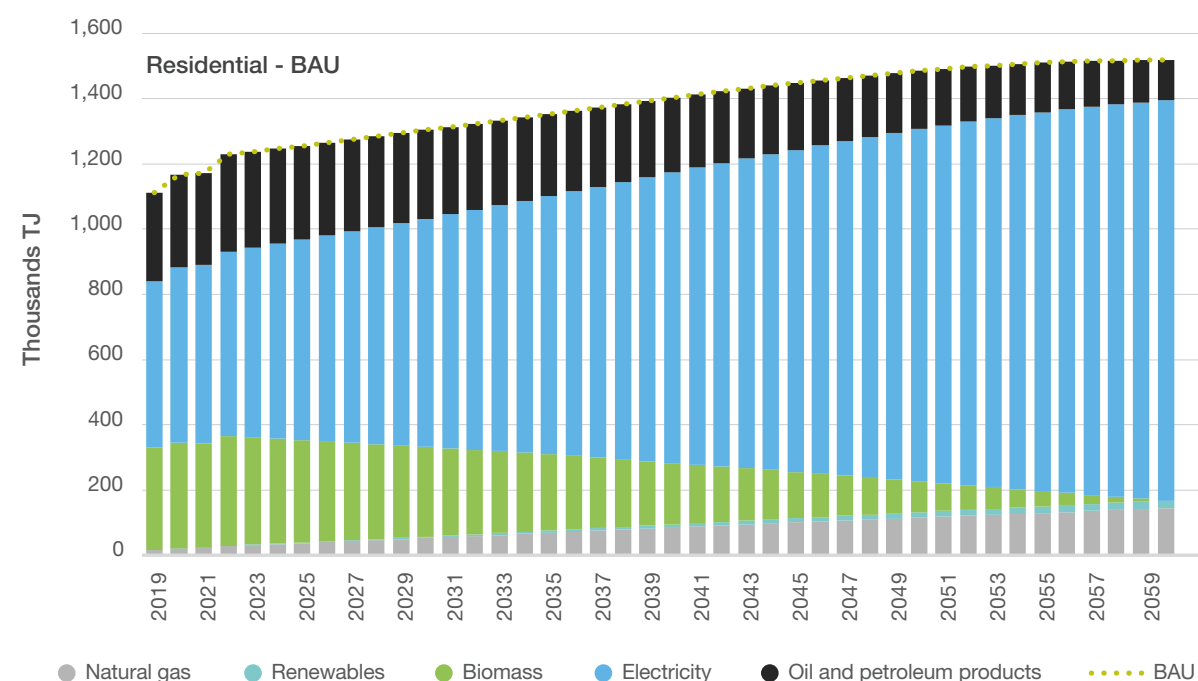
³⁷ It is estimated that the use of electricity or natural gas instead of firewood for cooking allows for very significant final energy savings

Graphic 42 A

► Residential sector: results by fuel and by scenario (10³ TJ)

Source: Own preparation. Note: The renewables category refers to solar thermal energy. The oil and petroleum products category includes LPG.

Graphic 42 B

► Residential sector: results by fuel and by scenario (10³ TJ)

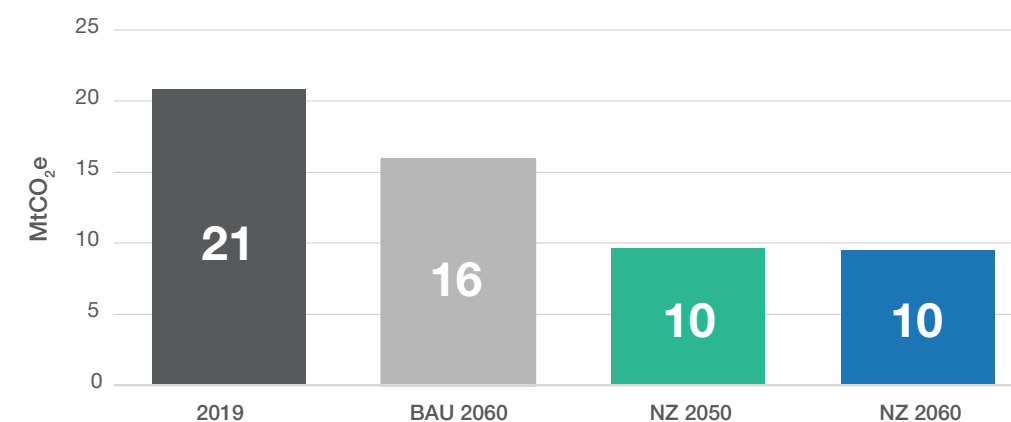
Source: Own preparation. Note: The renewables category refers to solar thermal energy. The oil and petroleum products category includes LPG.

In the BAU scenario (graphic on the left), we can see a 37 % increase in residential energy demand in the period (0.76 annually), mainly driven by the new thermal uses (including air conditioning) that are expected to accompany the increase in the projected standard of living. Firewood is replaced at the end of the period. Electricity and natural gas consumption grow considerably.

In the NZ 2050 and NZ2060 scenarios, power consumption covers a large part of final consumption (84 % and 85 %, respectively); there is a natural gas surplus and solar thermal energy is introduced to heat sanitary water. In turn, biomass

replacement occurs faster. More energy efficiency efforts³⁸, both for devices and buildings, allow compensating for the new uses that accompany the increase in GDP per capita to a large degree (the energy intensity of the sector, measured as demand per capita, is quite stable in the period).

Graphic 43

► Residential sector: direct emissions by scenario (MtCO₂e)

Source: Own preparation.

CO₂e emissions are reduced by 24 % in the BAU scenario, whereas they decrease by 54% in the NZ scenarios in the long term, thanks to the energy efficiency and electrification measures from clean generation sources.

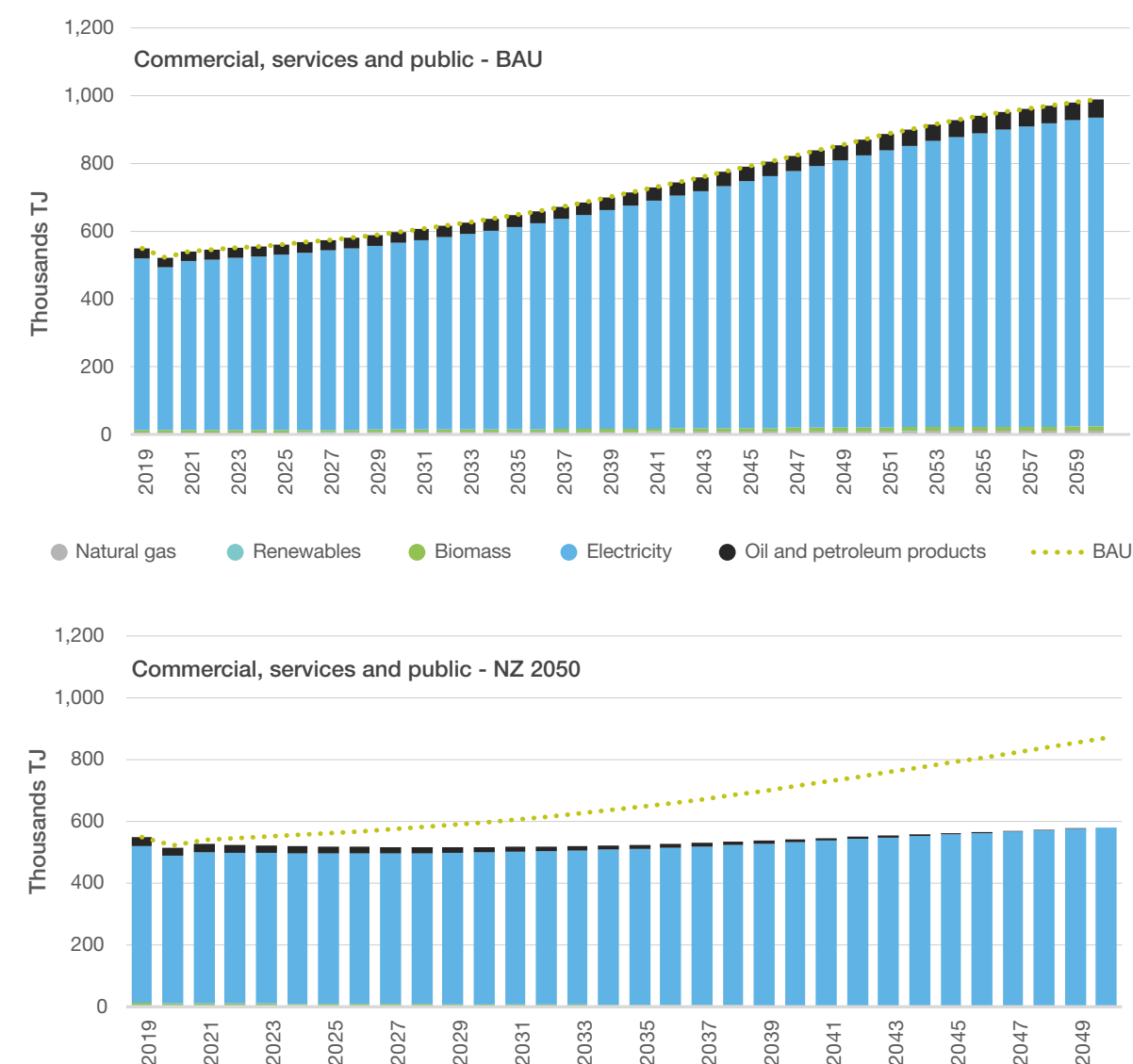
³⁸ There are only two lines of action to increase energy efficiency in all sectors: technological change and good energy use practices. For example, the replacement of incandescent bulb lighting with discharge units (bulbs to save energy) and later by LED bulbs, which took place in most countries, produces, by itself, a reduction in installed lighting capacity of up to 80%. However, this would result in a similar reduction in terms of energy consumption only if the same patterns of use previous to replacement were maintained. Or else, it may be higher if there is more care in the use of lights (with motion sensors, for instance); instead, it may be lower if all the lights are left on more time when switching for LED. Changing the technology is not enough; what is known as “good practices in the use of energy and operation and maintenance of facilities and equipment” should be applied.



Commercial, services, and public sector

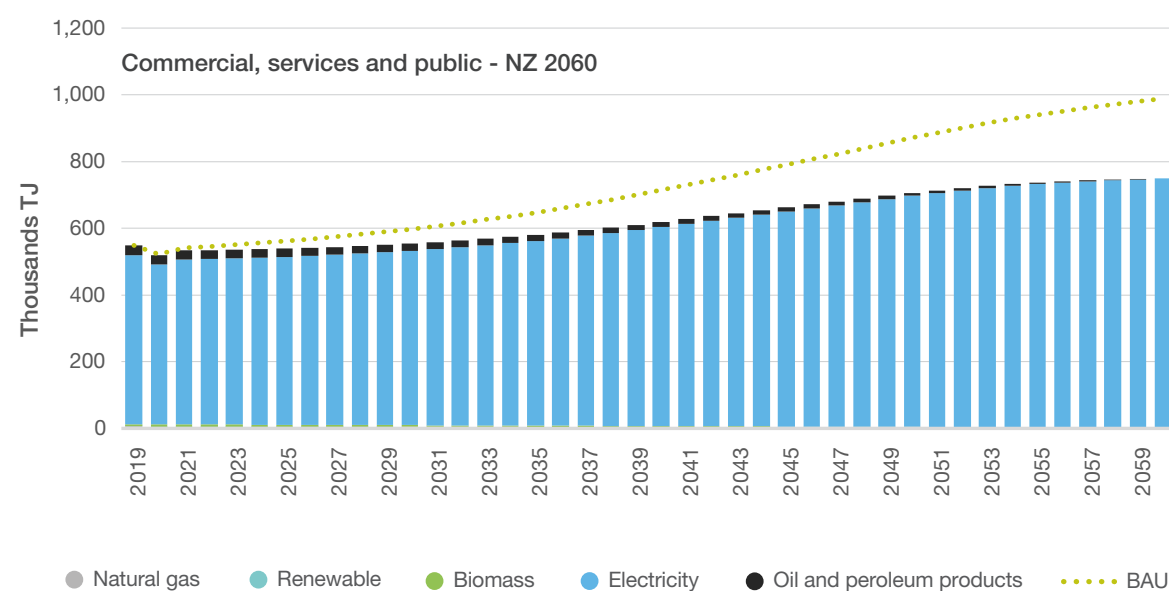
The commercial, services, and public sector is formed by the public administration, hospitals, hotels, and stores, etc. It is often a sector with little weight in terms of energy consumption (5 % of the total, in 2019) compared to the transportation, industrial, and residential sectors. It starts from a high electrification rate (92 % in 2019) and uses with electrification potential (SHW, space heating, motive force, cooking, etc.), as is the case of the residential sector. There is also potential for more energy efficiency, both in equipment and the buildings themselves (thermal renovation of existing buildings, application of strict thermal regulations for new buildings).

Graphic 44 A

► CSP sector: results by fuel and by scenario (10³ TJ)

Source: Own preparation. NB: The oil and petroleum products category includes LPG.

Graphic 44 B

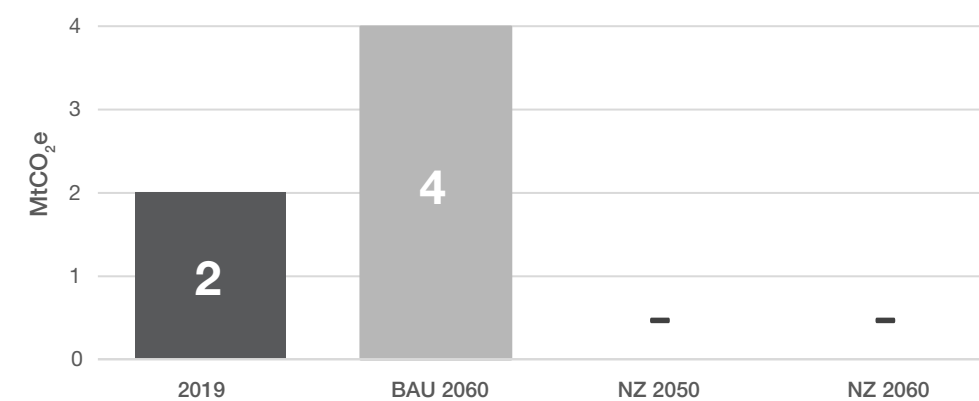
► CSP sector: results by fuel and by scenario (10³ TJ)

Source: : Own preparation. NB: The oil and petroleum products category includes LPG.

In the BAU scenario, the fuel share remains constant. On the other hand, even though the sector's GDP is almost trebled, the energy demand grows by 80% due to energy efficiency measures.

For the NZ scenarios, total electrification of the sector is considered. A 24% demand reduction is achieved by 2060 (NZ2060) and 33% by 2050 (NZ 2050) compared to the BAU scenario. Energy efficiency enhancements explain a large part of this phenomenon.

Graphic 45

► CSP Sector: direct emissions by scenario (MtCO₂e)

Source: Own preparation.

Direct CO₂e emissions grow in the BAU scenario but at a slower pace than the GDP; however, they are eliminated from the long-term NZ scenarios.

The energy transition measures required to limit GHG emissions in the commercial, services, and public sector include mature technologies related to refrigeration, lighting, and direct or indirect heat; therefore, electrification must be prioritized and the efficiency of the appliances should be enhanced. The sector itself, although it has little weight at energy level, is heterogeneous, with consumption related to cooking and refrigeration end uses in restaurants, IT equipment and lighting in offices, mixed end uses in hospitals or schools, etc.



Industrial sector

The industrial sector is formed by several industrial subsectors and is the second with the largest energy demand (31 % in 2019) after the transportation sector. Its starts from low penetration of electricity (21 %), conditioned by several sectors that are difficult to electrify, such as the steel and cement industries.

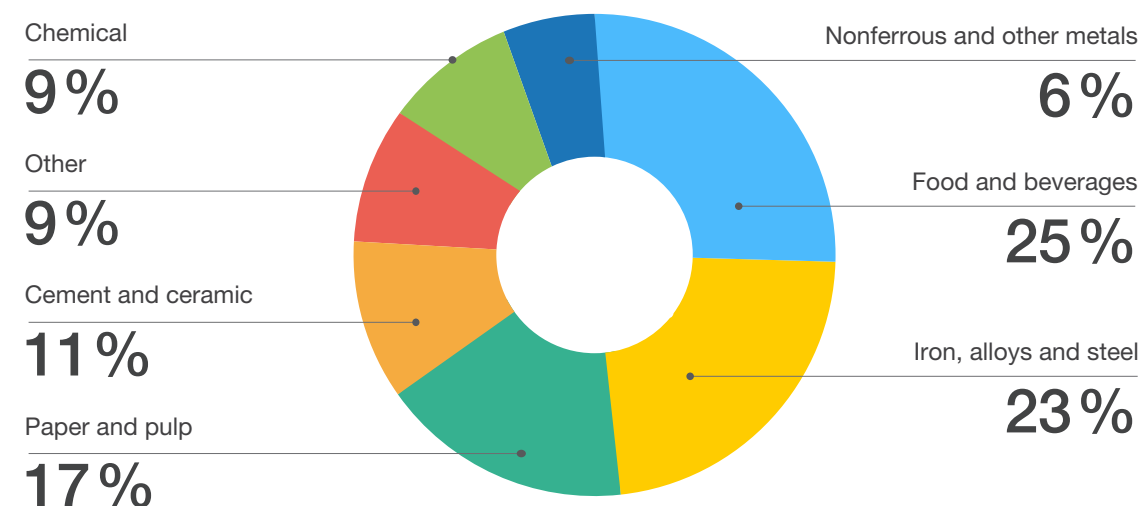
It is important to remember that fuel substitution possibilities may vary considerably from one industrial subsector to another, given the variety of existing industrial processes. To make the projections, the industrial subsectors were grouped together into a limited number of subsectors. The analysis focused more in detail on the subsectors with the greatest consumption and their associated uses.

