Atlas of Energy Efficiency

Brazil | 2021

Indicators Report

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Empresa de Pesquisa Energética

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This report has one special chapter...

which provides an analysis of the evolution of the road freight transport sector in Brazil, including the fundamentals associated with the increase in demand. Following this, a global section compares Brazil to other countries on key indicators, and provides examples of leading technologies and policy options for the sector to advance energy efficiency, carbon mitigation, and air quality improvements.

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Content

Objective

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The main objective of this document is to monitor the progress of energy efficiency in Brazil, through the use of indicators. In 2020 the first "Atlas of Energy Efficiency in Brazil - Indicators Report" was published - with analysis up to the year 2018. This document updates and complements, in a more condensed way, the first report with data up to the year 2020. This document consolidates the fifth cycle of EPE's work in the development of the database of energy efficiency indicators.

Definitions

ODEX

ODEX is an indicator that determines the progress of energy efficiency. It can be aggregated by sector (industrial, residential, services and transport) or for the economy as a whole. ODEX is used by the European Union in the ODYSSEE database program for monitoring efficiency gains.

ODEX by sector (e.g. industry) is based on unit consumption indexes by sub-sector (cement, ceramics, textiles, etc...), weighted by their share in the total energy consumption of the sector. The unit consumption per sub-sector can be expressed in different units in order to provide the best proxy for the evaluation of energy efficiency, be it the consumption per household, physical production, or number of vehicles, for example.

For the present report, 2005 was considered as the base year (value = 100), essentially due to the availability of data for most sectors from that year on. The decrease in the unit consumption index from 100 in 2005 to 80 in 2020, for example, represents an energy efficiency gain of 20% over the analyzed period. In contrast, if ODEX increases from 100 to 120, there will have been a deterioration in energy efficiency over the years in question.

In the case of global ODEX, the same method is applied with weighting factors, based on the shares of the total final energy consumption of each sector.

For the purposes of this technical note, the industrial, residential and transportation sectors were considered. The other sectors (energy, services and agriculture and livestock) were not included due to the unavailability of data.

Energy Intensity

Energy intensity refers to the amount of energy required to produce one unit of final product or service. It is the ratio between an energy indicator (ton oil equivalent [toe], Joule, calorie, Btu, among others) and an activity indicator (U$, R$, m², ton-kilometers, passenger-kilometers, among others).

Hypothetical examples:

- Industrial Energy intensity: 100 toe/U$ ppp 2010
- Energy intensity of residential building: 0.5 toe/m²
- Energy intensity of commercial building: 200 KJ/m²
- Energy intensity in the transport sector: 1,000 toe/tkm

The energy intensity of an economy corresponds to the ratio of the Total Energy Supply divided by the Gross Domestic Product of the country. This indicator is usually used to measure a country's energy efficiency. Nevertheless, it is important to consider that this ratio does not necessarily express energy efficiency, since a country can have a low energy intensity and be inefficient from an energy point of view. Just consider the case of a small country that has its economy based on the tertiary sector, which may have a lower energy intensity than another large nation whose economy is based on industrial production. However, the second country can use energy for its industries more efficiently than the first uses it to develop its economy based on trade and services.

Thus, the energy intensity should not be analyzed alone. Efficiency gains are only one component of this analysis, which must also take into account the structure (structural effect) of a country's economy (presence of energy-intensive industries, developed services sector, etc.) and changes in activity (activity effect), which are influenced by the size of the country (implying higher demand from the transport sector, for example).

In this report, the indicator will be calculated in two ways: from the perspective of total energy supply (TES), identified as Primary Intensity (i), and from the perspective of final energy consumption, denoted as Final Intensity (ii).

I. Total Energy Supply (thousand toe)/GDP (M$[2010])

II. Final Energy Consumption (thousand toe)/GDP (M$[2010])

Final Consumption

This is the energy that reaches end-use sectors for energy and non-energy purposes (raw material, for example). The sources used as input or raw material for transformation into other energy products are not included in this concept. These activities are classified, according to the Brazilian Energy Balance, as Transformation Centers (examples: water used to generate electricity or oil that will be transformed into gasoline, diesel oil, etc.).

In general, the sectors in this report were classified according to the Brazilian Energy Balance, with the exception of some energy-intensive sectors, for better representation of energy efficiency progress in Brazil.

Final consumption can be calculated in the following ways:

- **Final consumption** = primary final consumption (+) secondary final consumption, or;
- **Final consumption** = non-energy final consumption (+) final energy consumption

Where:

- **Primary final consumption** is the consumption of primary energy, i.e. consumption from sources coming directly from nature. Examples: natural gas, mineral coal, solar, wind, hydro and sugar cane products, among others
- **Secondary final consumption** is the consumption of secondary energy, that is, consumption from sources coming from the different transformation centers, which have as a destination different sectors of the economy. Examples: electricity, gasoline, diesel oil, ethanol, among others.
- **Non-energy final consumption** corresponds to the consumption of sources that, although they have energy content, are used as raw materials for other purposes. Example: use of naphtha for the manufacture of thermoplastics.
- **Final energy consumption** corresponds to the use of sources by economic sectors as energy.

INOVA-E

The INOVA-E digital platform was developed to make data on Brazilian investments in Research, Development and Demonstration (RD&D) in energy accessible to diverse audiences. This platform aims to deepen the understanding of investment trends in RD&D in energy and support various organizations including the EPE, the MME and the MCTI, in the formulation and promotion of public policies, research and new investments in the area of energy innovation. The strategic information made availabe at INOVA-E was organized in a single database providing an unprecedented overview of innovation efforts in the energy sector in Brazil.

Public RD&D investment - Public RD&D investments are calculated based on reimbursable and non-reimbursable RD&D projects expenditures carried out through public institutions that foster innovation in Brazil. The statistics presented on this platform gathered data from the following federal agencies: BNDES, CNEN, CNPq, FINEP; and also from the state of São Paulo: FAPESP.

Publicly oriented investment in RD&D - Publicly oriented investments refer to private investment induced by public policies, being compulsory for companies in the energy sector. These are resources that fit into public programs whose purpose is to induce companies to invest in RD&D. Within the scope of this platform, publicly oriented investments refer to RD&D projects regulated by Brazilian Electricity Regulatory Agency (ANEEL) and National Agency for Petroleum, the Natural Gas and Biofuels (ANP) agencies.

For more details, visit:

http://shinyepe.brazilsouth.cloudapp.azure.com/inova-e/index.html

Transport Sector

Activity

Activity in the Transport sector is internationally represented by the indicators passenger-kilometer and ton-kilometer transported. Passenger-kilometer is a unit that presents the work relative to the displacement of a passenger over a distance of one kilometer. Similarly, ton-kilometer is the unit that represents the work relative to the displacement of a ton of cargo at a distance of one kilometer. Also called transport momentum.

Intensity of use

Ratio between transport activity and distance traveled. It is expressed in ton-kilometer/kilometer or Passenger-kilometer/kilometer.

Fuel Economy

Ratio of the distance traveled by passengers or cargo and the fuel consumption in volume and expressed as a measure of range. Usually in kilometers/Liter.

Fuel Consumption

It represents the volume of fuel used to travel a given distance, usually 100 km. It is expressed in Liters/100km.

Energy Efficiency

Ratio of estimated activity (t.km or p.km) to total energy demand (in units with Joule [J], Watt [W] or tonne oil equivalent [toe]).

Transport Sector

Light Duty Vehicles (by size)

Automobile

Motor vehicle for passenger transport, with passenger capacity of up to eight people (excluding the driver);

Light commercial vehicles

- **Utility Vehicle** – vehicle for freight transportation with GCVW of up to 3,500 kg;
- **Medium Duty Passenger Vehicle** – mixed vehicle for passenger transport;
- **SUV** – Mixed vehicle characterized by its versatility of use, even off road.

Heavy duty vehicles

Trucks

- **Semi-light** – 3,5 t. < GCVW < 6 t.
- **Light** – 6 t. ≤ GCVW < 10 t.
- **Medium** – 10 t. ≤ GCVW < 15 t.
- **Semi-heavy** – GCVW ≥ 15 t. e MTC ≤ 45 t.
- **Heavy** – GCVW ≥ 15 t. e MTC > 45 t.

GCVW– Gross combined vehicle weight
MTC – Maximum Traction Capacity

Introduction

Share of renewables in the Energy mix

Historically, Brazil stands out for being a country with a high percentage of renewable sources in its total energy supply when compared to the rest of the world. Over the last 20 years, the share of renewables in the Brazilian energy mix has remained stable at over 40%, a level that has been challenging to maintain. More recently, between 2011 and 2014, there was a reduction in the share of renewables in the energy mix due to a drop in hydropower supply. As of 2015, renewable sources have resumed their growth trajectory with the expansion of the supply of sugarcane products, wind and biodiesel, reaching 48% in 2020.

Figure 1 – Share of renewable sources in the Total Energy Supply (TES): international comparison

Source: EPE (2021a)

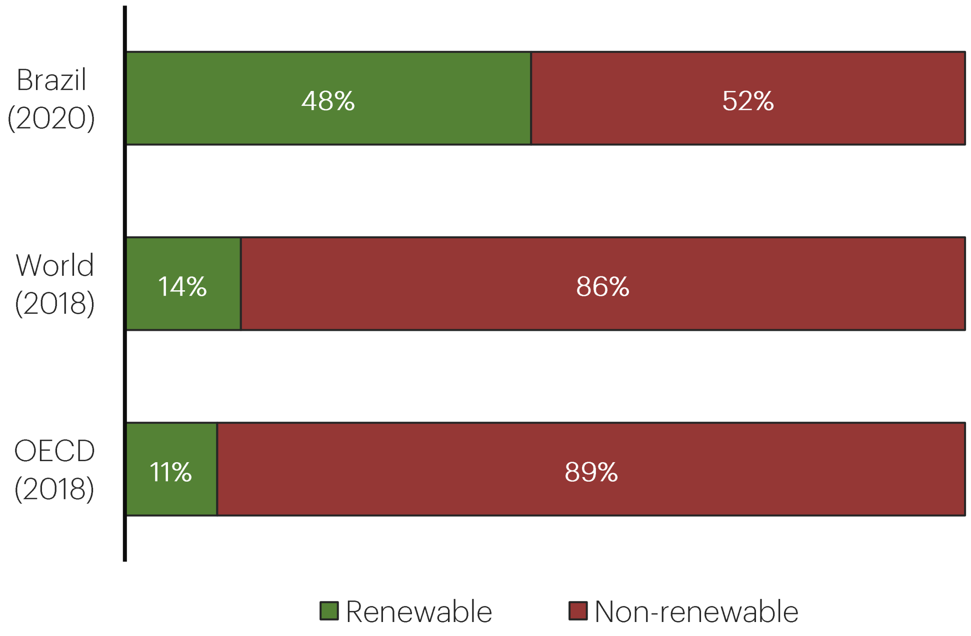
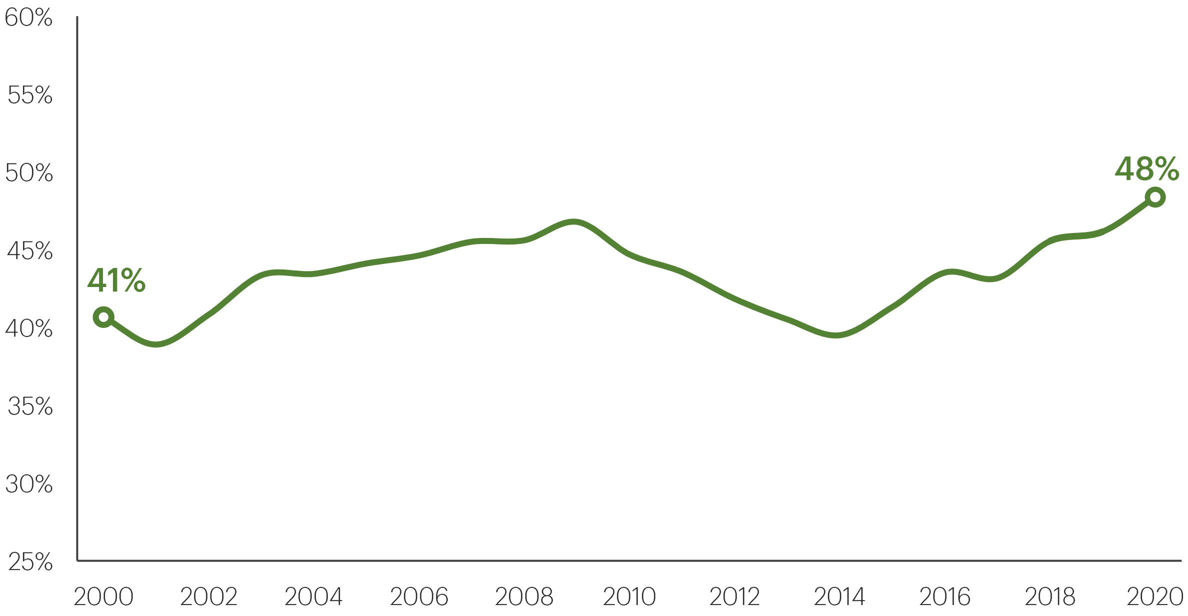


Figure 2 – Share of renewable sources in the Total Energy Supply (TES) – 2000 to 2020

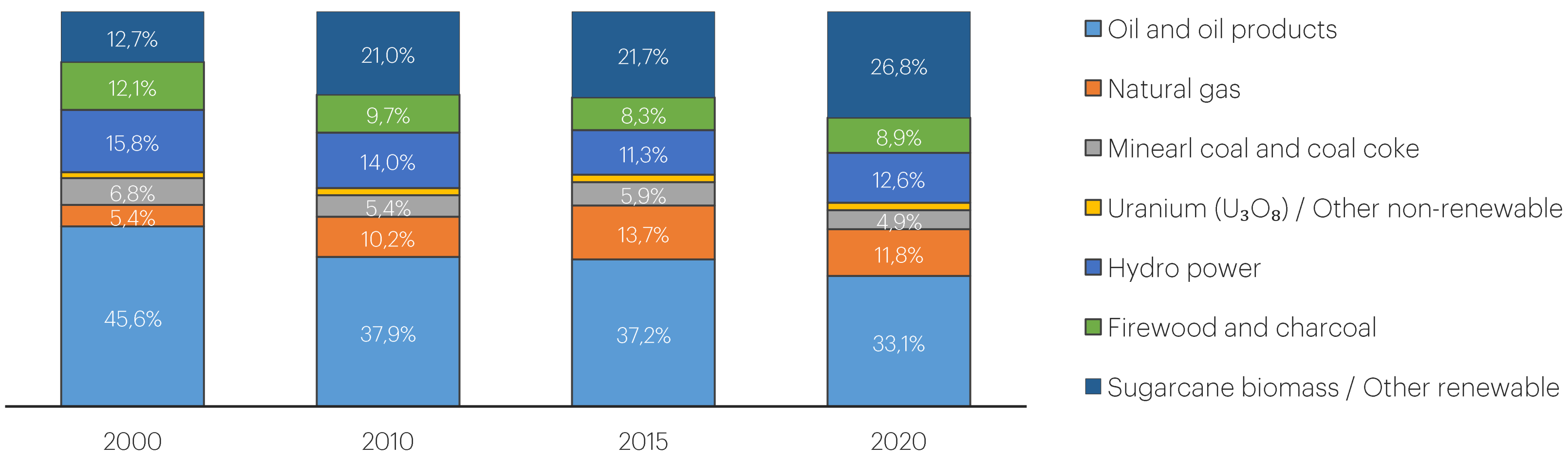
Source: EPE (2021b)



Evolution of final energy consumption by source

For non-renewable sources, oil and its products maintain the largest share. However, natural gas was the standout category, significantly increasing its share of the energy mix from 5.4% in 2000 to 11.8% in 2020 due to its use in thermoelectric power plants and extension of the pipeline network, which enabled its use both in industries and in residential, commercial and public buildings.

Figure 3 – Energy consumption by source – selected years
Source: EPE (2021b)



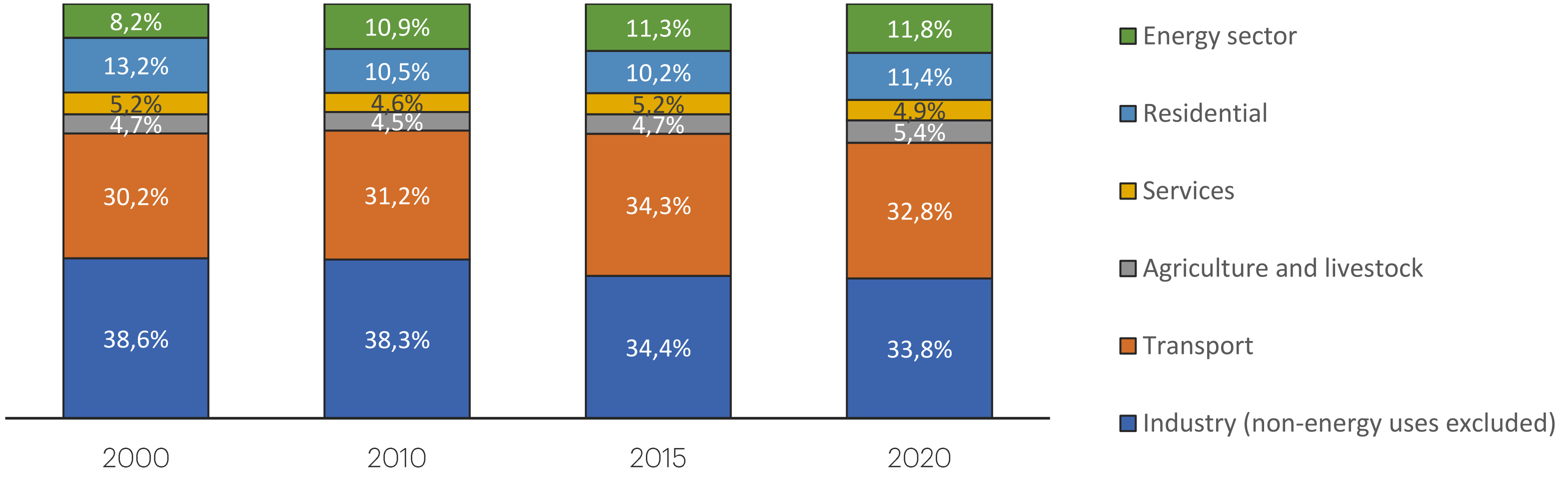
Renewable sources, on the other hand, developed at a faster pace, due to the expansion of the sugar-ethanol sector, and the strong expansion of other renewable sources, notably wind power, black liquor and biodiesel. From a negligible share in 2000, wind energy grew to the point that it contributed 4.9 million toe to the energy mix in 2020, while black liquor, which is directly associated with the pulp and paper industry, contributed another 9.6 million toe in 2020. Biodiesel has been favored by the policy of adding this fuel to fossil diesel. In 2020, the percentage reached 12%. The most used raw material for its manufacture in the Brazil is soy oil. Brazil is the second largest producer of biodiesel in the world, only behind the United States.