Projections by subsector

Brazil's National Energy Balance presents the information on the industrial sector broken down into various subsectors grouped together as follows:

Graphic 46

► Industrial sector: Energy consumption by industrial subsector, 2019 (%)

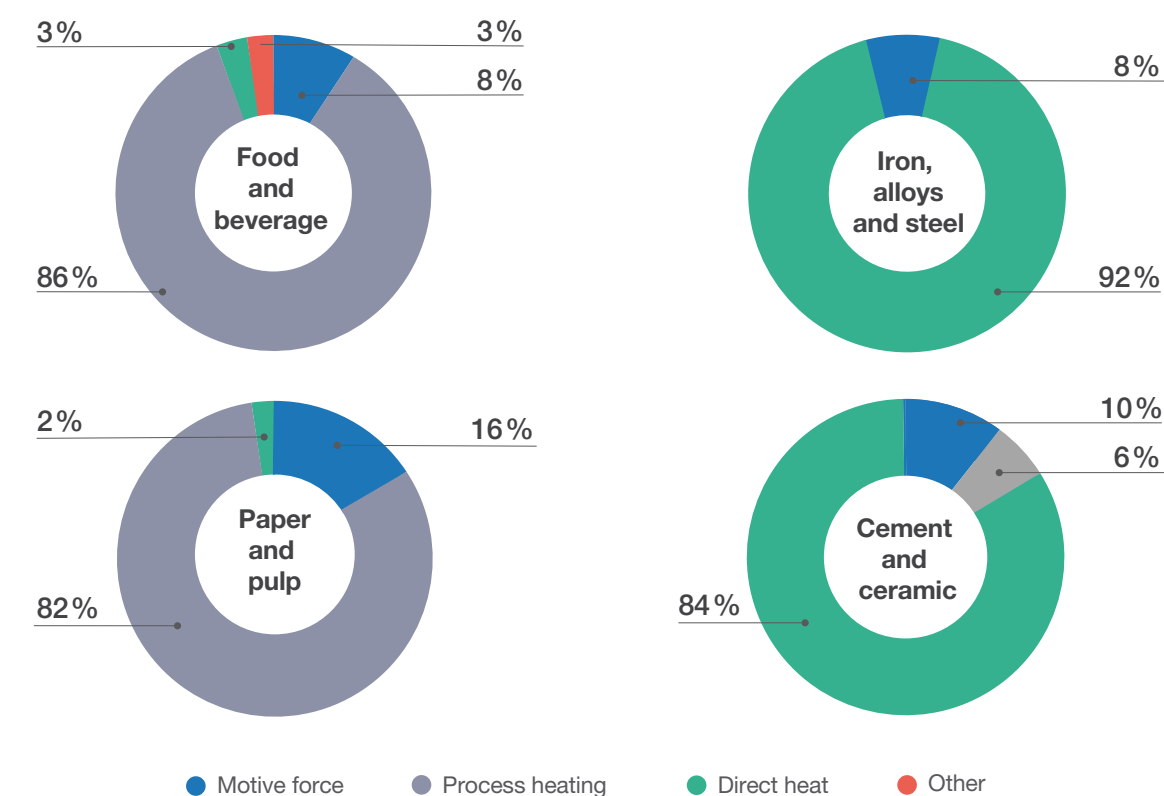


Source: Own preparation based on data from the useful energy balance of the industrial sector (EOE) and Brazil's energy balance (OLADE).

The food and beverages; iron, alloys, and steel; paper and pulp; and cement and ceramic subsectors account for 76 % of the energy consumption in the sector. The use of process heating prevails in the food and beverages and paper and pulp categories (86 % and 82 %, respectively). In the iron, alloys, and steel, and cement and ceramic categories, the direct heat use prevails, with 92 % and 84 %, respectively.

Graphic 47

► Industrial sector: energy consumption by use for the main subsectors (%)



Source: Own preparation based on data from EPE³⁹.

³⁹ <https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-de-energia-util-para-segmentos-selecionados-da-industria>



Transition measures focus on **enhancements in terms of efficiency and fuel substitution**. Energy efficiency is achieved thanks to the optimization of energy use in industrial processes and technological replacement towards more recent and efficient appliances and facilities.

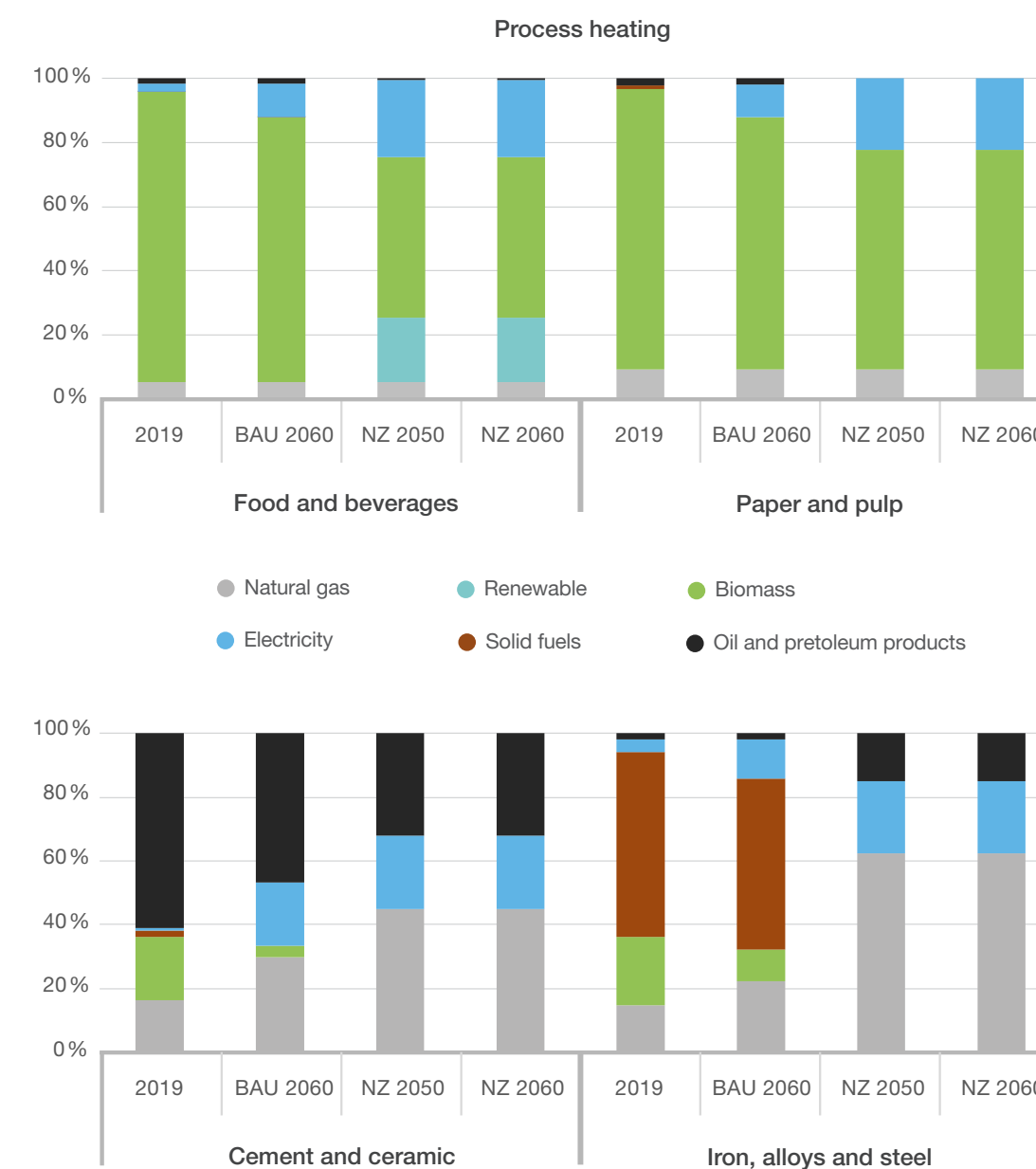
The substitution alternatives considered for Brazil are as follows:

- sustainable biomass use is considered in the subsectors with available biomass for their processes (for example, sugar cane products, black liquor, etc.) and the substitution of other sources (electricity, solar thermal, etc.) for firewood is also considered;
- a strong reduction in consumption (higher in the NZ scenarios) is considered for industrial subsections with high penetration of fossil fuels and substitution potential;
- natural gas and LPG fully replace fuel oil and diesel in the next decade and a gradual penetration of solar thermal energy for indirect heat is assumed in some sectors;
- replacement of coal is assumed in the NZ scenarios.

Graphic 48 shows the evolution of final consumption by fuel for the main uses in the different scenarios.

Graphic 48

► Industrial sector: evolution of main uses in the most relevant subsectors in industry, by scenario (%)

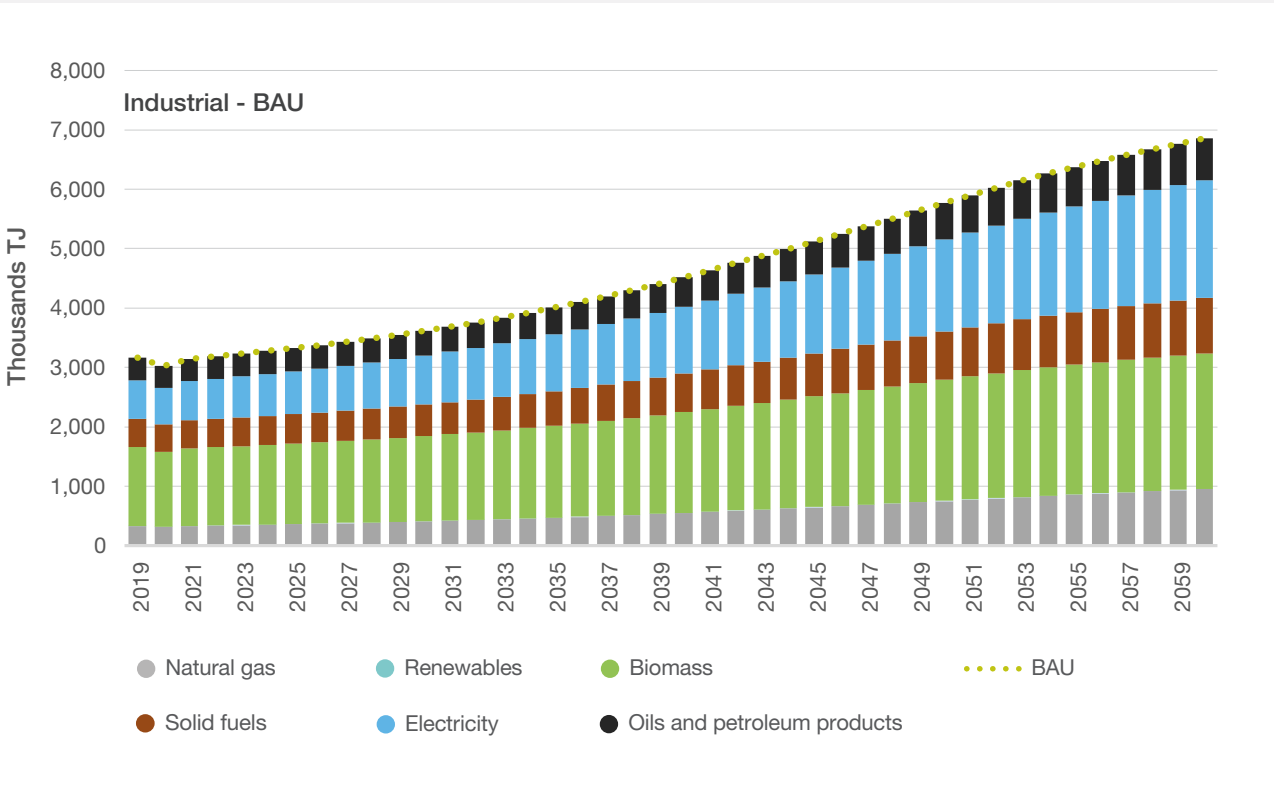


Source: Own preparation. The category oil and petroleum products includes LPG. The category biomass includes black liquor, *bagasse*, firewood, etc. The category renewables includes solar thermal.

Results

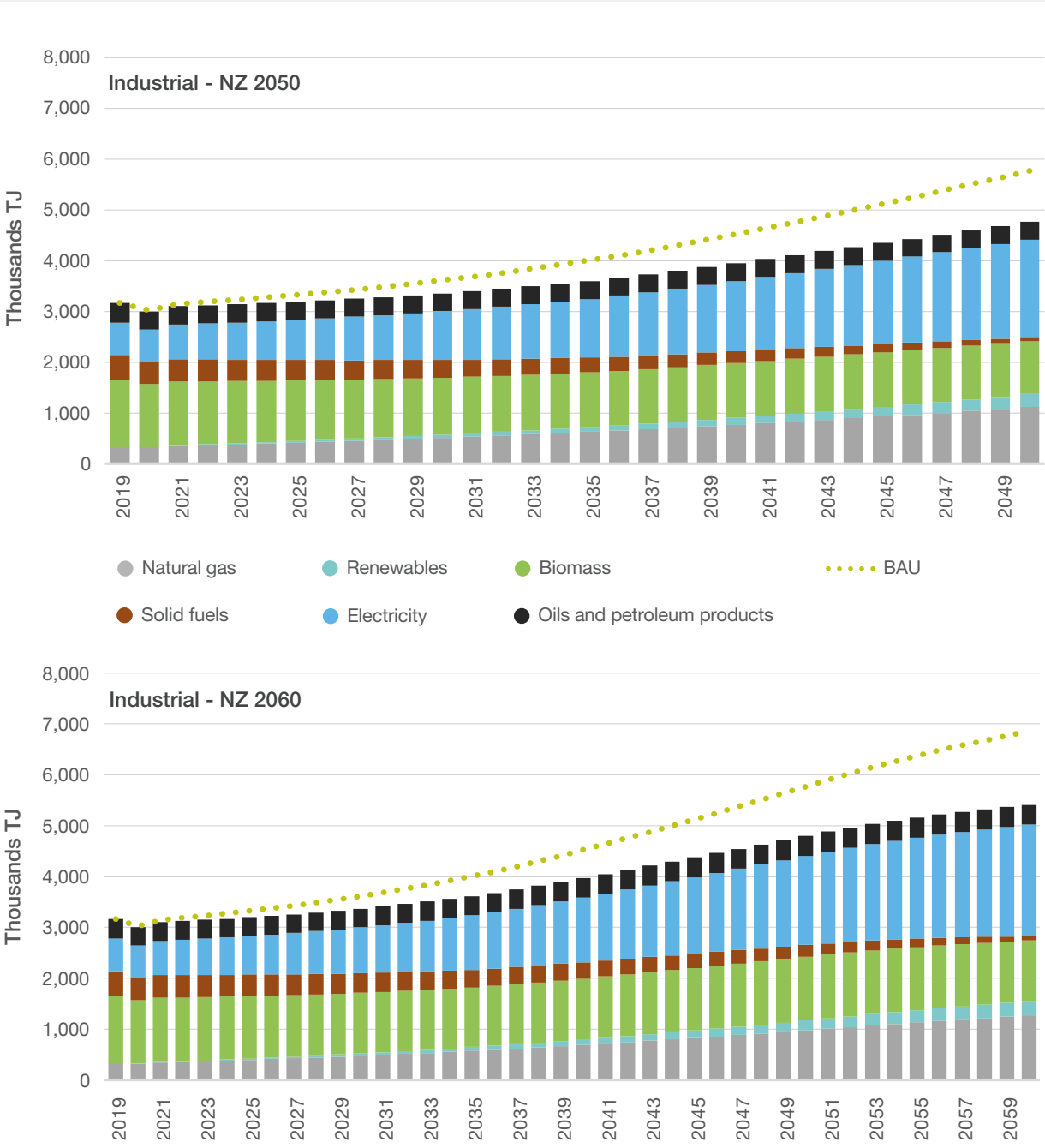
Even though an increase of 172 % in the GDP of the sector has been projected, the final energy demand in the BAU scenario will grow by 117 % due to fuel substitution and energy efficiency measures. The electrification of the final demand will grow from 21 % to 29 %.

Graphic 49 A ▶ Industrial sector: Final consumption by fuel and by scenario (10³ TJ)



Source: Own preparation.

Graphic 49 B ▶ Industrial sector: Final consumption by fuel and by scenario (10³ TJ)

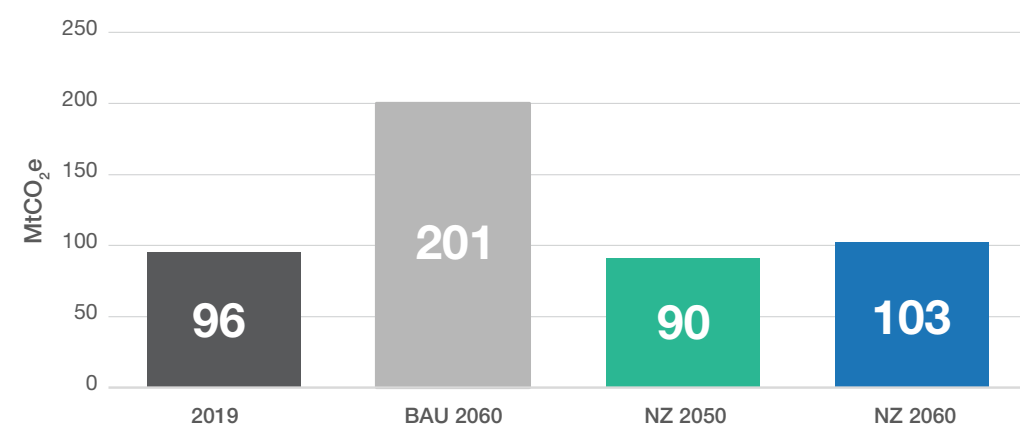


Source: Own preparation.

For the NZ scenarios, the electrification of the sector grows from 21 % to 40 % and mainly substitutes solid fuels and biomass. In addition, an increase in natural gas and renewable energy consumption can be observed.

Graphic 50

► Industrial sector: direct emissions by scenario (MtCO₂e)



Source: Own preparation.

CO₂e emissions grow in the BAU scenario (+108 %), but at a slower pace than the GDP. On the other hand, emissions in the NZ scenarios are similar to those of 2019, with -6 % variations (NZ 2050) or +7 % (NZ 2060), thanks to energy efficiency measures and fuel substitution. Carbon capture, which could be developed firstly for large scale industrial sites, should be added to these emissions in the NZ scenarios, as well as the proximity of storage.

The energy transition measures required to limit GHG emissions in the industrial sector relate to existing technologies worldwide but that are not always mature. It will be necessary to gradually adapt the industrial processes with the best technological option available over the years and, in turn, rethink processes in a comprehensive manner.

“Transition measures focus on efficiency improvements and fuel substitution. Energy efficiency is achieved through optimizing energy use in industrial processes and technological replacement towards newer and more efficient equipment and installations.”



Transportation sector

In Brazil, the transportation sector is the maximum energy consumer (35% in 2019) and greenhouse gas emitter. It mainly consumes liquid fuels (diesel, gasoline, etc.) and biofuels. Even though electric vehicle sales have increased worldwide in recent years, these vehicles account for a small portion in Brazil. Road transportation accounted for 93% of total final consumption in 2019, led by road passenger transportation (58%).

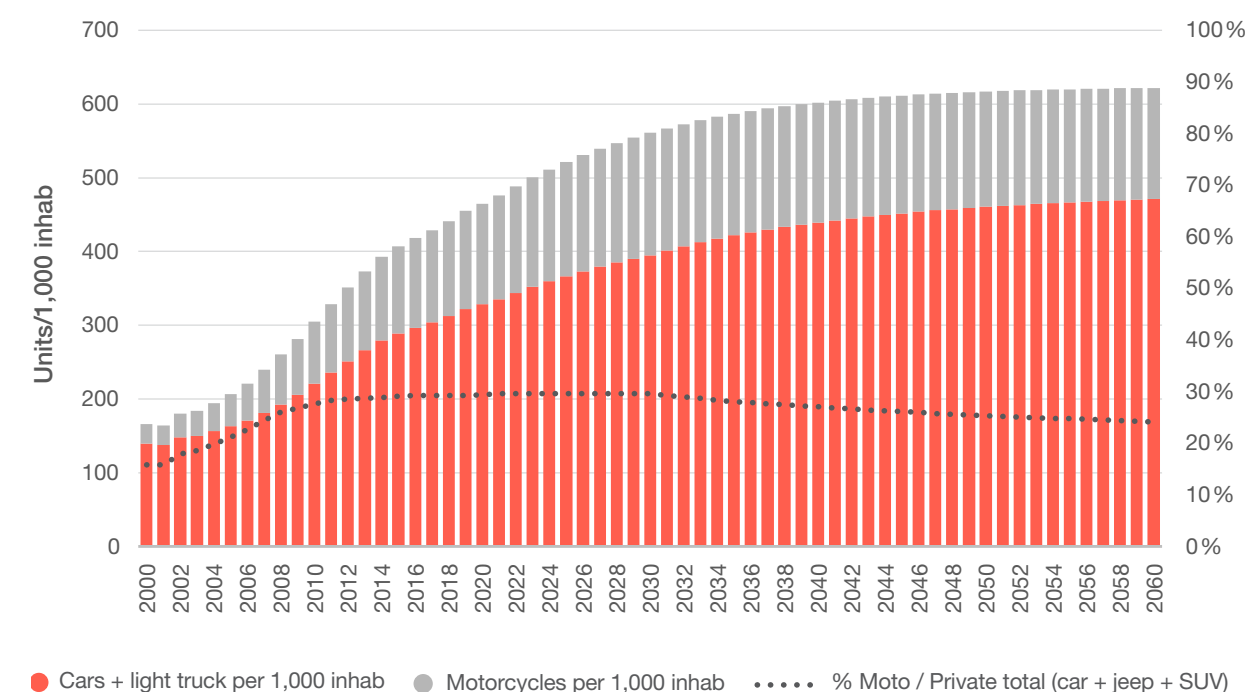
Road passenger transportation

Energy consumption by road transportation mainly depends on the evolution of the number of vehicles. A **significant increase in motorization** is expected in all the scenarios, in line with the growth in the standard of living and the recent trends in Brazil. This increase is initially evidenced with a rise in the number of motorcycles per 1,000 inhabitants. Starting from a certain GDP per capita level, the motorization increase begins to focus on cars⁴⁰. 622 vehicles per 1,000 inhabitants are projected for 2060, 24% of which are motorcycles and 76% are cars.

⁴⁰ Law, Hamid & Goh (2015), *The motorcycle to passenger car ownership ratio and economic growth: A cross-country analysis*.

Graphic 51

► Number of private vehicles per 1,000 inhabitants and share of motorcycles (%)



Source: Own preparation.

In this motorization context, measures will be required to promote energy transition in order to limit the increase in GHG emissions. The main measures that Brazil may contemplate are the use of **alternative green fuels** (for example, green diesel) and the **electrification** of the vehicle fleet, which reduces emissions and total consumption (a reduction of 75% to 80% in consumption by km compared to a standard vehicle). The use of hybrid vehicles also allows

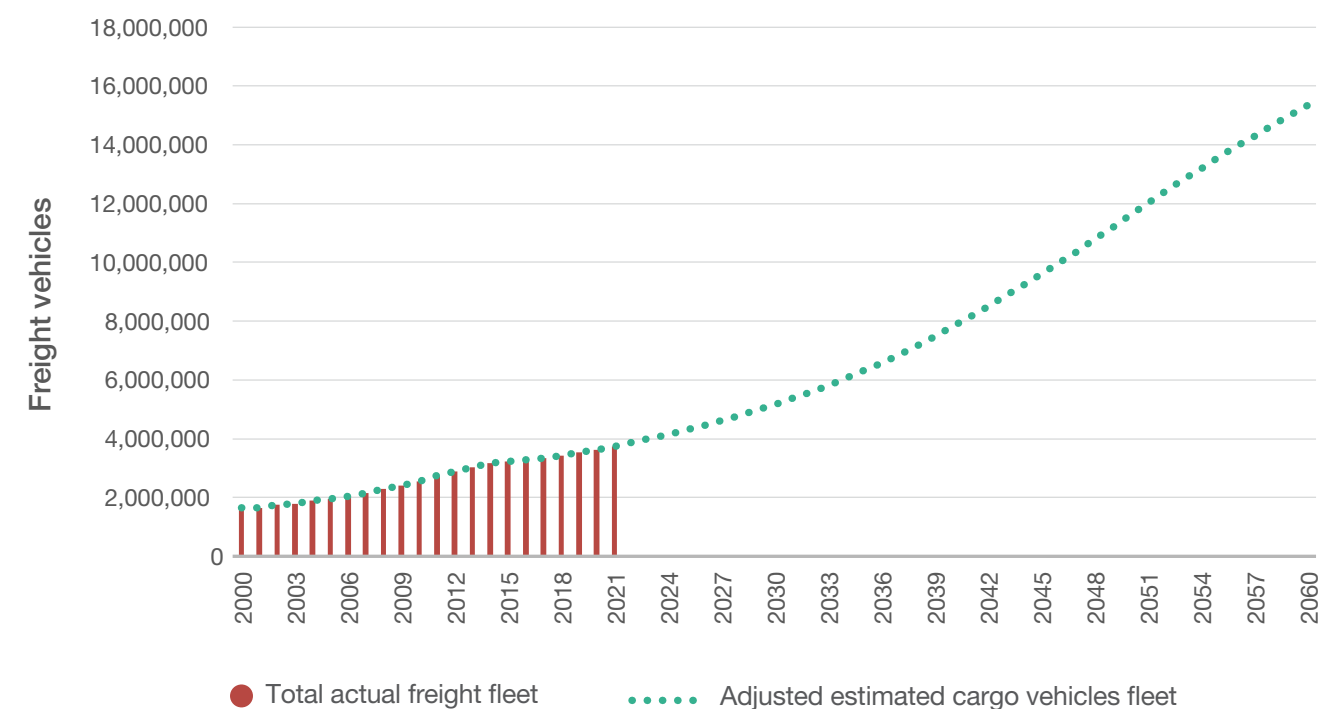
for a significant reduction in unitary energy consumption. In the case of cars, it is estimated that their share will be 20 % electric by 2060 and 20 % hybrid in the BAU scenario. Instead, in the NZ scenarios, a 40 % share of electric, 40 % of green diesel, and 20 % of hybrid must be reached by the end of the period to ensure a significant decrease in GHG emissions. In addition, the electrification of the motorcycle and public bus fleet is expected until 100 % of the fleet is reached in both scenarios within the planning horizon (see *Just Energy Transition / Projection Assumptions report*).

In line with historical observations, the average efficiency of the vehicle fleet is expected to improve due to technological enhancements and/or the reduction in vehicle weight.

Finally, a decrease in the average distances traveled is envisaged by vehicle (km/vehicle) as a result of the **digitalization** of society (remote work, etc.) and greater penetration of **public transportation** systems.

Road freight transportation

Road freight transportation grows with economic activity (GDP), taking into account the historical elasticity of income. In this context, sustained growth in the number of freight vehicles is expected in the period (3.7 % annual average), both for trucks (80.2 % of the total) and for truck tractors.

Graphic 52**► Total number of freight vehicles**

Source: Own preparation.

In order to limit the increase in GHG emissions, it will be necessary to promote energy transition fuels pursuant to the time horizon considered: in Brazil, where the biofuel industry is highly developed, no relevant inclusion of natural gas is expected; instead, a great development of synthetic fuels is envisaged. Moreover, the energy transition must be accompanied by vehicle **performance enhancement, logistics enhancement, and shift to railway**.

In 2060 and in the BAU scenario, the total number of trucks and truck tractors is expected to continue running on diesel. It is important to point out that diesel is

sold with a 10% addition of biodiesel. In the NZ scenarios, more transition efforts are required, with 50% electric trucks and 40% truck tractors in the long term. The remaining trucks run on green diesel while the rest of the truck tractors is divided between green diesel (20%) and hydrogen (30%).

Electrification appears as a relevant alternative for trucks and truck tractors, but a smaller electrical penetration is expected for truck tractors, as technological solutions for very heavy freight transportation are still being developed and electrification is not always a solution.

Hydrogen cells may also play an important role in this segment in the long term. In Brazil, green fuels are key to the transition in both segments.

Airmaritime/river, and railway transportation

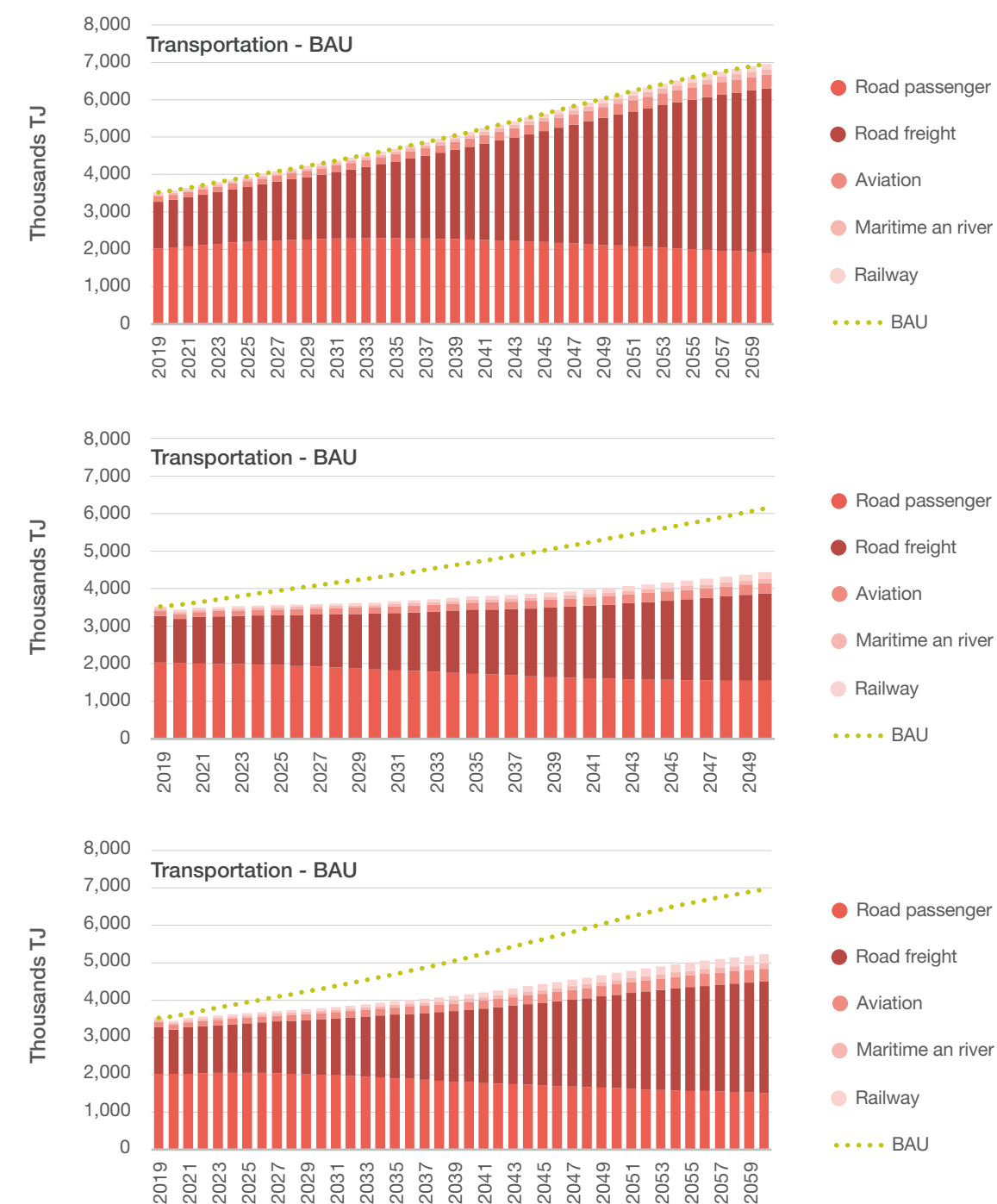
These sectors are more difficult to transform (in particular, the air and maritime/river subsectors are not electrifiable). Some of the energy transition options available are synthetic fuels and ammonia (H₂ byproducts), contemplated in the NZ scenarios.

Results

In the BAU scenario, energy consumption in the transportation sector doubles, driven by the freight sector. Oil and petroleum products consumption doubles, electricity grows considerably in the private and public passenger sector whereas synthetic fuels become relevant in the freight sector (included in the renewable energy category).

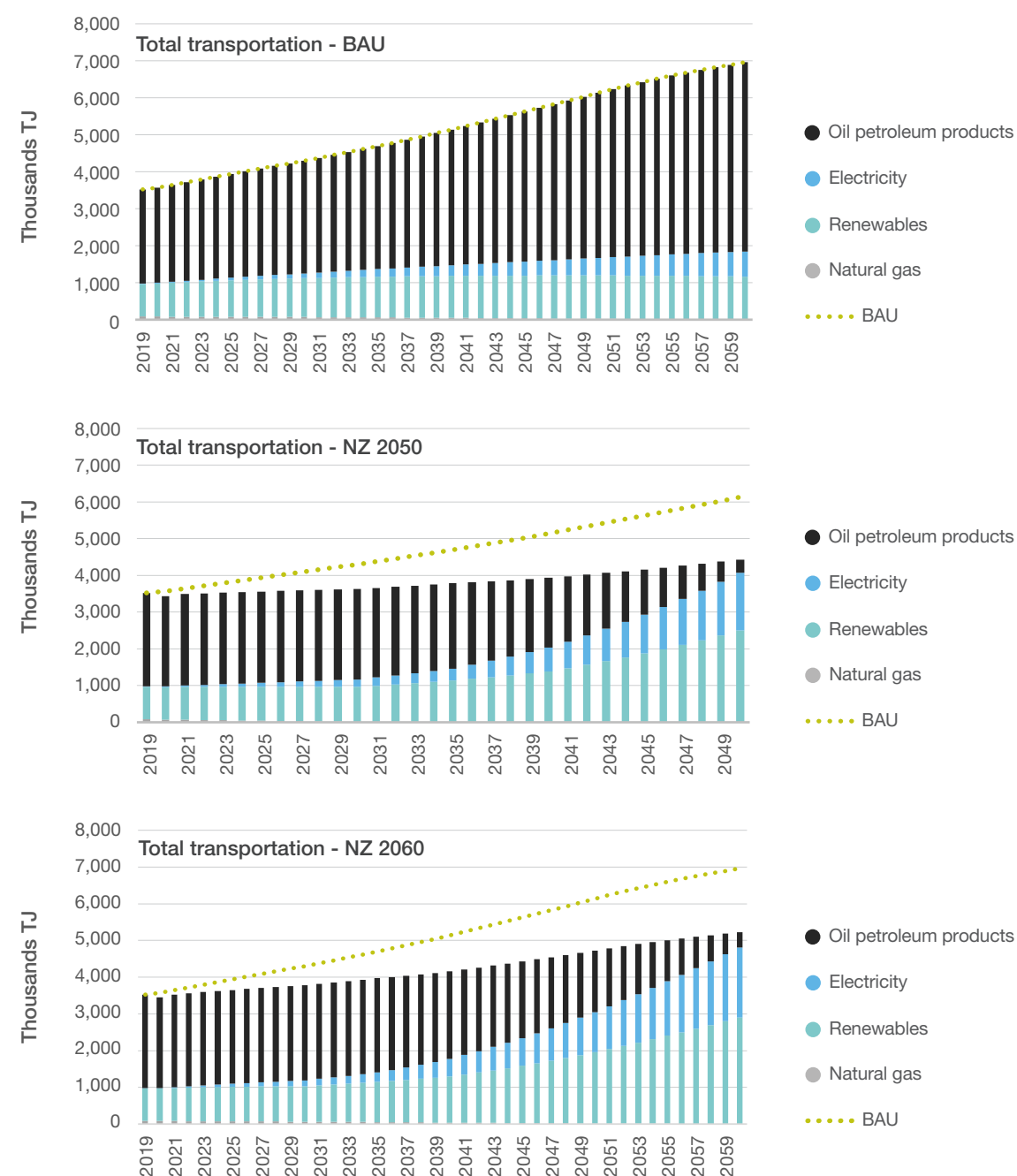
Graphic 53 A

► Transportation: final consumption by type/fuel and by scenario (10³ TJ)



Source: Own preparation. The renewables category includes bioethanol, biodiesel, green diesel, and synthetic fuels

Graphic 53 B

► Transportation: final consumption by type/fuel and by scenario (10³ TJ)

Source: Own preparation. The renewables category includes bioethanol, biodiesel, green diesel, and synthetic fuels



For the NZ 2050 scenario and in the analyzed period, energy demand in the transportation sector decreases compared to the BAU scenario due to the measures aiming to promote electric transportation and synthetic fuels.