Final energy consumption by sector

The main change observed in this period was the decline of industry's share alongside an increase in that of the transport and energy sectors. The Transport sector even surpassed industrial consumption in 2018 and 2019. However, with the outbreak of the Covid-19 pandemic, consumption for transportation retreated -6.4% and brought this sector back to second position among the most energy-consuming sectors in Brazil.

Figure 4 – Energy consumption by sector – selected years

Source: EPE (2021b)

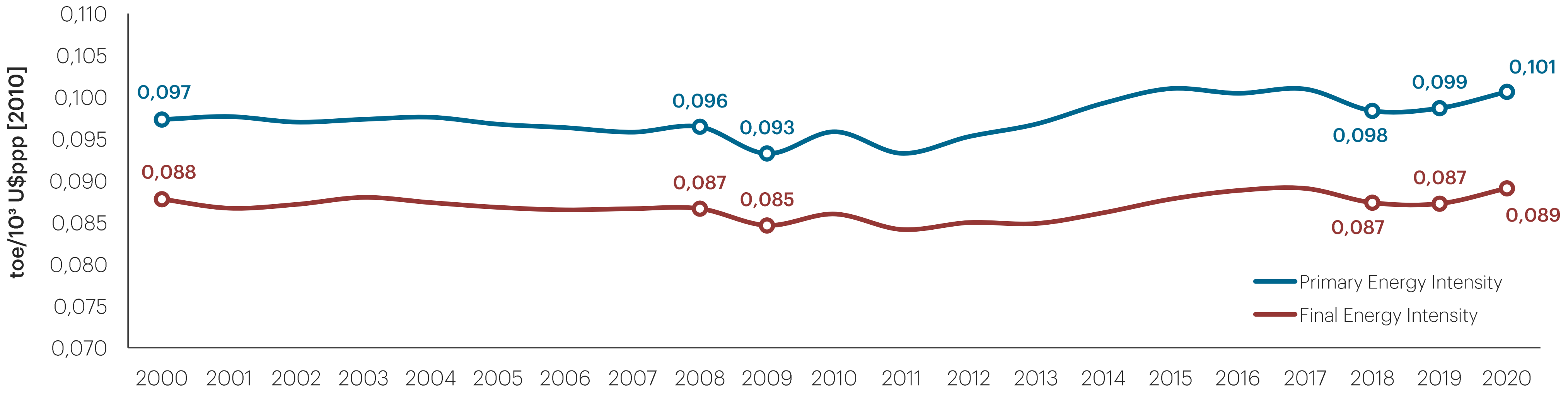


The cement/steel aggregate that consumes more than 20% of all energy for the industry grew at a less intense pace than the transport sector, which in the same period had its energy consumption evolving at an average annual rate of 2.6%. The cement industry, besides the gradual reduction of the clinker/cement ratio from 73.2% in 2000 to 69.4% in 2020, had its clinker production (intensive in energy consumption) growing at an average annual rate of 1.9%. Steelmaking in turn expanded its physical production at an average annual rate of 0.6%. The energy sector, driven by oil and ethanol production, which in the period grew at annual rates of 4.4% and 5.7%, had its energy consumption in 2020 increased by 15.6 million toe compared to the year 2000.

Energy Intensity

In 2000-08, primary energy intensity remained stable at around 0.097 toe/10³ US dollars (USD) at purchasing power parity (PPP) [2010]. Similarly, final energy intensity stabilized at values close to 0.087 toe/10³ USD PPP [2010]. In 2009, the effects of the international crisis on industry contributed to a reduction in primary energy intensity to 0.093 toe/10³ USD PPP [2010]. In that year in particular, it was possible to observe the shutdown of more inefficient (less competitive) units with higher energy intensities

Figure 5 – Energy intensity
Source: EPE (2021b)



Between 2010 and 2013, primary and final intensities grew at rates of 0.9% and 0.1% per year respectively, reflecting growth in Total Energy Supply that outpaced growth in GDP. Between 2014 and 2020, primary energy intensity grew by 0.6% per year, even with the economy in recession (an average contraction of -0.9% per year). In the same period, final energy intensity grew by 0.7% per year. This upward trend in energy intensity may be associated with the growth in production of low value-added, energy-intensive items aggregated together in the production schedule, as compared to other manufactured products

RD&D Investments in Energy Efficiency

In competitive sectors such as industry, energy efficiency is part of the day-to-day production process, because without efficiency, many businesses would have difficulty competing. Technological changes are among the main sources of wealth creation and long-term economic growth.

According to the INOVA-E[1] platform, between 2013 and 2018, Brazil has invested more than 1 billion reais on research, development and demonstration (RD&D) in energy efficiency projects arising from public or publicly oriented[2] investments. Almost half of this amount came from BNDES, while ANEEL and Finep corresponded to 23% and 27%, respectively.

Figure 6 – Evolution of RD&D investments in Energy Efficiency

Fonte: EPE (2021c)

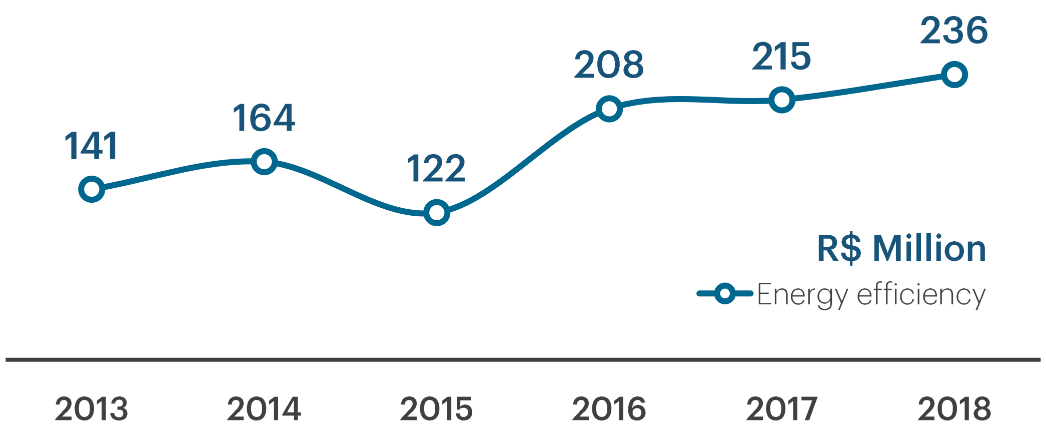
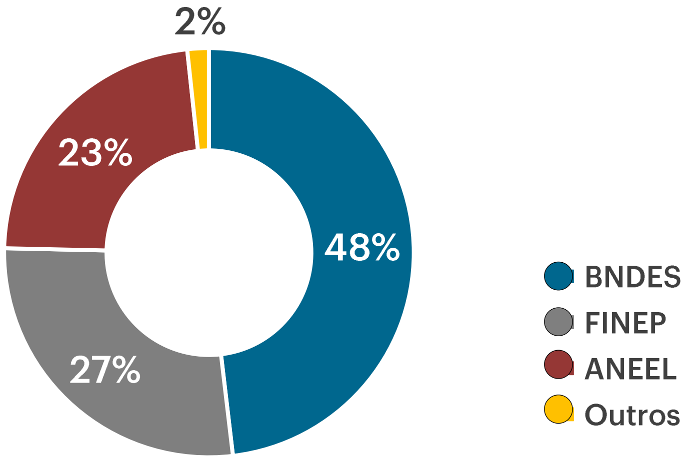


Figure 7 – Origin of resources for Energy Efficiency investments

Fonte: EPE (2021c)



inova e BRASIL

Data from Inova-e shows that between 2013 and 2018, 1 billion reais of public and publicly oriented resources were applied to R&D projects in Brazil, an annual average of more than 180 million reais over the six years period.

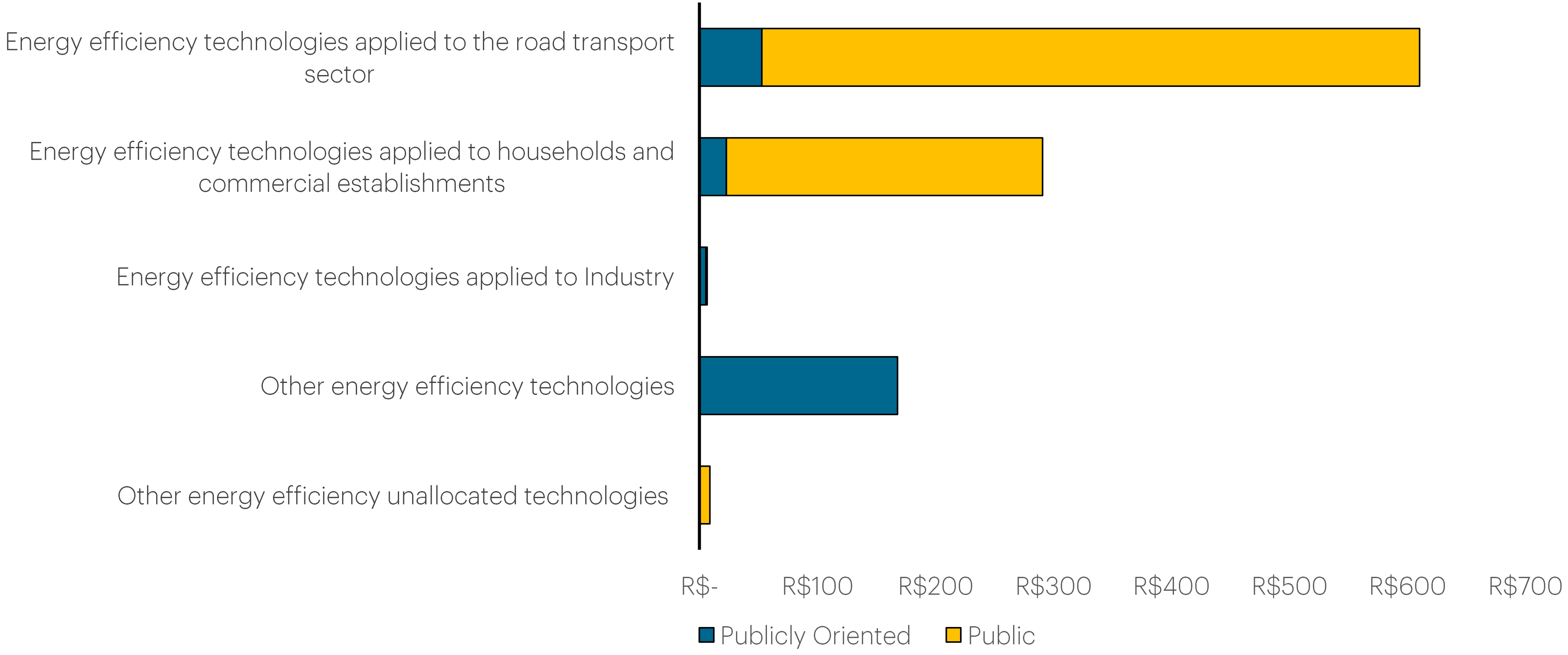
[1] To find out what INOVA-E is, go to Definitions

[2] For the definition of the meaning of the expressions "public" or "publicly oriented investments" see the chapter Definitions

RD&D Investments in Energy Efficiency

Figure 8 – Nature and modality of investments, in millions of reais - 2013 to 2018

Source: EPE (2021c)

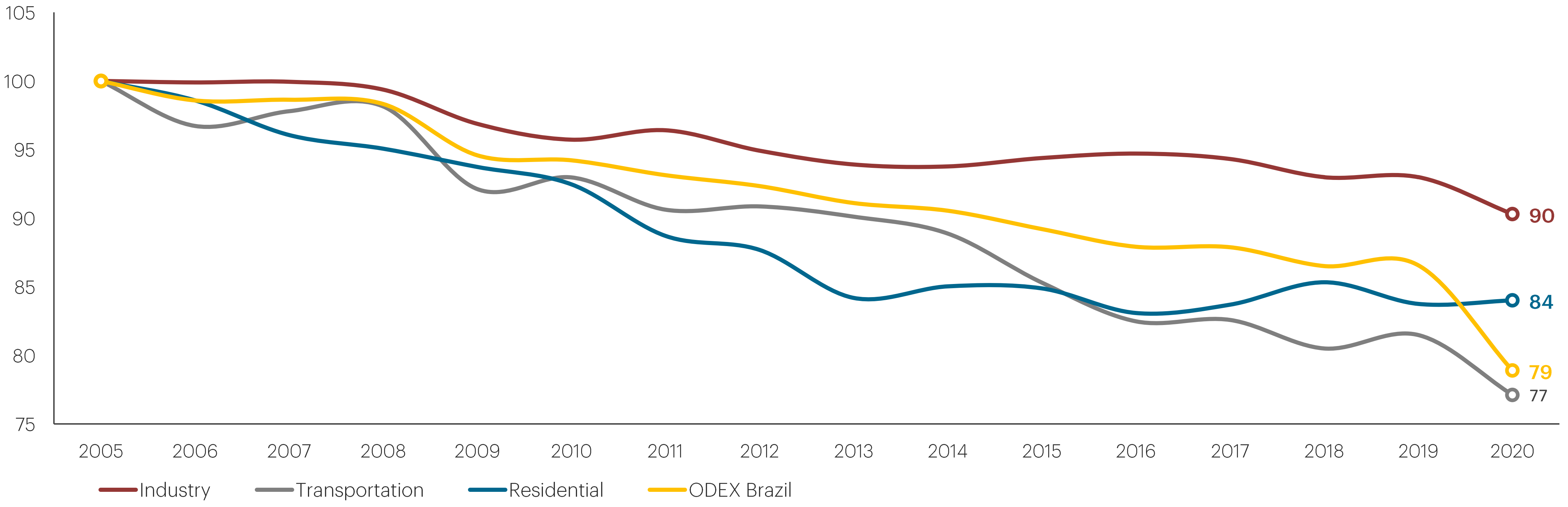


ODEX

In this report, 2005 was set as the base year (100), covering the industrial, residential, transport sectors and Brazil as a whole. In this period, all sectors analyzed showed efficiency gains, with the largest gains occurring in the transport (23%) and residential (16%) sectors. The ODEX calculated in 2020 shows that the country became 21% more energy efficient in the period.

Figure 9 – ODEX Brazil

Source: Compiled by EPE



Buildings

Evolution of consumption in buildings: residential, commercial and public sectors

The main energy source used in the buildings is electricity. Households use 46% electricity, 26% LPG and 24% firewood. Commercial and public buildings, on the other hand, use electricity with a 92% share.

Figure 10 – Total energy demand in buildings
Source: EPE (2021b)

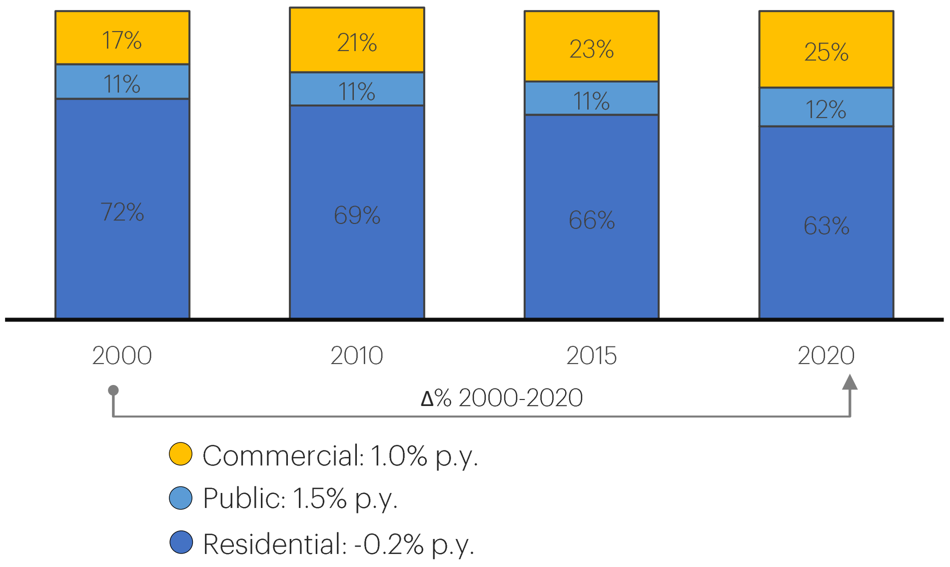
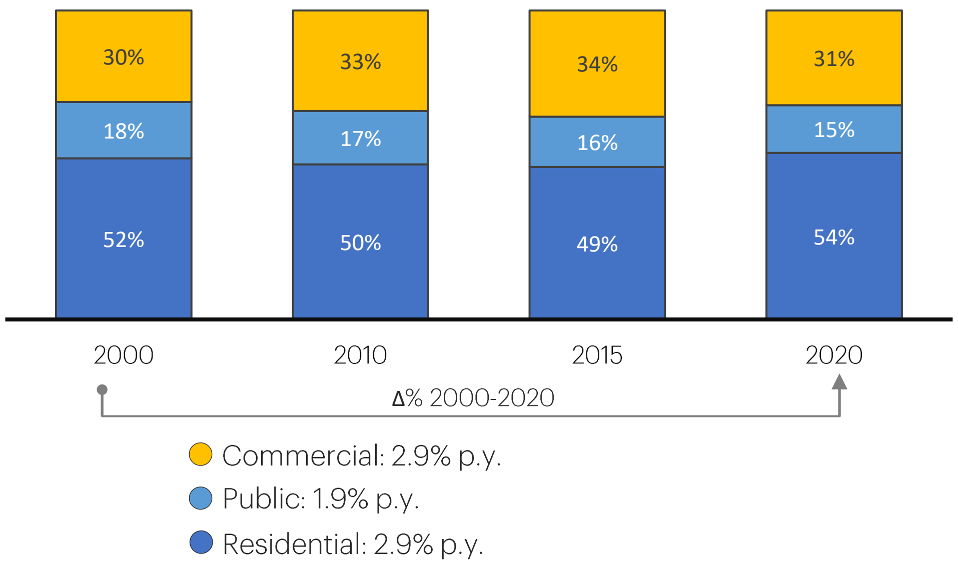