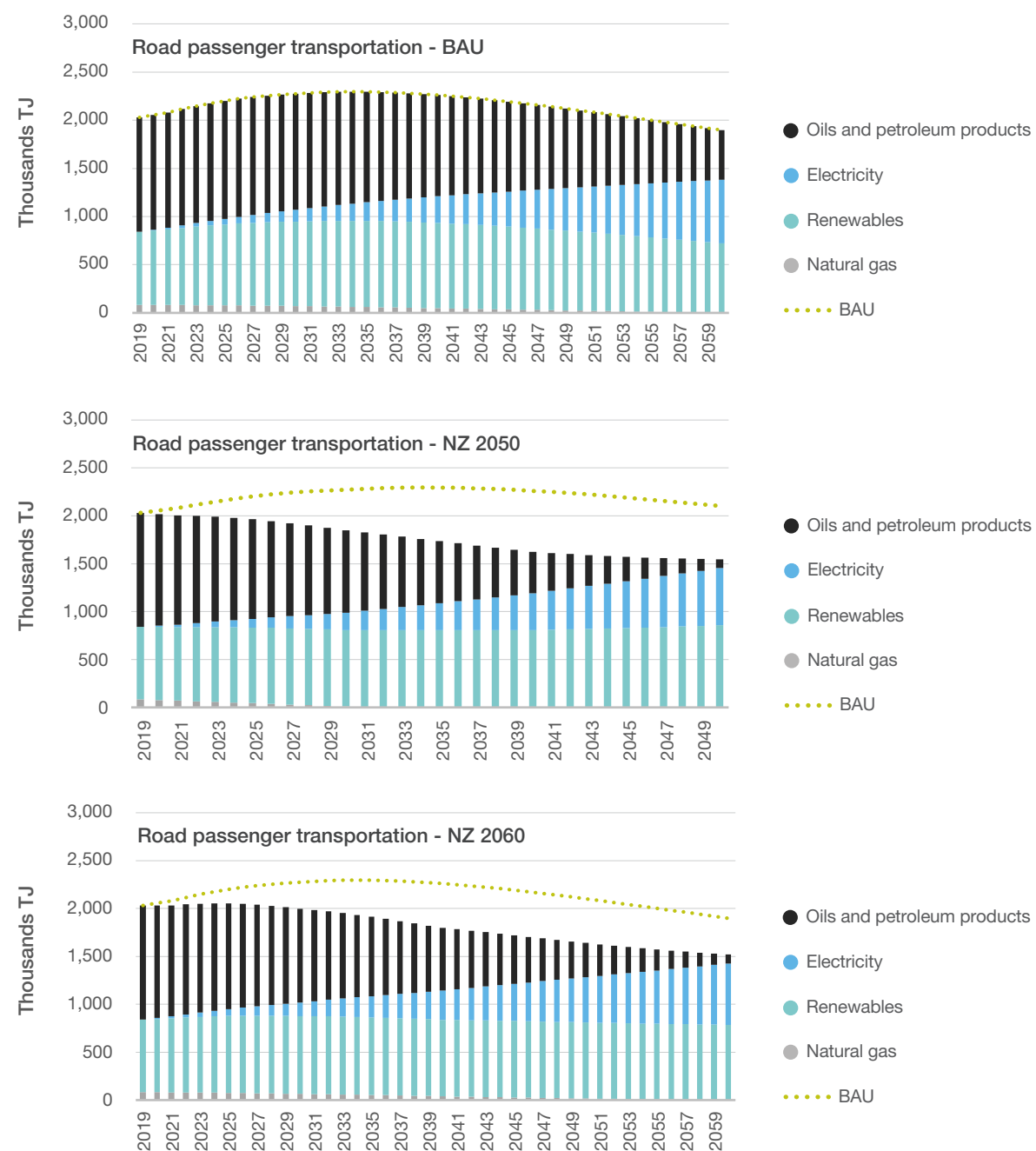
The proportion of electrification and synthetic fuels increases strongly in the passenger sector, with a segment using gasoline in hybrid vehicles.

As to freight transportation, electrification and synthetic fuels appear once again as solutions to trucks whereas hydrogen cells are added to truck tractors.

Bearing in mind these considerations, the passenger sector reduces its energy consumption considerably whereas the freight transportation sector grows slightly. The NZ 2060 scenario is very similar to the one mentioned above, with a slower implementation of the measures.

Graphic 54 A

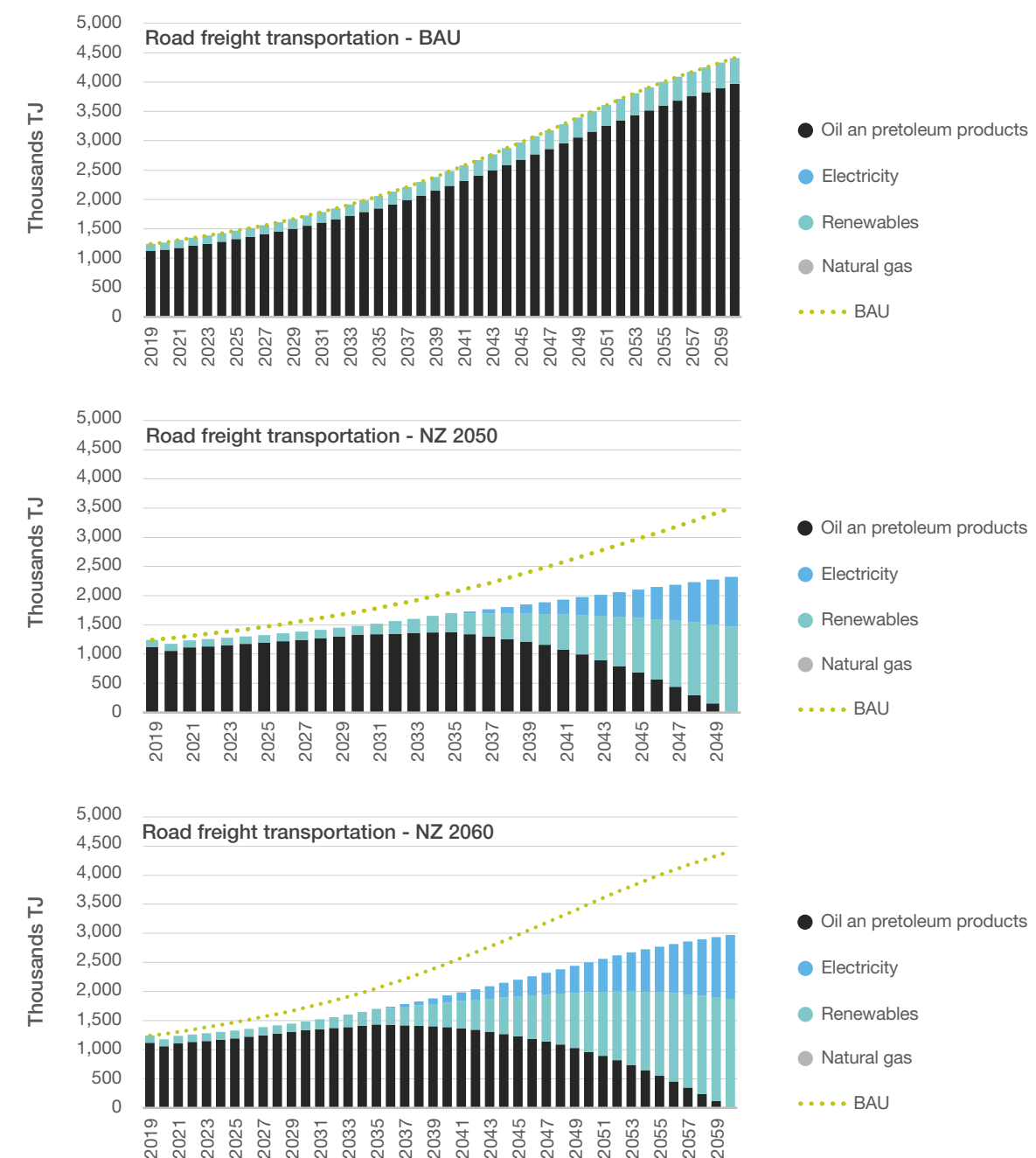
► Final consumption, road passenger and freight transportation, by fuel and by scenario (10³ TJ)



Source: Own preparation. The renewables category includes bioethanol, biodiesel, green diesel, and synthetic fuels.

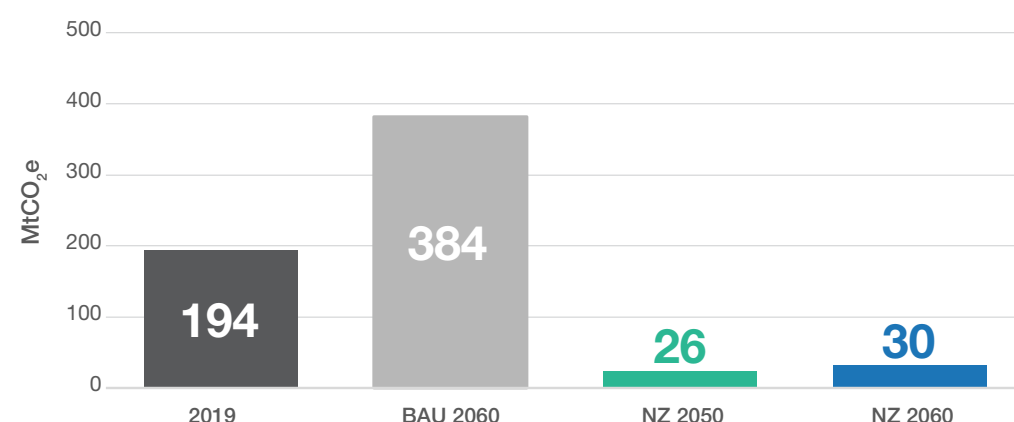
Graphic 54 B

► Final consumption, road passenger and freight transportation, by fuel and by scenario (10³ TJ)



Source: Own preparation. The renewables category includes bioethanol, biodiesel, green diesel, and synthetic fuels.

Graphic 55

► Transportation sector: direct emissions by scenario (MtCO₂e)

Source: Own preparation.

CO₂e emissions double in the BAU scenario, but at a slower pace than that of the vehicle fleet. On the other hand, emissions are considerably reduced in the NZ scenarios in the long term, thanks to fuel substitution (mainly electrification), energy efficiency, and behavior change measures.

The energy transition measures required to limit GHG emissions in the transportation sector relate to mature technologies for the light vehicle segment and developing ones for the other segments. Substantial changes are expected in all scenarios, given the strong motorization associated with economic growth.



Agricultural, fishing, mining, and construction sector

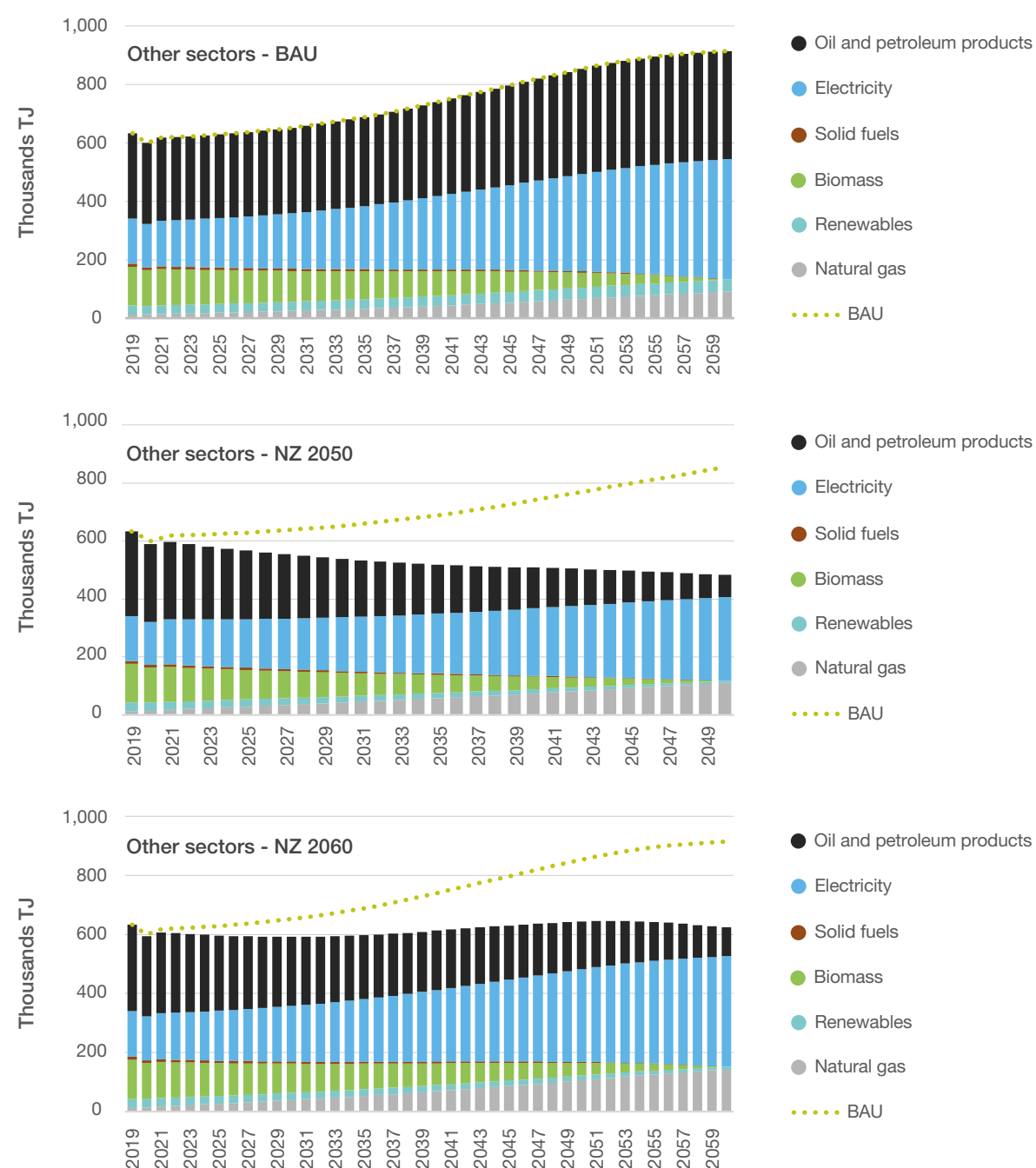
The agricultural, fishing, mining, and construction sector, along with the commercial, services, and public sector, are the sectors with the lowest energy consumption. The electrification of the sector is low (24 % in 2019). When analyzing the demand by subsector, we can see the importance of the agricultural sector, which accounts for 84 % of the total in Brazil, whereas the mining sector adds up 16 %⁴¹. Both subsectors show electrification potential. The mining sector has high potential to electrify the uses related to motive force or mining trucks, among other things, whereas strong electrification of agricultural machinery is expected in the long term, in line with the trends observed in this subsector. There is also potential to increase the energy efficiency of the equipment in both subsectors.

In the BAU scenario, the demand of this sector grows by around 0.9% annually (cumulative 44 % in the period), which causes the sector to electrify gradually, more in line with the historical trend. An enhancement of the energy intensity of the sector is observed (GDP growth is higher than that of demand).

⁴¹ No disaggregated information on fishing or construction is available.