Figura 11 – Electricity demand in buildings
Fonte: EPE (2021b)



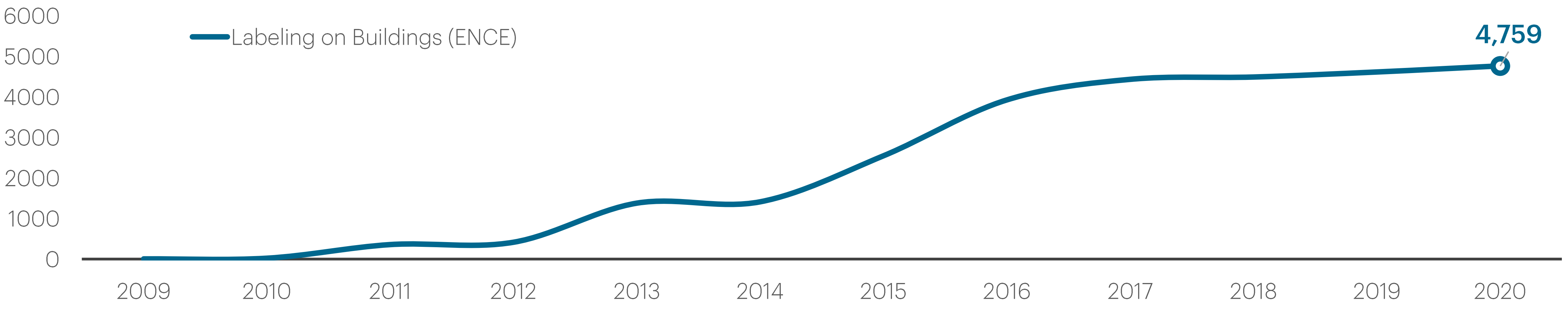
Buildings consume 51% of the country's electricity and because they have a large consumption of electricity it is in this segment that the greatest potential for electrical efficiency lies. PROCEL estimates that the Procel Buildings Label avoided consumption of about 29,25 GWh in buildings built between 2015 and 2020. (Procel, 2021).

Note: the public sector includes public lighting and sewerage.

Evolution of Labeling on Buildings - Brazilian Labeling Plan (PBE Edificações)

The labeling of buildings in Brazil began in 2009, with the publication of methodologies for rating the level of energy efficiency for residential, commercial, service, and public buildings. The label can be awarded for the project and for the constructed building. The cumulative data in the figure show the potential for penetration that exists in this policy, which informs the performance requirements of the building.

Figure 12 – Evolution of the National Label for Energy Conservation in Buildings – ENCE
Source: INMETRO (2021)



In 2014, the buildings owned by the direct federal public administration, autonomous and foundational, were made to comply with Labeling of Buildings. This was done through the SLTI Normative Instruction No. 2/2014 (IN 02/2014), of the Ministry of Planning, Budget and Management (MPOG), which provides on the rules for the acquisition or leasing of energy-consuming machines and appliances and the use of the National Energy Conservation Label (ENCE) in projects involving new construction or retrofitting of federal public buildings. According to IN 02/2014, for buildings, projects must be developed or contracted to obtain the General ENCE class "A" for Project, and the construction of the new building must be carried out or contracted to ensure that the General ENCE Class "A" for Constructed Building is obtained.

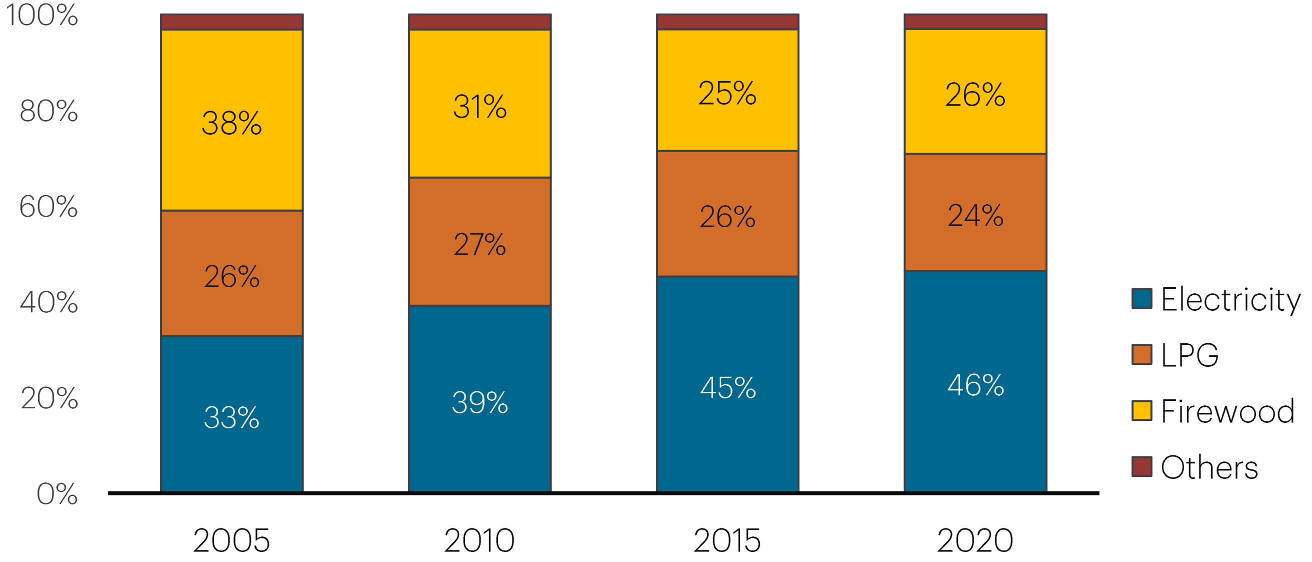
Residential Sector

Evolution of energy consumption by source in households

Electricity continues to be the most widely used energy source in Brazilian households, with a 13.6% increase between 2005 and 2020 (4% p.y.). Electricity is widely used in households, and can be used for air-conditioning, food conservation and cooking, electrical and electronic equipment and water heating.

Figure 13 – Energy consumption by source in households – selected years

Source: EPE (2021b)



LPG (liquefied petroleum gas) maintains an intermediate share (24,4% in 2020), and its main use is associated with cooking. Natural gas (included in "Other") is used predominantly for cooking and water heating, mainly in the most developed regions of the country that are supplied with this source. The share is still very low in total consumption.