Graphic 56

► Results of the agricultural, fishing, mining, and construction sector, by scenario (10³ TJ)

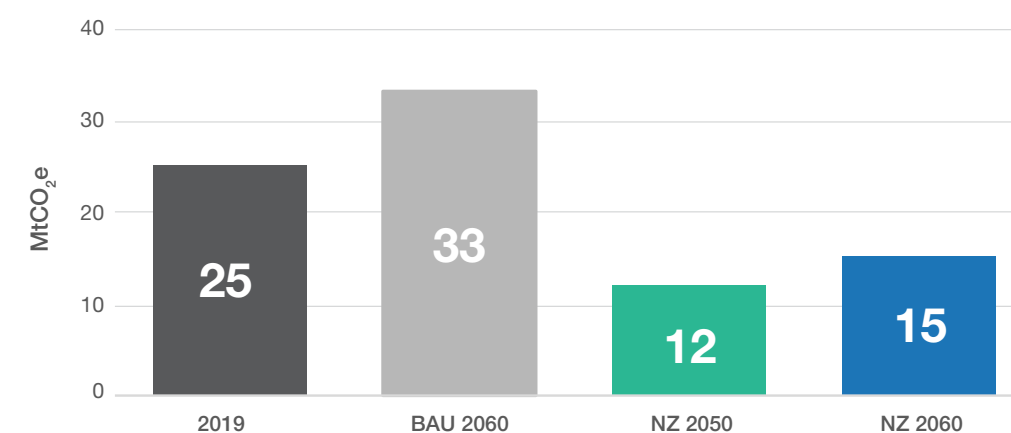


Source: Own preparation.

In the NZ scenarios, 60 % electrification is reached; natural gas and oil are the drivers for the rest. In the NZ 2060 scenario, consumption remains relatively constant in the analyzed period due to the combined effect of greater energy efficiency and the savings from the expected electrification of some uses. The NZ 2050 scenario shows a slight downward trend.

Graphic 57

► Agricultural, fishing, mining, and construction sector: direct emissions by scenario (MtCO₂e)



Source: Own preparation.

CO₂e emissions grow in a limited manner in the BAU scenario (+33 %), at a slower pace than the GDP. On the other hand, emissions fall by 52 % to 38 % in the NZ scenarios in the long term, thanks to the electrification of the sector and energy efficiency efforts.

The energy transition measures required to limit GHG emissions in the sector relate to technologies that are expected to be mature on a global basis in the next few years, such as the use of electric agricultural machinery and electric mining trucks.



Power sector

Brazil starts from quite a clean power generation matrix, mainly because of the large hydroelectric participation in national energy production. It has abundant natural resources, among which are its uranium and lithium reserves, as well as areas with high solar and wind potential.

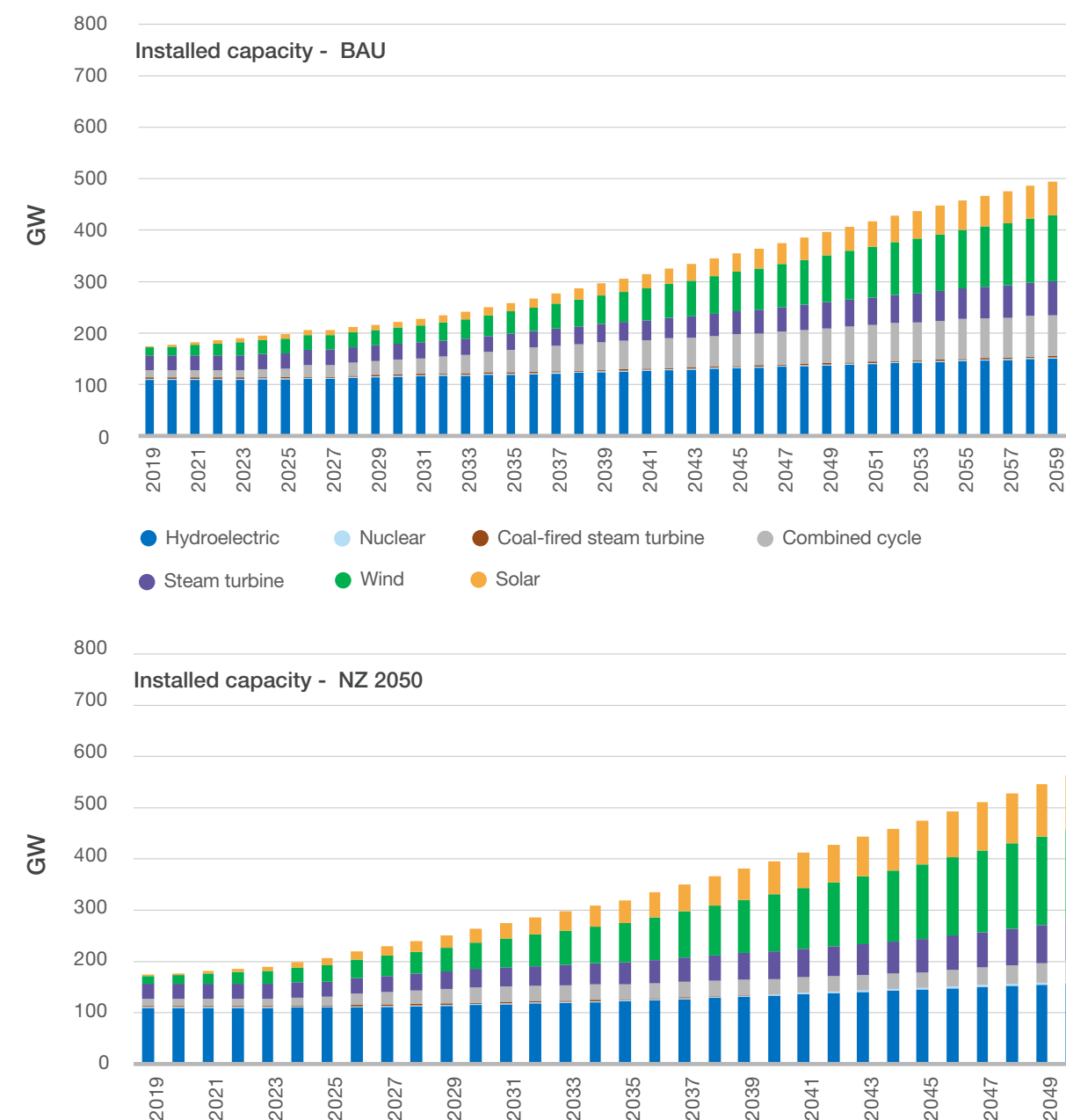
Growth is expected in all the scenarios presented, in solar and wind capacity and, to a lesser degree, in hydro and biomass. In the BAU scenario, the additional renewable capacity to be installed is 263 GW, 117 GW of which is wind and 66 GW, solar.

In the NZ scenarios, more renewable capacity needs to be installed to cover the greater power demand and ensure a significant reduction in GHG emissions. In the NZ 2050 scenario, the addition of 363 GW of renewable energy is expected, 165 GW of which will be wind and 104 GW, solar. In the NZ 2060 scenario, the installation of 449 GW of renewable energy is required, 195 GW of which will be wind and 121 GW, solar.

In all the scenarios, the installation of new thermal plants is also required, particularly combined cycles (CCGT), which play a backup role especially in dry hydrology situations as well as batteries and smart grids that help to achieve a better integration of renewable power in the grid. Biomass plants also provide firmness to the system.

Graphic 58 A

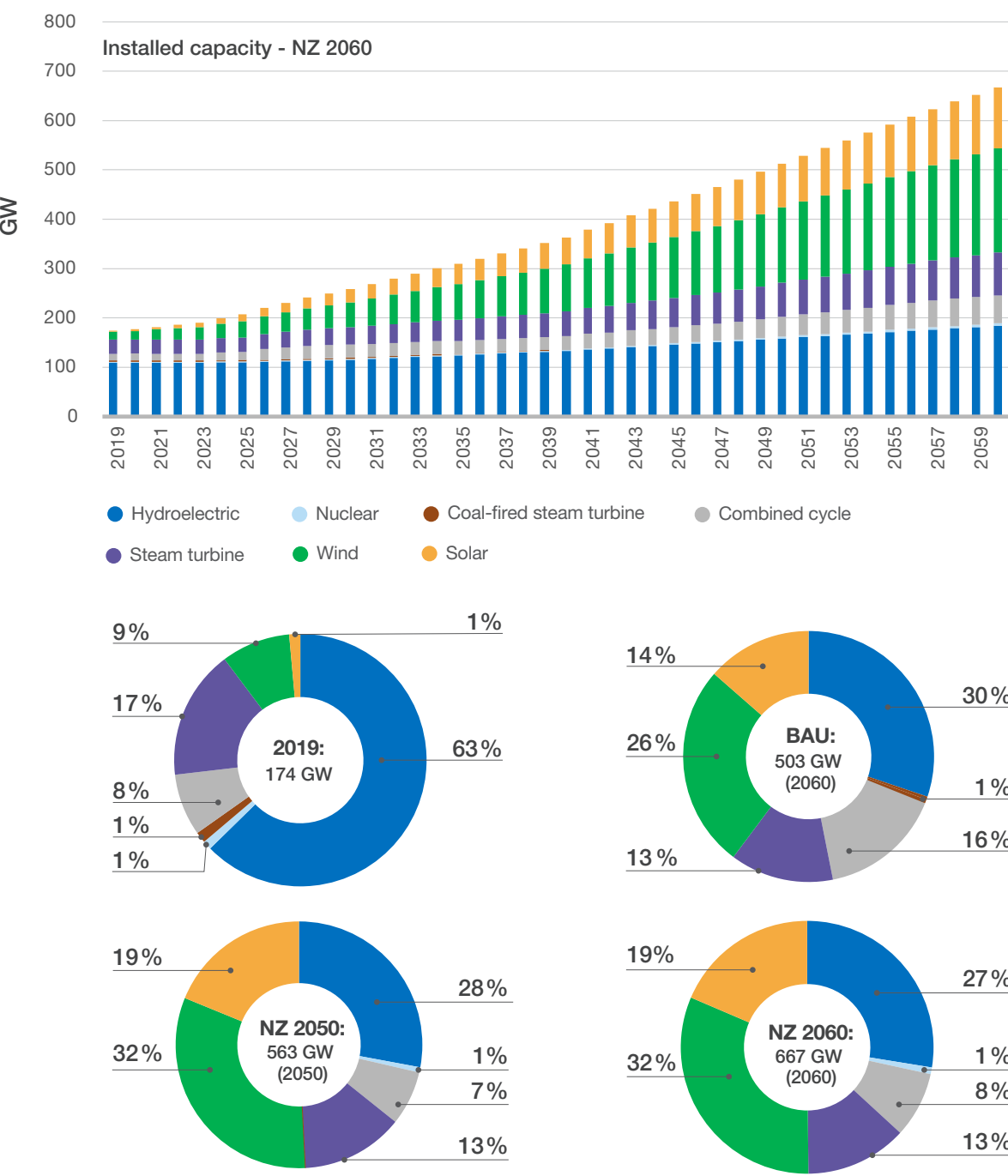
► Installed capacity projection by source and by scenario (GW)



Source: Own preparation. The turbo steam category includes biomass plants.

Graphic 58 B

► Installed capacity projection by source and by scenario (GW)



Source: Own preparation. The turbo steam category includes biomass plants.

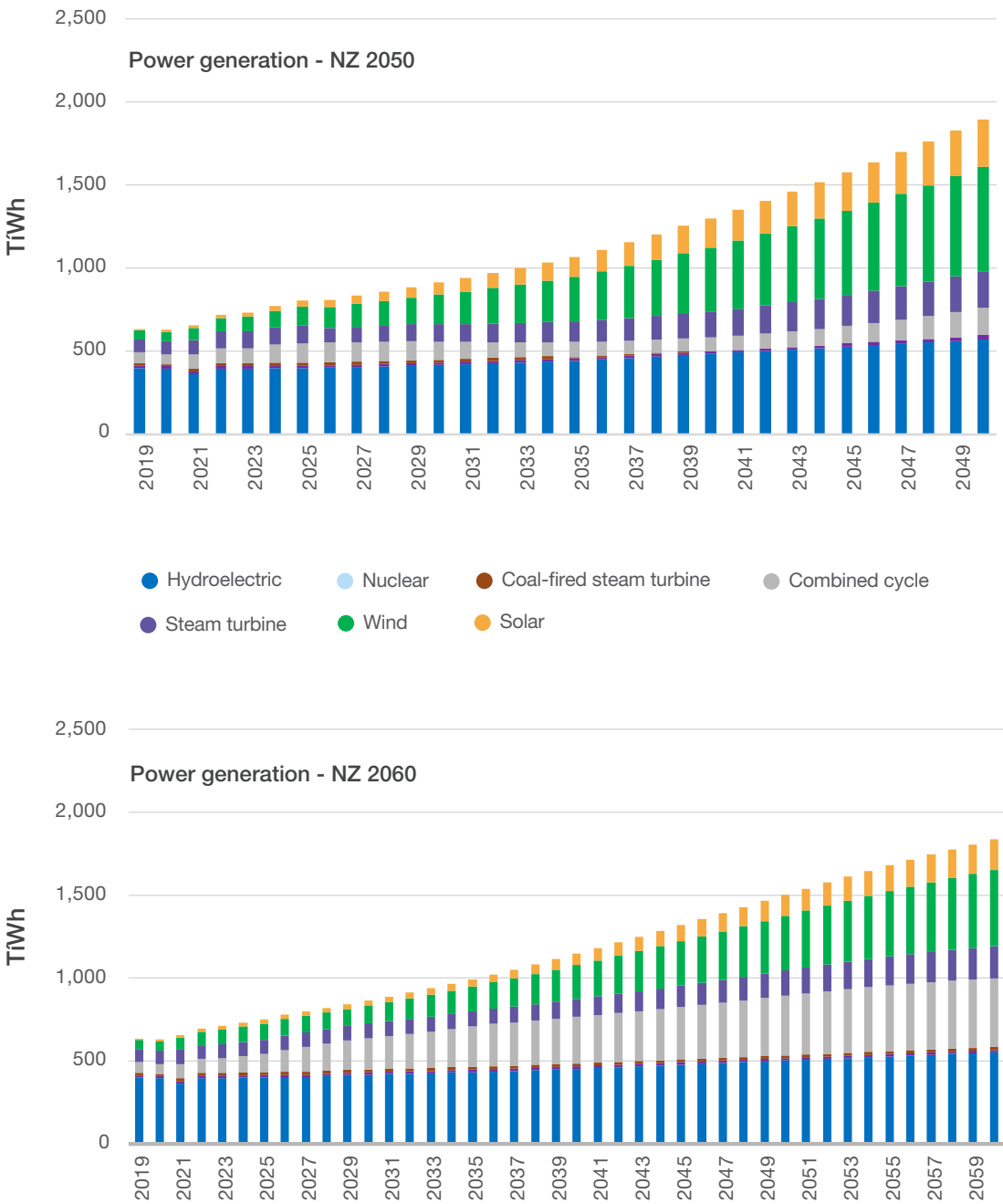
In all the scenarios, a much higher growth of the generation fleet than the growth observed in the last 20 years is required.

In the NZ scenarios, generation becomes more renewable and exceeds 85%. Hydroelectric production continuous playing an important role in all the scenarios, although lower than its current relevance.



Graphic 59 A

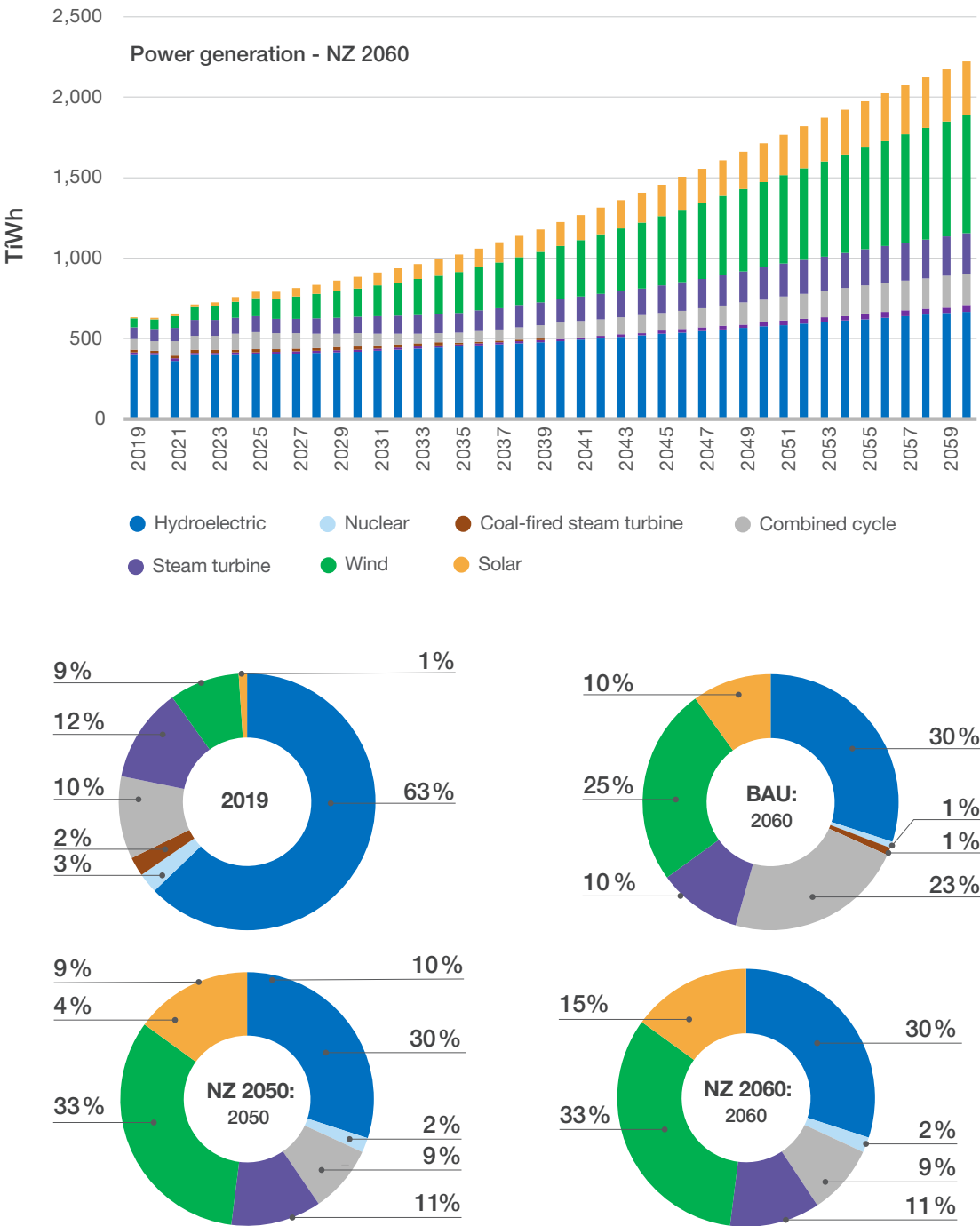
► Projection of power generation by source and by scenario (TWh)



Source: Own preparation. The turbo steam category includes biomass plants.

Graphic 59 B

► Projection of power generation by source and by scenario (TWh)



Source: Own preparation. The turbo steam category includes biomass plants.

3. Energy transition financing

Chapter 3 presents total investment related to each scenario, as a consequence of all the just energy transition measures described above.

The main items requiring investment are shown below, including a brief description of the assumptions used to derive the amounts presented in the following sections:

1. power generation (and the need for additional power grids as well as flexibility measures);
2. electrification of the road transportation sector (investment in electric vehicles and charging stations);
3. energy efficiency measures and electrification of subsectors and end uses in the other sectors;
4. use of technologies of the carbon capture and storage type.



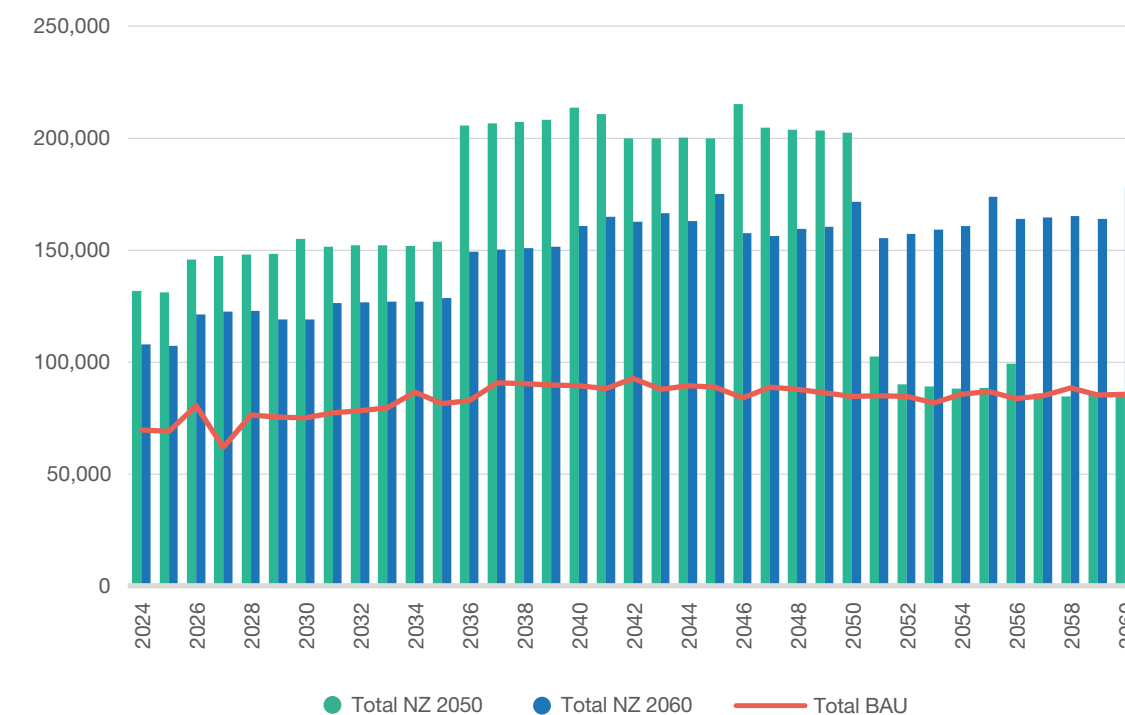
Total investment

Investment is calculated on an annual basis and the total investment amount is applied as of the first year in which it is possible to reduce CO₂ emissions. This is a simplification of the model, as large investment must take place in advance, one to five years before, depending on construction times or the implementation of the investment considered (hydro plants, for example, are characterized by a construction period of several years).

Graphics 60 and 61 show the estimated annual investment by scenario, in millions of USD and as a percentage of the GDP, according to the guidelines and the assumptions described in item 5 of the chapter “Investment”, “Methodological section and assumptions” in the *Just Energy Transition / Projection assumptions report*.

Graphic 60

► Estimated annual investment (millions of USD)



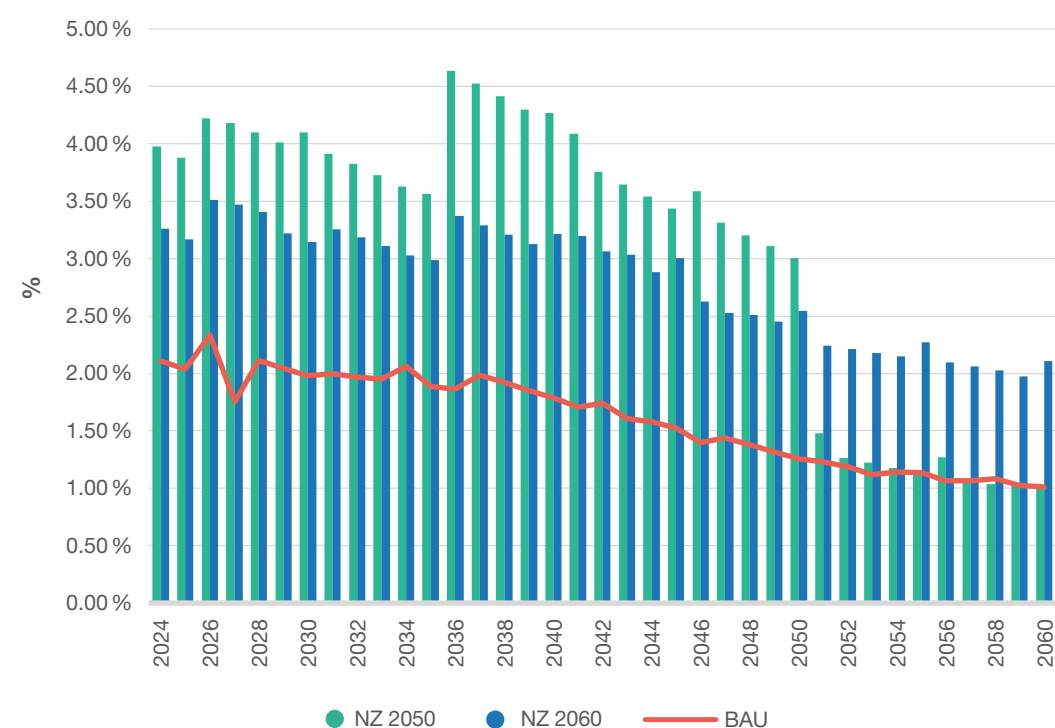
Source: Own preparation.

The cumulative investment in the period 2024-2060 is approximately USD 3,080,000 million for the BAU scenario, USD 5,700,000 million for the NZ 2050 scenario, and USD 5,490,000 million for the NZ 2060 scenario.

By year, variable investment is observed over the whole period. The maximum annual investment in the BAU scenario is approximately USD 93,000 million whereas it amounts to around USD 215,000 million in the NZ 2050 scenario and USD 180,000 million in the NZ 2060 scenario, which implies almost doubling annual investment in the NZ scenarios. As from 2051, investment in the NZ 2050 scenario is lower than in previous years and similar to the BAU scenario.

Graphic 61

► Total estimated annual investment in GDP % (%)



Source: Own preparation.

The investment effort, measured in GDP percentage, amounts to 2.3 % in 2026 in the BAU scenario, 4.6 % in 2036 in the NZ 2050 scenario, and 3.5 % in 2027 in the NZ 2060 scenario. Investment in GDP % shows a downward trend due to the increase in GDP, which is more significant than the increase in investment.

Investment by type is presented in the following chapters.



Power sector

Investment in the power sector includes:

- investment in new power generation plants, in line with the generation expansion presented in the “Power sector” subsection, “Results and assumptions by sector” section, by using capital expenditure (CAPEX) prices projected by the National Renewable Energy Institute (NREL) to start up new facilities⁴²;
- investment in infrastructure and flexibility, including the concepts of smart grids, batteries, and modernization of old hydro plants, estimated at 15 % additional to investment in power generation⁴³. This investment is key to facilitate the integration of intermittent power generation in the electric dispatch;
- investment in transmission and distribution grids, which accompanies the very significant growth in power demand as a result of the projected economic growth and the electrification of end uses, based on a 16% share for transmission and 44 % for distribution⁴⁴;

⁴² Table 9, *Just Energy Transitions/ Projection Assumptions*.

⁴³ This generic amount is in line with the global investment amounts estimated by the International Renewable Energy Agency (IRENA) in its report *World energy transitions outlook 2023: 1.5 °C pathway*.

⁴⁴ See again the *Just Energy Transition / Projection Assumptions report*.

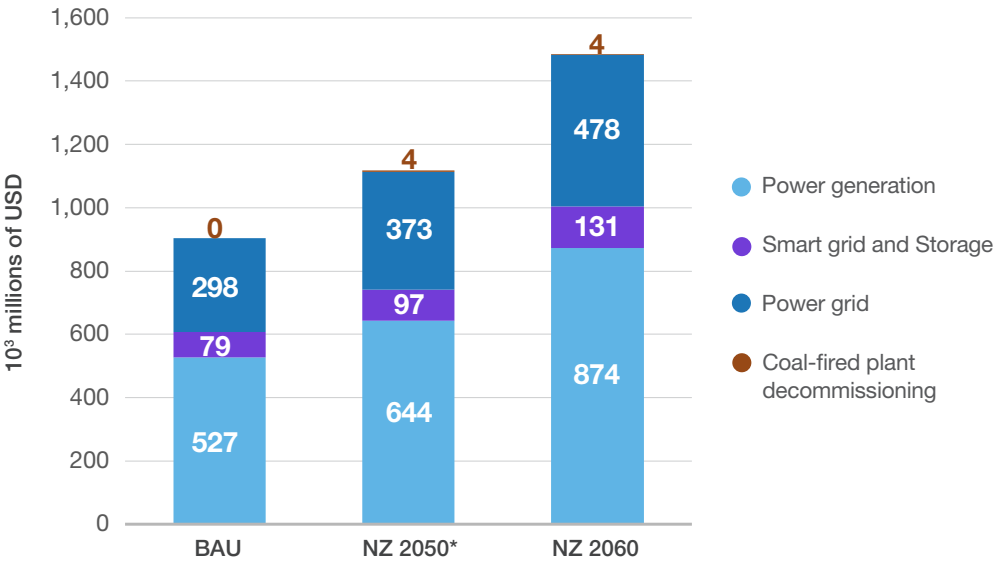
- the estimated investment required for the phase-out of coal-fired plants before the end of their useful life (stranded assets or sunk assets). It was estimated by using 50 % of the CAPEX of a new coal-fired thermal plant published by the NREL⁴⁵.

It is important to point out that, even though the addition of new power generation capacity grows in the long term, the unitary costs of some of the renewable technologies are expected to fall gradually over time as a result of the technological enhancements and the returns to scale originating in the sector's growth.

The cumulative investment in the transition period is presented below for each scenario.

Graphic 62

► Power sector: cumulative investment in the transition period (thousands of millions USD)



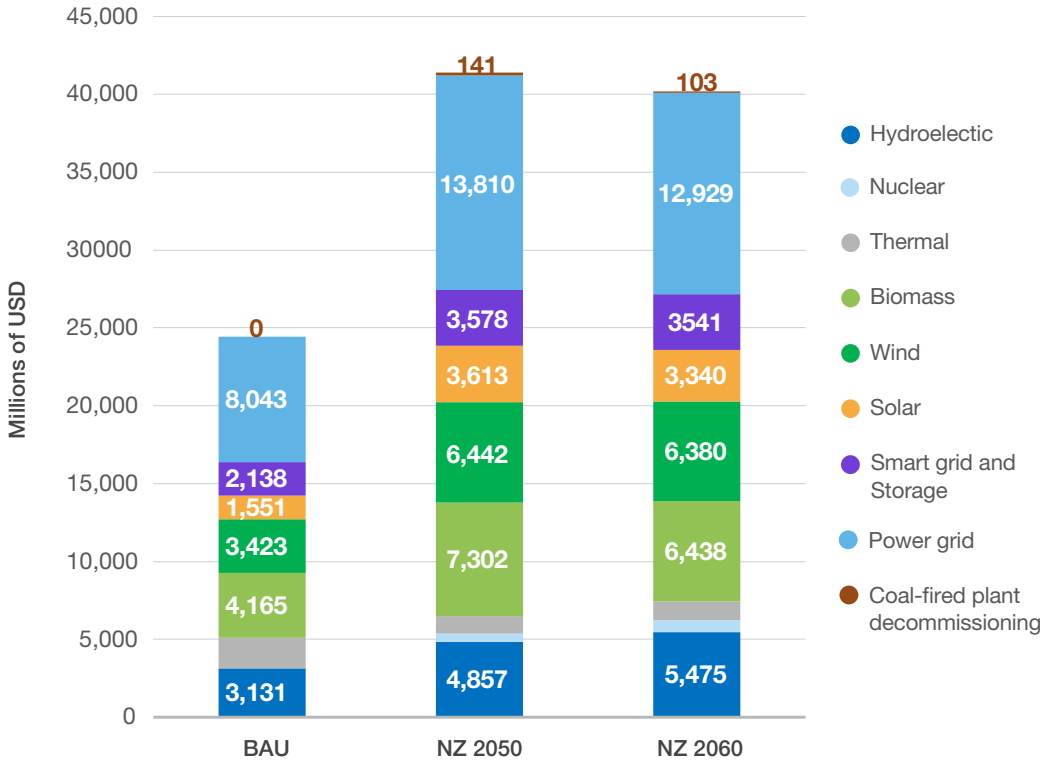
Source: Own preparation. *Investment in the NZ 2050 scenario refers to the period 2024-2050, whereas it refers to the period 2024-2060 in the other scenarios.

⁴⁵ Table 10, *Just Energy Transition/ Projection Assumptions*

The cumulative investment related to the power sector is approximately USD 900,000 million in the period 2024-2060 for the BAU scenario; USD 1,120,000 million in the period 2024-2050 for the NZ 2050 scenario; and USD 1,490,000 million in the period 2024-2060 for the NZ 2060 scenario. The investment related to power generation, smart lines, and storage adds up to around two thirds of this, whereas investment in the power grid is about one third.

Graphic 63

► Power sector: annual investment by type (millions of USD/year)



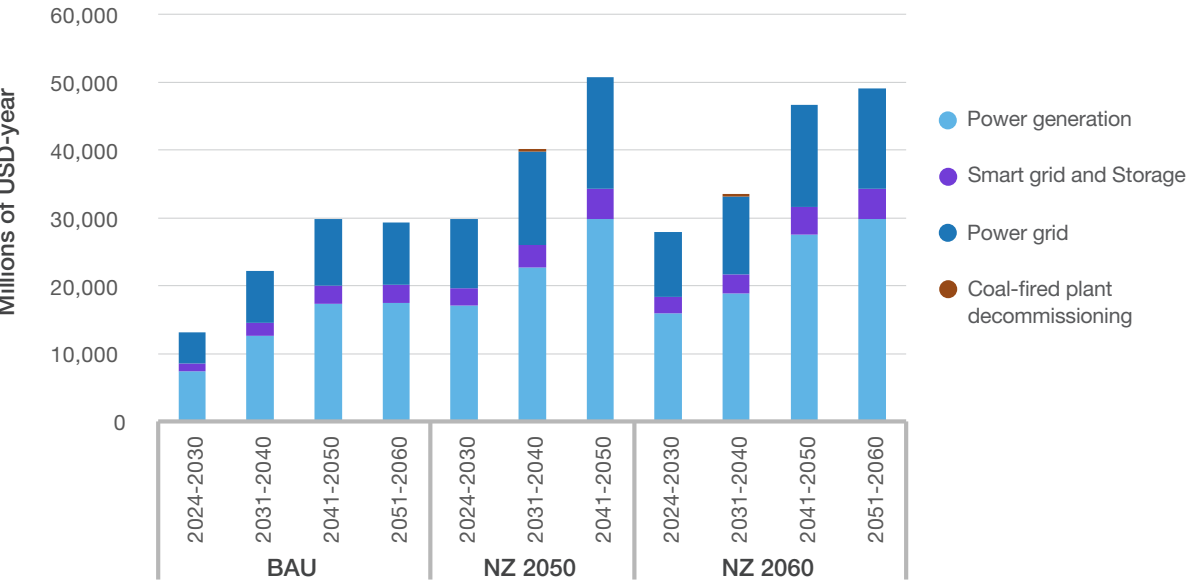
Source: Own preparation.

By year (average value), the required investment is higher in the NZ 2050 scenario, with USD 41,381 million. The NZ 2060 scenario continues with USD 40,182 million and, finally, the BAU scenario with USD 24,436 million.

By technology, the largest investment in power generation is in biomass, wind, hydro, and solar. Even though the cumulative biomass or hydro capacity to be installed is lower than the wind or solar capacity, the unitary CAPEX of the former is six times higher, depending on the technology and the year considered.

Graphic 64

► Power sector: annual investment by period (millions of USD/year)



Source: Own preparation.