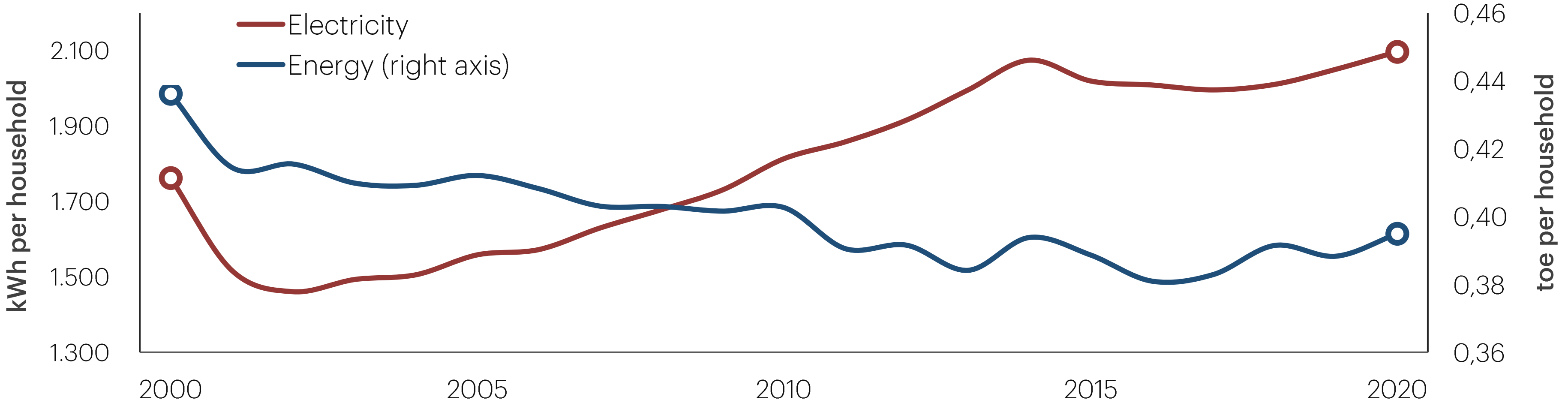
The decrease in the consumption of biomass (firewood and coal) as an energy source in households occurred due to the improvement in economic conditions of families, especially between 2005-2014. The share of firewood in cooking food increased in 2020 when compared to 2015, due to adverse economic times, replacing LPG in poorer households.

Evolution of electricity and energy consumption in households

While energy consumption per household fell 9.4% (decreasing 0.5% annually) from 2000 to 2020, electricity demand per household grew 19% (increasing 0.9% per year). In this period, demand for electricity increased as a result of economic progress among families, the advance of credit for the purchase of household appliances, government policies on access to electricity, especially in rural areas, and housing programs and incentives to reduce Brazil's housing deficit.

Figure 14 – Electricity and energy consumption by household

Sorce: EPE (2021b)



Final energy consumption fell in the period as a result of the reduction in the use of less energy-efficient sources (traditional biomass - firewood and charcoal) and the consequent substitution by more efficient sources (LPG, natural gas, electricity). Total energy and electricity consumption fell sharply in 2001 due to the country's electricity rationing. This stimulated a change in habits and promoted energy efficiency measures in Brazilian households. It is important to point out the reduction in energy consumption per household until 2015, when it began to advance due to the return of the use of firewood for cooking food, replacing the relatively more expensive LPG, especially in poorer families with the economic crisis.

Existing policies for energy efficiency in households

The main energy efficiency measures in households are implemented through policies of mandatory or voluntary standards and labelling on equipment and appliances. These policies include: Minimum energy efficiency indexes (or maximum consumption), comparative labelling (mandatory or voluntary) and endorsement labels.

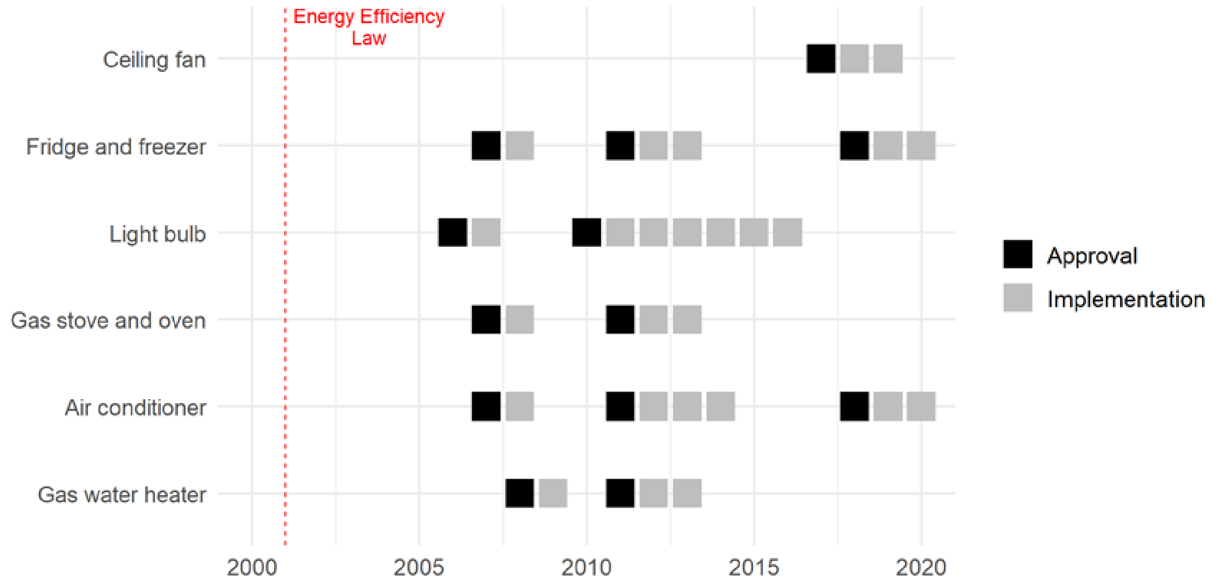
These initiatives have been implemented in Brazil since 1984, with the creation of the Brazilian Labeling Program (PBE), coordinated by the National Institute of Metrology, Quality and Technology (INMETRO), which created comparative energy performance labels for equipment, providing consumer education and encouraging the manufacture of products with higher efficiency levels by the industry. According to INMETRO, PBE currently has 38 programs involving different types of products, from air conditioners to buildings and light vehicles.

In partnership with PBE, PROCEL (for electrical equipment) and CONPET (for products that use oil products and natural gas as fuels) stamps were created in 1993 in order to value and reward the most energy efficient devices.

In addition to standards and labeling policies, there are complementary initiatives in the country that seek to promote energy efficiency through norms, certifications and programs, which include not only electricity-consuming appliances, but also the thermal performance of buildings, their relations with the residents and the encouragement for the use of alternative energy generation systems in social interest housing (HIS).

Figure 15 – Period of approval and implementation of policies for minimum energy efficiency standards for residential appliances

Source: Compiled by EPE based on MME data



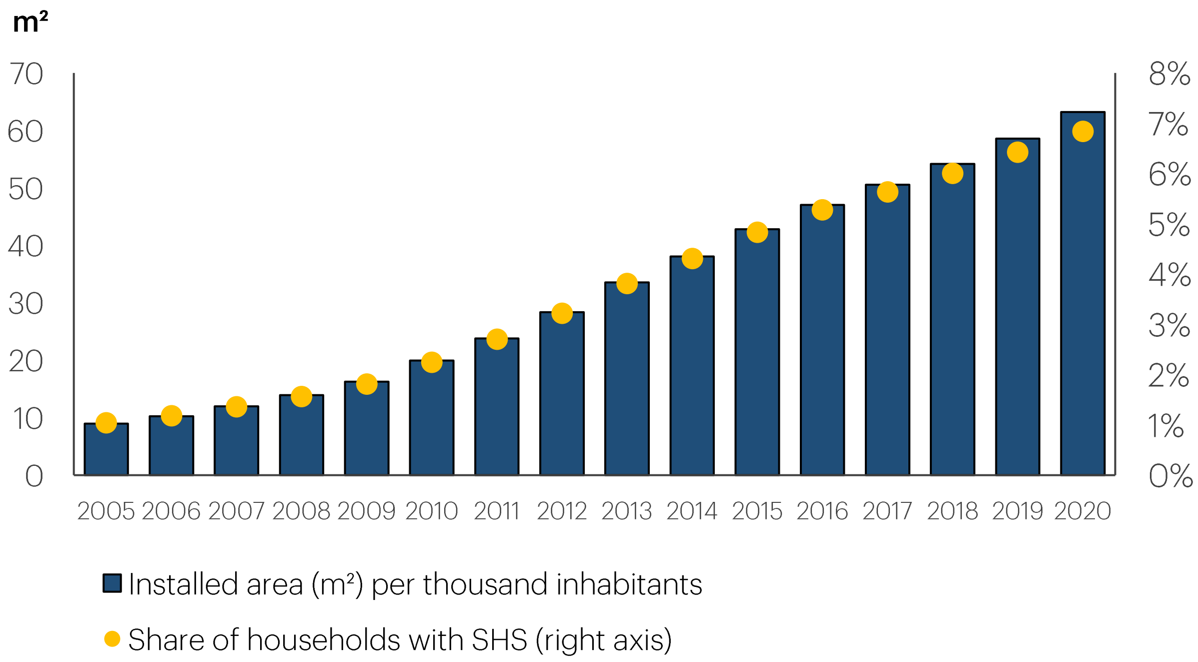
Note: Dates contained in specific regulations and target plans are considered. For lighting data, the specific regulations and target plans for incandescent and compact fluorescent lamps are considered.

Solar Heating Systems (SHS) in households

The conversion of the sun's energy into thermal energy is based on the absorption of solar radiation and its transfer in the form of heat to an element that will provide a certain energy service. In general, solar thermal energy can be used to heat water in households and in industrial processes. Solar water heating systems are composed of solar collectors and a thermal tank, where the heated water is stored. The SHS have complementary heating equipment, which can use electricity or gas, and are activated in periods of low solar intensity. The quality standards for the collectors and reservoirs are standardized by the Brazilian Labeling Program, coordinated by INMETRO.