By time interval, the need for investment grows over time. This need for investment occurs in a context of demand growth as a result of the strong economic development and the electrification of end uses.



Final uses

From the point of view of investment related to energy end uses, it is possible to mention the following:

- road transportation sector, in which the total investment⁴⁶ in electric vehicles (EV) and hybrid vehicles (VH) is estimated on the basis of the unitary CAPEX projected by the International Renewable Energy Agency (IRENA), and on the number of new vehicles, as well as the charging stations, based on an estimation of the number of stations required and a unitary cost;
- energy efficiency measures, electrification, use of alternative fuels (hydrogen and its byproducts, among others), and behavior changes with an impact on the end uses sectors, except for road transportation and carbon capture, use, and storage technology (CCUS). A proxy⁴⁷ was considered by final consumer sector, equal to a unitary CAPEX expressed in USD/ton of avoided emissions, times the savings in emissions in each sector;
- carbon capture and storage (CCS), which is presented as an option for very polluting industrial sectors with higher CO2 emissions and which are difficult to transform.

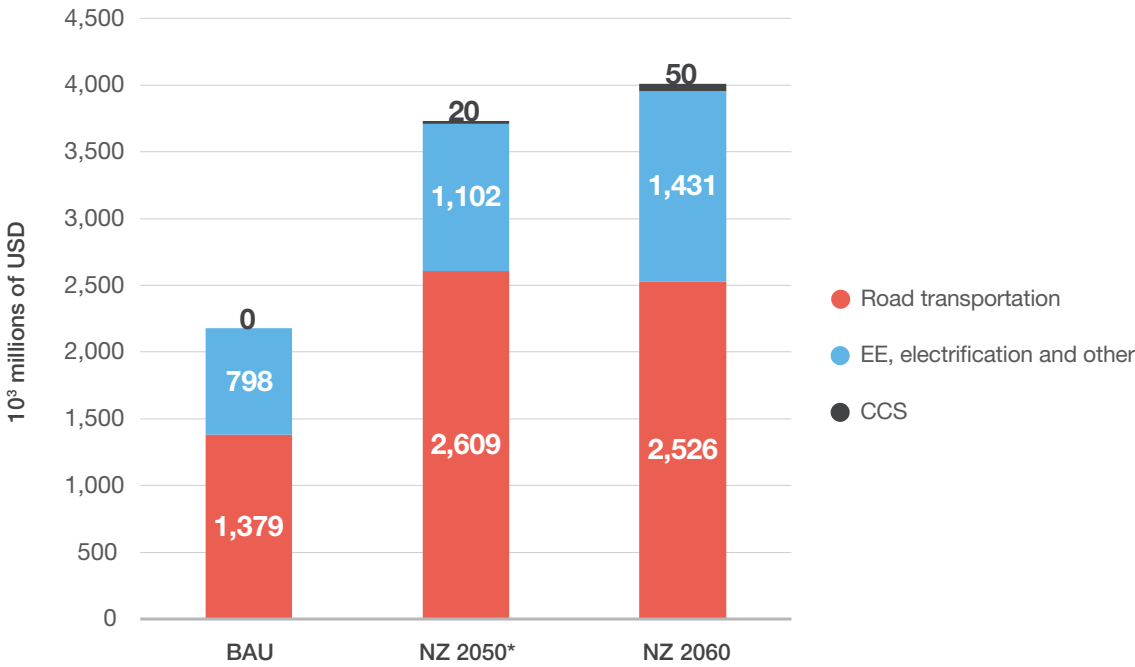
Graphic 65 presents cumulative investment in the transition period for each scenario.

⁴⁶ This investment does not consider the necessary replacement of EVs at the end of their lives or the anticipated replacement of batteries.

⁴⁷ This This equivalent CAPEX by sector was estimated on the basis of a study conducted by the Climate Change Committee (CCC).

Graphic 65

► End uses: cumulative investment in the transition period (thousands of millions of USD)



Source: Own preparation. *Investment in the NZ 2050 scenario refers to the period 2024-2050, whereas it refers to the period 2024-2060 in the rest of the scenarios.

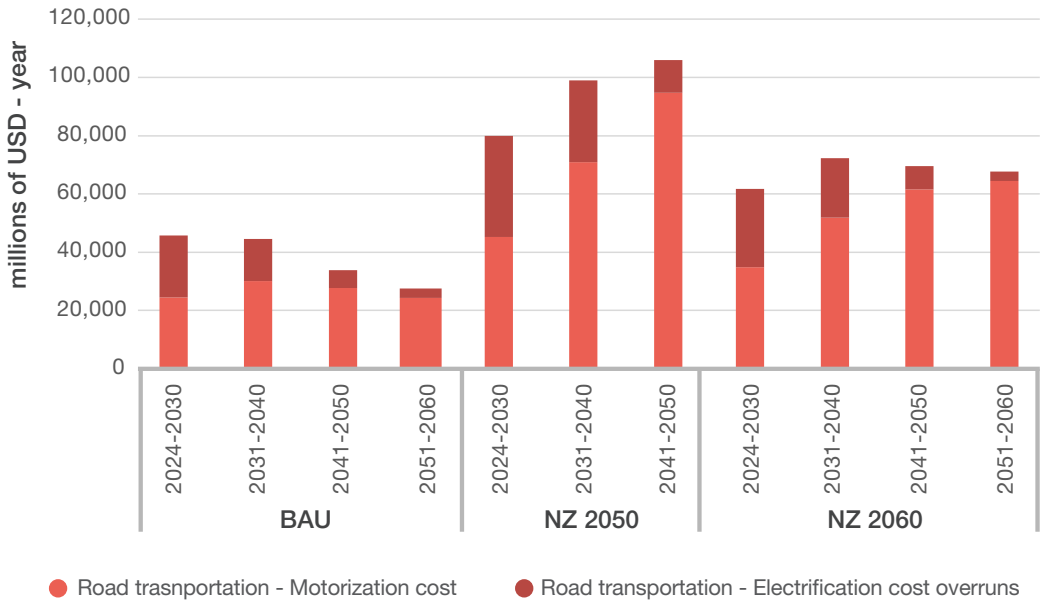
The cumulative investment related to end uses is approximately USD 2,180,000 million in the period 2024-2060 for the BAU scenario; USD 3,7300,000 million in the period 2024-2050 for the NZ 2050 scenario; and USD 4,010,000 million for the period 2024-2060 for the NZ 2060 scenario. The investment related to road transportation amounts to approximately 60% and 70% of this investment if total investment related to EVs and HVs required for this segment is contemplated. If only the cost overruns related to this investment (calculated in a simplified way as the difference in cost between buying EVs, HVs, and investing in charging stations, and buying a vehicle that runs on fossil fuel) are considered, road transportation adds up less than half the investment related

to end uses (see Graphics 66 and 67, dark red segment related to electrification cost overruns).

Graphic 66 illustrates the difference between both concepts for road transportation.

Graphic 66

► Road transportation: annual investment by period (millions of USD/year)



Source: Own preparation.

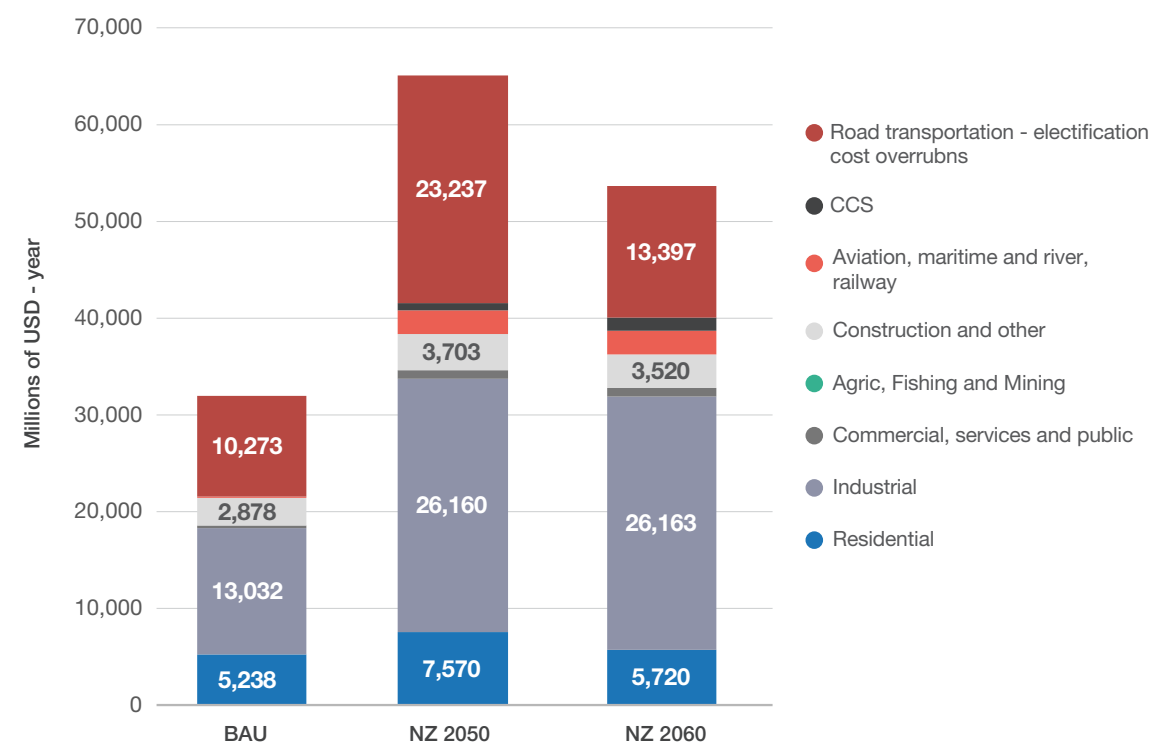
It is important to point out that all the analyzed scenarios present a future reduction in the cost of electric vehicles of about 60% during the period. In addition, the scenarios contemplate an increase in motorization, evidenced through the possession of vehicles per 1,000 inhabitants, as indicated in the assumptions by sector. The need for investment includes two major effects: access to mobility and mobility electrification. The latter represents lower cost overruns in the long term due to the competitiveness of EVs against vehicles running on fossil fuels in almost all the vehicle segments.

It is important to remember that, for private passenger transportation, an increase in the possession of cars and a reduction in the annual unitary use of cars were estimated. Other schemes may also exist, such as shared autonomous vehicles, which could partially reduce the total number of vehicles and their associated investment.

Graphic 67 presents investment by type, without considering the cost of motorization.

Graphic 67

► End uses: annual investment by type (millions of USD/year)



Source: Own preparation. This graphic does not consider the cost of motorization.

By year (average value), the investment required is higher in the NZ 2050 scenario, since the transformation of the sector should be achieved fast. By technology, the investment with more participation is that of the industrial sector, followed by road transportation, and the residential sector.

“The largest investment volumes in the transition scenarios will be allocated to the following areas: power generation and grids, energy efficiency, and the electrification of road transport and other end uses.”

4. Main transitions indicators

Table 12 presents some of the indicators of the just energy transition.

These indicators illustrate the increase in the penetration of renewable energy in final consumption and power generation, energy intensity enhancements in the sector, the use of energy per capita, and the penetration of electric mobility, among other aspects related to the just energy transition.

Table 12 ► Indicators by time horizon and scenario

Number	Potential indicators	Unit	2019	BAU 2060	NZ 2050	NZ 2060
E-2.1	Share of renewable energy in total final energy consumption	%	48%	38%	66%	67%
	Share of renewable energy in power generation	%	82%	65%	78%	78%
E-2.1bis	Installed renewable energy generation capacity	GW	144	352	444	518
E-2.2	Energy intensity measured on the basis of primary energy and GDP	TJ/ MUSD PPP 2017	3.9	2.3	1.9	1.8
E-2.3	Efficiency of energy conversion	%	43%	50%	50%	50%
	Efficiency of energy distribution	%	79%	79%	79%	79%
E-2.4	Energy intensity by sector (industrial)	TJ/ MUSD PPP 2017	8.4	6.7	5.8	5.3
	(Agricultural, fishing, and mining)		2.7	1.4	1.0	1.0
	(Services and commercial)		0.3	0.2	0.1	0.1
	(Transportation)		1.1	0.8	0.7	0.6
E-2.5	Energy intensity in the residential sector	TJ/ 1,000 inhabitants	5.3	6.7	5.4	5.8
E-2.6	Penetration of electricity in the transportation sector	%	0.2%	10%	35%	37%
	Penetration of natural gas in the transportation sector	%	2%	0%	0%	0%
E-2.7	Penetration of hydrogen in the transportation sector	%	0%	0%	2%	2%
	Penetration of green fuels in the transportation sector	%	25%	17%	52%	50%
S-1.4	Energy use per capita	TJ/ 1,000 inhabitants	42.7	84.0	57.5	66.4
A-1.1	GHG emissions per year, energy*	MtCO ₂ e	368	879	239	241

Source: Own elaboration. *Does not include fugitive emissions.



1. The environment for the transition



Projections

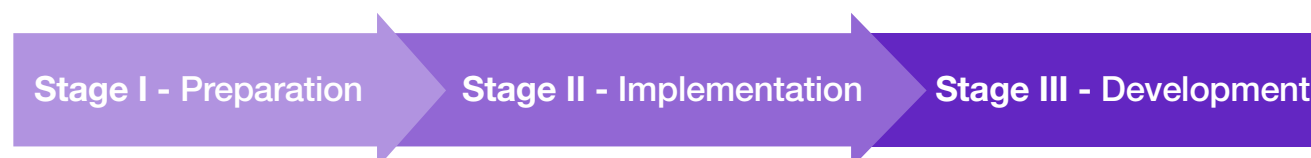
When analyzing the results of the projections of the energy matrix in Brazil in the long-term NZ scenarios, we observe more consumption electrification, a reduction in the demand for liquid fuels (that is, refined hydrocarbons), an increase in natural gas consumption, the appearance of distributed generation, and a reduction in biomass, considering the substitution of woodfire as energy source. The transportation segment in Brazil is characterized by a large penetration of biofuels, which increase their share, both in the mixes of biodiesel with diesel and alcohol with gasoline, or used at 100%.

In Brazil, the transition has its own characteristics, since many of the technologies from renewable sources were already introduced in the energy matrix over 30 years ago. In transportation, we observe great biomass participation, which is part of the liquid fuels y causes emissions from the use of certain type of technologies to be different when compared to international standards. Power generation presents the use of renewable sources of hydroelectric, wind, and solar origin (over 80% of generation in a normal year) in the wholesale market, and an important introduction of generation with solar panels in consumers in the last 5 years.

To conceptualize the transition in Brazil, we can divide the projection into three stages: the preparation stage between 2020 and 2030, the implementation stage with strong investment between 2030 and 2040, and the development stage as from 2040.

Graphic 68

► Roadmap: stages



STAGE I – Preparation (between 2020 and 2030). Investment levels are still low, due to the following:

- The recent development of large oil and gas fields by Petrobras in the pre-salt region allowed Brazil to become a net exporter of oil and petroleum products⁴⁸;
- The Brazilian power sector has a large share of renewable energy; therefore, the investment required in the first years to transform the existing matrix is reduced; even more, the first decade will be characterized by the need to install thermal equipment to provide firmness to the power system⁴⁹;
- it is expected that electric vehicles and batteries for power generation will not be so massive and competitive as in the following decades.

It is important to point out that Brazil has a roadmap for green hydrogen and is in the process of defining a public policy and strategy for mining essential minerals for a decarbonization pathway (for example, lithium).

In the second half of this period, we can point out investment in energy efficiency, renewable generation (in particular, wind and solar) and thermal generation

⁴⁸ Oil production grew from 1.2 Mbbl in 2000 to 3.2 Mbbl in 2023. Natural gas production grew from 17.0 MMm³/day in 2002 to around 50.0 MMm³/day.

⁴⁹ In recent years, the intensification of El Niño phenomenon, generating cycles of droughts and heavy rains has required reinforcing the generation system with firm generation

based on natural gas, the associated transmission grid, and the introduction of distributed generation (or renewable energy as final energy supply in the projection models prepared in this report).

Core industrial sectors in Brazil include heavy industries like steelworks, aluminum, etc., which are analyzing the elimination of coal from their production processes. During this period, it is assumed that these industries will introduce blue or green hydrogen in the industrial matrix.

In the vehicle sector, hybrid vehicles and lower emissions from vehicles are promoted, given the high share of ethanol that will require a slower energy transition to EVs in the transportation sector.

Brazil has five LNG plants; three are connected to the natural gas transmission grid and two provide natural gas for power generation. In addition, in 2023, two additional floating storage and regasification units (FSRU) were expected to start operating and one was expected to shut down. There are several projects for new regasification terminals.

STAGE II – Implementation (between 2030 and 2040). It is assumed that the technologies for the use of renewable sources⁵⁰ will be massive, available, and will have high demand. The CAPEX of the energy transition technologies (in particular, electric vehicles, power generation, batteries⁵¹) will continue their downward trend, which allows for their massive development.

In this decade, the introduction of clean technologies and the enhancement of energy efficiency in the value chains of the energy sector will gain speed, investment in natural gas will be maintained, and the supply of hydrogen-based technologies will start. Investment in natural gas-based generation will allow Brazil to increase the penetration of intermittent energy, like solar and wind energy.

⁵⁰ Brazil manufactures wind turbines and parts for solar panel equipment.

⁵¹ It is important to mention that the batteries will only be used in this decade as mechanisms to enhance the reliability of the whole power system.

Brazil has developed its hydrocarbon sector in the last 20 years and, due to the high penetration of ethanol in fuels, both industries require the continuation of the other; therefore, the early promotion of hybrid vehicles will allow for a reduction in consumption.