Figure 16 – Solar Heating Systems (SHS) in households

Source: Compiled by EPE



While for consumers, the use of SHS can reduce their total energy expenditure, for the electricity sector, its use can reduce grid electricity consumption, peak demand in critical periods, and technical losses in the system, contributing to postpone new investments in generation, transmission, and distribution. Finally, from the environmental point of view, the use of SHS can help reduce GHG emissions.

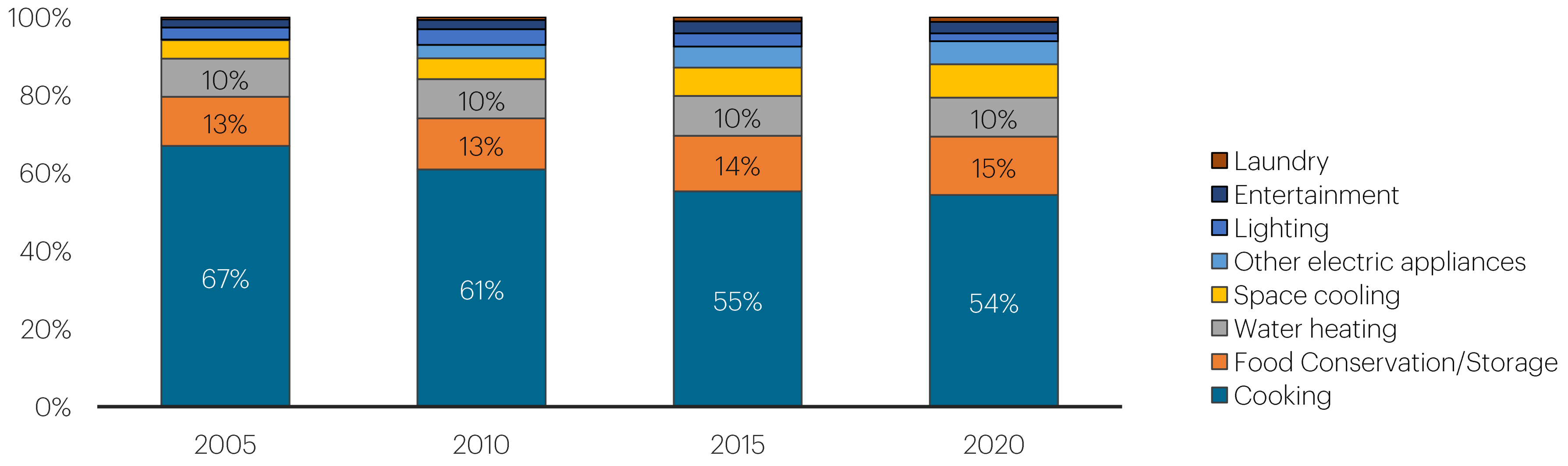
The total accumulated area of collectors reached around 19.2 million m² in 2020. It is noteworthy that the residential sector is the main destination of collectors, with almost seventy percent of the total new area installed in 2020 (ABRASOL). The diffusion of SHS technology displaces the use of electricity in electric showers to heat water for bathing.

Evolution of energy consumption by final use in households

Cooking represents the main energy end-use in households, followed by electrical appliances, water heating, space cooling and lighting. The reduction in consumption for cooking during 2005-2019 can be explained by the replacement of traditional biomass with modern fuels as families make economic progress. Lighting, on the other hand, has been losing share over time due to the increasingly widespread use of more efficient light bulbs, especially compact fluorescents and LED (light-emitting diode) technology.

Figure 17 – Residential energy consumption by end use

Source: Compiled by EPE



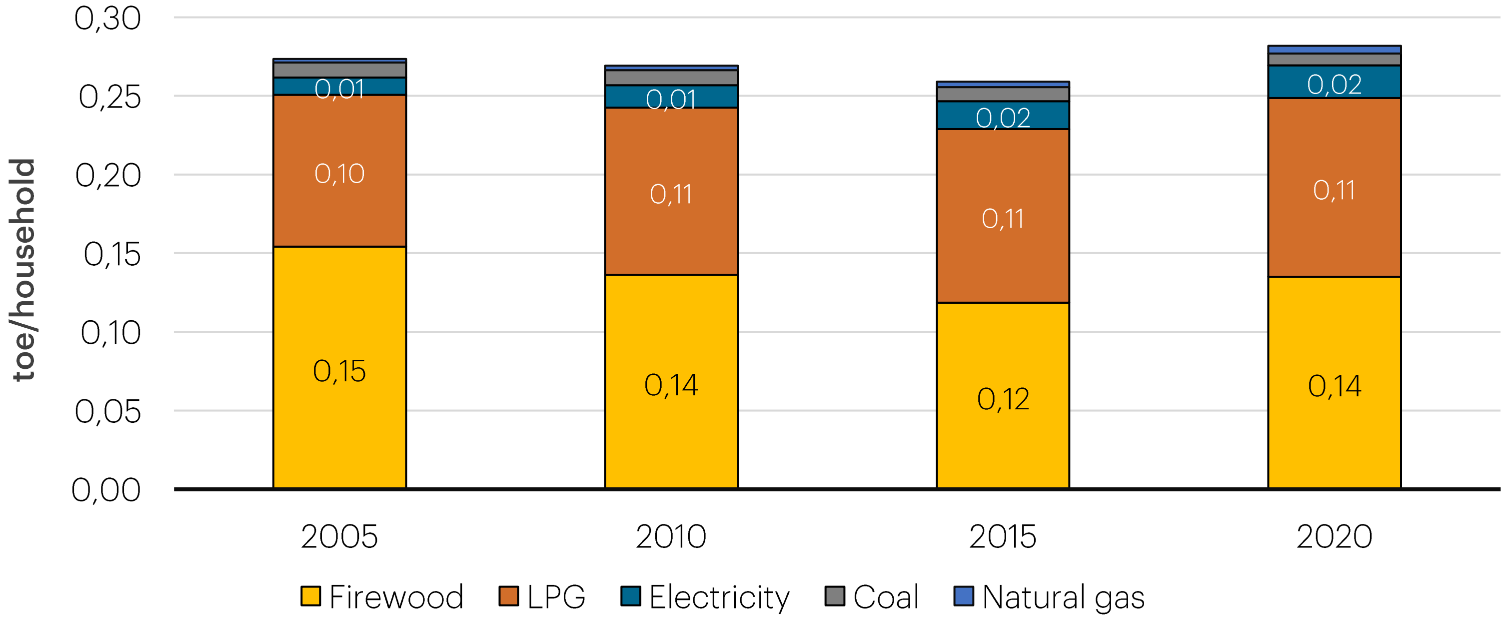
The growth in the share of electrical and electronic appliances in the period can be explained by an increase in ownership by families due to increased income, the ease of access to credit and reductions in appliance prices. Space cooling has been gaining ground over time due to the increased use of air conditioners, as families are able to afford them, replacing relatively cheaper fans and air circulators. Uptake can also be in response to an increase in average cooling degree days over the years.

Evolution of energy consumption for cooking by source

Firewood is the source that has the highest energy consumption per household in the country, due to its lower performance compared to other more modern sources, generating more waste in relation to the generated energy. LPG, on the other hand, manages to have a large in Brazil, reaching around 94% of Brazilian households in 2020.

Figure 18 – Evolution of energy consumption for cooking by source

Source: Compiled by EPE



The share of electricity use in food cooking is still very small, corresponding to the use of electric and microwave ovens and stoves. Cooking is predominantly done by sources such as LPG and traditional biomass. The use of natural gas is also very small, basically restricted to urban areas of cities with installed infrastructure.