Public policies to modernize and expand the transmission and distribution grids gain speed so that they can accept and transportation clean energy for long distances in an efficient way (minimizing technical losses) and give way to a smart grid that allows electrification (electric vehicles, solar roofs, etc.).

The energy efficiency policy is promoted in all the segments of the economic activity, in line with Brazil's actions in the last 20 years.

The introduction of electric vehicles in Brazil will imply the development of electric vehicle production lines; therefore, the creation of the industrial value chain will have to be completed. In this sense, it is expected that the introduction of electric vehicles will be slow and emerging during this period.

STAGE III - Development (as from 2040). Clean technologies are already mature and massive; therefore, their prices are competitive and the cost of the transition is more related to accelerating the phase-out of the technologies with more CO₂ emissions. In the case of Brazil, this process will only start after 2050; until then, new natural gas-based plants will have to be introduced to back up the entry of renewable energy.

Investment in the sectors responsible for CO₂e emissions ends; in the case of natural gas, investment remains to operate the plants still working without additional expansion and as a marginal step towards the technologies that will replace it, like hydrogen and the CCUS.

The reduction in oil and gas consumption due to electrification reduces the use of hydrocarbon assets; thus, public policies are required to allow this market to reduce without generating price volatility.



The implications for public policies

Brazil's human development index (HDI) value in 2021 was 0.754, which places the country in the category of high human development and in position 87 out of 189 countries and territories⁵². Moreover, it is not a country in Annex I to the Paris Agreement. Therefore, its policies should focus on those that enable it to comply with its emission reduction commitments and the need to make its economy grow to reach the maximum emission reductions in the shortest possible time; it is likely to meet the net zero emissions target after 2050.

Stage I - Preparation

During preparation stage I, Brazil's policies must focus on each of the following points:

- 1. Public policies.** Brazil has a legal framework aimed at reducing its impact on the environment that is previous to the Paris Agreement and falls in line with it. In 2007, it passed the National Policy on Climate Change⁵³ and the NDC⁵⁴ which, together with the National Energy Plan 2050, establish emission reduction and clean energy adoption targets. Brazil has already started this process; therefore, it is expected to update and enhance its regulations. It has also developed specific policies for hydrocarbons, natural gas, and the power market.

⁵² The UNDP establishes four categories: low (less than 0.55), medium (between 0.55 and 0.70), high (between 0.70 and 0.80), and very high (over 0.80).

⁵³ National Policy on Climate Change (PNMC, in Portuguese), Law No. 12187 of 2009: it defines the national voluntary commitment to reduce emissions by between 36.1% and 38.9% by 2020.

⁵⁴ Nationally determined contribution (NDC): a commitment to reduce GHG emissions by 37% by 2025 and 43% by 2030, with 2005 as the reference year.

- 2. Access.** Achieve full electricity coverage and universal access to clean cooking in order to substitute and displace firewood (and other inefficient fuels with high CO₂ emissions) in the residential sector, especially in highly marginal rural areas. Moreover, Brazil has geographically distant areas with isolated power systems that use liquid fuels as energy source; at present, the introduction of renewable energy is already being promoted in these areas through Law No.14300 of 2022. The CDE is the mechanism to increase coverage and introduce renewable energy in isolated grids.

- 3. Energy efficiency.** Energy efficiency programs in Brazil started 40 years ago and the country has a National Energy Efficiency Plan in line with the NDC. Brazil must continue implementing its plan and maintaining 10-year updates.

The promotion of hybrid vehicles as part of energy efficiency in transportation has great impact on countries with strong penetration of biofuels.

- 4. Renewable energy.** Brazil has good solar and wind resources. In addition, it has launched programs to develop renewable energy and distributed generation. Three auctions for alternative sources were carried out in 2007, 2010, and 2015 for the purpose of developing renewable sources and making them compete between them, and nine auctions for reserve energy were carried out.

Brazil's electricity matrix has a renewable penetration of over 80 %, based on hydroelectric power, which may suffer from drought situations.

In this period, the penetration of distributed generation and microgeneration must continue being promoted, in addition to attending to the coordination aspects of the administration of generation outside the transmission grid, mentioned in the automation aspects.

5. Subsidies and prices. Energy efficiency policies require price schemes that reflect well focused prices and subsidies for them to be effective. In general, prices and tariffs reflect costs. This shows that Brazil started implementing these policies 40 years ago. The main task to reduce subsidies in Brazil is the implementation of access policies to reduce the energy development account.

6. Regulations. Eventually maintain the fiscal and financial incentives that promote investment in renewable energy and energy efficiency. Promote banking regulation to incentivize loans associated with energy transition (renewable sources and transition fuels) and penalize investment in the oil and petroleum production chain. Within the fiscal incentives, taxes on carbon should be considered, and they should relate to the international prices of carbon credits so that they adequately reflect the mitigation cost⁵⁵. Develop detailed policies and regulations to continue promoting policies related to hydrogen and CCS in order to reduce uncertainty in this business and allow for its development in the long term.

6. Transition fuels. The consolidation of gas supply and its transportation systems must take place in this period, guaranteeing the possible depreciation of the production, import, and storage projects that are developed without cost overruns. In the case of Brazil, it implies the development of the LNG terminals required to supply gas and reinforce the pipeline network. This policy should not seek to massify the use of gas in the areas with no coverage, just in those where there already is a distribution network.

8. Reconversions. Brazil is a net importer of natural gas and coal; the country produces oil and, to a lesser extent, natural gas.

⁵⁵ It is important to mention that price signals should be constant over time in order to be effective; therefore, developing levelized mitigation costs could be another alternative.

As regards coal and fuel oil-fired plants, there is no official phase-out plan, or a clear just transition mechanism. Even though the Brazilian Government has recently enacted Law No. 14299/22 or the so-called Just Energy Transition Act, this law guarantees that Brazil will continue using and subsidizing coal as an energy source at least until 2040. Around two thirds of the coal-fired plants operating today in Brazil were installed between 2010 and this date. Installed capacity is around 7 % of the total and is distributed between areas in the integrated system and other independent ones in isolated areas. Brazil should start working to introduce renewable energy in the distributed areas, and the phase-out of these plants in the next period – when batteries can be introduced – is being planned. Coal and fuel oil-fired plants must be dismantled and replaced. Brazil has developed a hydrocarbon industry with large investment in infrastructure associated with oil and gas in the Río de Janeiro and São Paulo area. It is expected that some of these assets will be operative after 2050; however, the impact of reducing this industry in these states should be analyzed and reconversion plans should start being implemented in this decade.

9. Smart grids. Modernize energy infrastructure by promoting investment in smart power lines and energy storage systems to facilitate the integration of renewable energy and enhance supply reliability. The federal government must analyze and cover the costs of introducing smart grids in low-consumption demand as part of the agenda to facilitate energy efficiency.

10. Transportation. Foster hybrid vehicles in this decade and start promoting electric vehicles while biofuels are being developed and green biodiesel becomes stronger. The development of electric charging networks is, undoubtedly, a big challenge for a country as large as Brazil.; therefore, in this decade,

regulations should start being introduced to enable the appearance of these supply networks.

Policies to introduce electric railways also constitute a mechanism to accelerate energy transition and replace freight transportation running on liquid fuels. Therefore, studies, layout-related expropriations, and tenders to develop these projects should be promoted.

The energy transition in Brazil will last between ten and twenty years after 2050; therefore, gas-based technologies will have time to be depreciated.

11. Markets. Develop secondary markets in the power sector, focusing on electricity trading and its financial derivatives (futures, swaps, options, etc.) to allow residential and commercial segments to select the energy products they want to acquire and allow industrial sectors to calculate their prices in the very long term. This implies making deeper reforms in the power sector to adopt schemes of the Consumer Choice type, which allow regulated end users to select the electricity service provider that suits them best.

12. Education. Promote education policies on energy transition to develop habits regarding energy consumption in the population. During this stage, the energy transition must be included at all education levels and in awareness campaigns addressed to society.

Stage II - Implementation

In the second stage, the largest investment will take place.

1. Public policies. Develop the transition plans towards NZ detailed in the planning horizon that is finally defined.

2. Energy efficiency. Continue promoting energy efficiency in all segments of the economy (residential, industrial, commercial, transportation, agricultural, public sector, etc.) in order to reduce energy consumption.

Promote equipment and car replacement and scrappage programs, focusing on vehicles (trucks and cars), given the expected progress in EV development and prices.

These programs should focus on replacement with hybrid vehicles.

3. Subsidies and prices. Prices must be defined in the energy markets and should maintain subsidies for people with unfulfilled energy needs.

4. Regulations. Foster tariff schemes that envisage investment in mitigation and adaptation to climate change.

Promote restrictive regulations for the vehicle fleet in order to incentivize the phase-out and replacement of units with high CO₂ emissions and the design of cities that allow using alternative transportation systems (electric public transportation, bicycles for short distances, etc.).

Within the fiscal incentives, it should be established that taxes on carbon should relate to remediation and adaptation costs and they should not fall behind for not being updated with the required frequency.

Develop detailed regulations to promote policies related to hydrogen and CCS to reduce uncertainty in such businesses.

5. Social aspects. Propose socio-environmental agreement schemes to make the development of hydrogen and CCUS projects viable as well as projects for clean energy in marginal communities, and compensation projects for regions that must change their production orientation (from fossil to clean energy or to another type of activity to produce goods or provide services).

6. Transition fuels. Finance the hydrocarbon and gas sectors normally and suspend financing of new projects to expand hydrocarbon systems. It should be considered that the energy transition in Brazil includes biofuels

as a way to reduce emissions; therefore, oil assets should reduce their participation but maintain their operation as part of the sector while their production capacity decreases. This decade is characterized by the oil sector as support for biofuel growth.

- 7. Reconversions.** Given that Brazil has largely invested in its hydrocarbon sector in the last 15 years, these assets will be operative throughout the whole third decade of the century. As indicated above, the importance of these sectors in certain regions or states implies that, during the third decade of the century, these cities and value chains must be transformed to make them resilient to the sector's phase-out between 2040 and 2060.

Therefore, during this period, public reconversion policies should be developed in the regions that have abandoned coal and those that will gradually have to abandon the production of hydrocarbons.

- 8. Smart grids.** Consolidate energy infrastructure promoting investment in smart grids and energy storage systems to facilitate the integration of renewable energy and enhance reliability of supply. The introduction of smart metering systems seeks to provide more adequate price signals to energy consumption. In addition, data transmission schemes should be envisaged to be able to create a safe administration scheme of the centralized transmission and distribution grids (including cybersecurity aspects) without neglecting distributed generation.

- 9. Transportation.** Foster clean technologies in transportation, including biofuels and green fuels, the promotion of freight vehicles running on LNG or CNG as transition fuel, and hybrid or electric vehicles and their associated charging infrastructure. Implement electric railway transportation to transport cargo and passengers.

- 10. New technologies.** Develop concessional financial instruments to implement hydrogen and CCS projects⁵⁶.

Stage III - Development

In the third stage, efforts are concentrated on few objectives.

- 1. Energy efficiency.** Promote energy efficiency in all segments of the economy (residential, industrial, commercial, transportation, agricultural, public sector, etc.) in order to reduce energy consumption. The alignment of prices, subsidies, financial regulations to promote energy transition, and a carbon price (taxes on carbon or emission trading systems) should foster this investment. Promote replacement and scrappage programs for equipment and cars, focusing on all the equipment using liquid fuels.
- 2. Subsidies and prices.** Prices must be defined in the energy markets, and subsidies for people with unfulfilled energy needs should be maintained.
- 3. Regulations.** Within the fiscal incentives, carbon price mechanisms reflecting social costs should be established so that they incentivize equipment scrappage and replacement.
- 4. Reconversions.** Financially assist those regions and production sectors that will be affected by the phase-out of assets from oil extraction and coal mine exploitation.

⁵⁶ Several pilot projects are being proposed to finance hydrogen and CCUS; however, these mechanisms seek to allow an increase in the amount of funds through the development of these technologies. Here, what is proposed is financing technologies that have already been developed.

5. **Transportation.** Promote clean technologies in transportation, hydrogen and electricity, and their associated charging infrastructure.
Reinforce the introduction of biofuels in transportation and maintain the supply value chains and their production.
Implement transportation by electric railway, and electric or hydrogen-based freight and passenger transportation.
6. **New technologies.** Promote massive adoption of new technologies with proven reduction in emissions, such as new energy efficiency practices.

2. Roadmap

In order to develop the roadmap, three stages have been proposed. In the first stage, there are two phases, one for debate and another for development, where the public policies to be developed and the segments that require concessional financing or support are defined. Table 13 shows the policies by topic and the expected action.

The debate phase will focus on conceptualizing, with the countries, the implications of the just energy transition between 2024 and 2025. This transition raises the need to combine economic plans that allow high growth rates and the enhancement of the population’s quality of life through public policies that focus on reducing energy needs.

Moreover, the just energy transition must also discuss the financing of the transition measures in line with the content of Article 7 of the Paris Agreement.

Table 13

► Roadmap to be promoted from CAF

Policy	Between 2024 and 2025	Between 2026 and 2030	Between 2031 and 2040	After 2040
Public policies	- Integrate the concepts of JET in national energy plans and the policies developed by the Ministry of Energy on a federal and state basis, regulatory agencies, the ANP, ANEEL, and the state agencies.	- Issue the first plans for the JET.	- Adjust JET plans to the deadlines to comply with decent standards of living.	

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Policy	Between 2024 and 2025	Between 2026 and 2030	Between 2031 and 2040	After 2040
Access	- Achieve total coverage of electricity services and universal access to clean cooking. - Introduce renewable generation in all isolated systems (solar, wind, and mini hydros).		- Start introducing batteries in isolated systems.	- Implement isolated supply schemes with no fossil fuels.
Energy efficiency	- Design, finance, and implement home appliance replacement and scrappage policies (refrigerators, air conditioners, space heating, etc.). - Establish promotion policies to introduce hybrid and electric vehicles. - Analyze scrappage and replacement programs for trucks and vehicles over 20 years old.		- Continue replacement policies, including all types of home appliances and insulating equipment in households. - Promote plans to replace low-efficiency private vehicles with hybrid vehicles and start introducing electric vehicles.	-Continue replacement policies, including all kinds of home appliances and insulation equipment in households. - Promote heavy vehicles running on green hydrogen.
Energy subsidies	- Focus subsidies on inhabitants with unfulfilled energy needs.			
Fuel prices	- Increase the content of biofuels in liquid fuels and promote the development of green diesel.		- Increasingly internalize remediation costs in fuel prices, either through taxes on emissions or emission trading systems.	
Public services tariffs	- Decoupled distribution tariffs should cover costs separately from generation.		- Internalize investment in mitigation and adaptation in tariffs.	
Regulations	- Intensify fiscal and financial incentive policies that promote investment in renewable energy and energy efficiency. - Promote financial regulations that incentivize loans associated with energy transition (renewable sources and transition fuels). - Promote regulations to favor hybrid vehicles focusing on the private fleet. - Promote strict regulations for the freight vehicle fleet to incentivize the replacement of units with high CO₂ emissions.		- Within fiscal incentives, establish coal taxes related to remediation and adaptation costs. - Develop detailed regulations to promote policies related to hydrogen and CCS in order to reduce the uncertainty of such businesses.	- Within fiscal incentives, establish that taxes on coal should reflect their social cost to incentivize scrappage and replacement of such equipment.
Socio-environmental aspects for project development			- Propose socio-environmental agreement schemes to make the development of hydrogen and CCUS projects viable.	

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Policy	Between 2024 and 2025	Between 2026 and 2030	Between 2031 and 2040	After 2040
Transition fuels	-Allow financing and regulating the oil and gas sector in banking regulations.	- Promote the expansion of biofuels. - Promote investment in the natural gas assets required to allow the progress of renewable energy and the reconversion of Brazilian industries using coal.	- Maintain investment in the oil and gas sector focusing financing on operations and not expansion. - Increase biofuels as much as possible.	
Reconversions	- Initiate studies on the impact of natural gas, oil and other minerals on communities. - Start developing plans to reconvert hydrocarbon-dependent economies in order to develop regulations and business rules to allow the promotion of new businesses in the region. - Develop strategic reconversion plans for regional economies associated with extractive industries to ensure the JET.		- Implement strategic plans to reconvert regional economies associated with extractive industries to ensure the JET.	- Establish programs to mitigate the impact of the JET on sectors that have not achieved their reconversion.
Coal and fuel oil-fired plant phase-out		- Establish regulations to phase out coal and fuel oil-fired plants that remain operative.		
Hydrocarbon asset phase-out	- Establish a plan of additional assets to be developed for the transition.	- Implement regulations and rules to promote highly hydrocarbon-based areas.	- Develop plans to compensate and contribute resources in areas to be reconverted. - Start financing policies to make new businesses possible in the region.	- Implement financing policies to make new businesses possible in the region. - Develop the policies required to incentivize population relocation in case reconversion plans are not effective.
Development of smart grids and advanced metering infrastructure (AMI)	- Analyze mechanisms to integrate smart transmission and distribution grids and international financing in order to allow for a better administration of the system as a whole.	- Introduce smart metering.		

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Policy	Between 2024 and 2025	Between 2026 and 2030	Between 2031 and 2040	After 2040
Integration of renewable energy and storage systems		- Estimate storage needs in the long term to integrate large amounts of renewable energy as a complement to hydroelectric storage.	Design mechanisms to remunerate the storage services to facilitate its development.	
Operation of transmission and distribution grids in a coordinated manner		- Develop integrated operation mechanisms between distributors and transporters.		
Development of secondary electricity markets		- Deregulate commercial and residential commercialization to introduce consumption decisions based not only on prices but also on the type of energy produced. - Introduce derivative markets in all energy segments. - Advance in final supply competition schemes for regulated consumers.		

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