Electricity – Final uses, ownership and average annual consumption by appliance

Figure 19 – Residential electricity consumption by end use

Source: Compiled by EPE

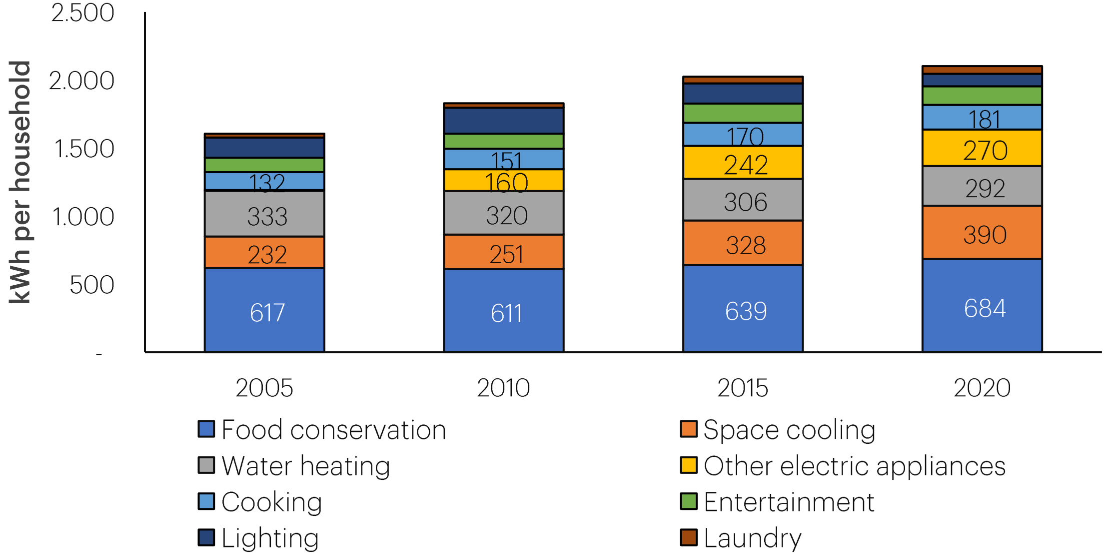
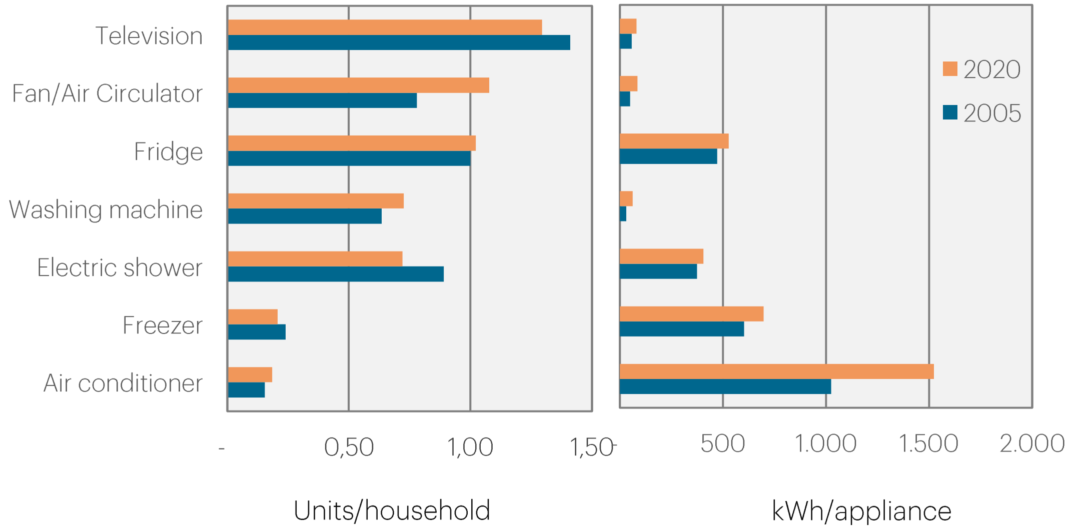


Figure 20 – Ownership and average annual consumption by equipment type

Source: Compiled by EPE



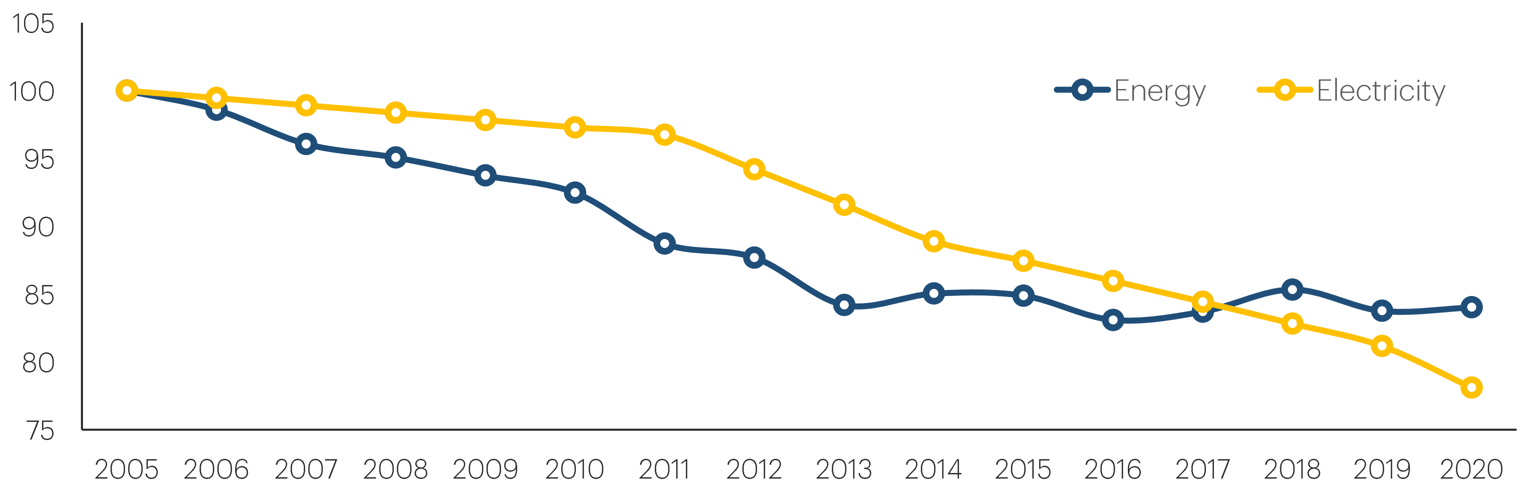
Food preservation is the end use with the highest consumption per household in the country, due to the fact that refrigerators are in almost every Brazilian home, stay on 24 hours a day every day of the year and have a significant specific consumption. Fans and air circulators have an ownership level slightly higher than 1 unit/household, being a lower cost solution for space cooling. The reduction in the use of electricity for water heating is due to the increased penetration of solar water heating systems (SHS) and the expansion of the natural gas network over the period 2005-2020.

While the penetration of new and more efficient equipment tends to reduce the average energy consumption of the existing stock in the country, in another way, the increase in the frequency of use of the appliances over the years, still repressed in many cases, contributes to increase it. Despite the low ownership of 0.18 unit/household of air conditioners in 2020, they have the highest specific consumption. The ownership of freezers and electric showers fell in the period. Regarding freezers, the reduction is largely a result of the change in the habits of families in the last decades that have stopped replacing appliances that have reached the end of their useful life and been scrapped.

Residential ODEX

ODEX is an efficiency indicator that, for households, aggregates the consumption trend of the different end uses, or appliances, based on their share in total consumption.

Figure 21 – Evolution of residential ODEX calculated for total energy and electricity
Source: Compiled by EPE



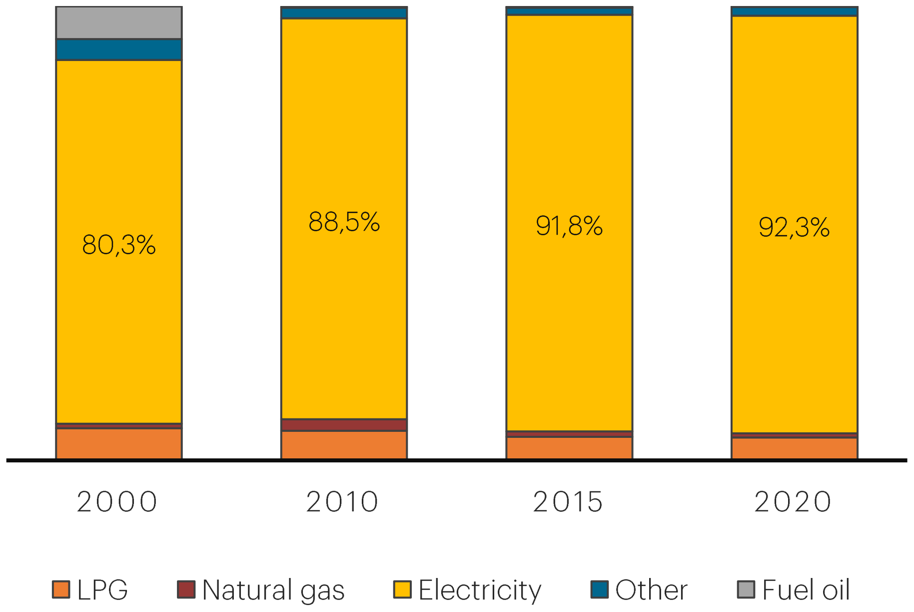
While ODEX calculated for total energy fell approximately 16% (1.2% p.y.) between 2005 and 2020, the decline of ODEX for electricity consumption fell 22% (1.6% p.y.). It is observed that in recent years the retraction of the indicator is more significant for electricity, suggesting the importance of this source in residential energy conservation in the Brazil.

The indicators associated with energy consumption in households analyzed in this document suggest that when we consider the main end uses, as well as the main electrical appliances, we observe a trend toward energy efficiency in the Brazilian residential sector between 2005 and 2020. For electricity, we observe a reduction in the average specific consumption of the national stock of equipment, due to the first purchase or replacement by more efficient appliances those at the end of their useful life or those that have become unused. On the other hand, the replacement among the energy sources influences the behavior of the energy indicator, such as, for example, the return to the use of firewood in moments of a weakened economic scenario and the increase in the cost of LPG, especially for low-income families. In addition to inducing public policies, energy efficiency is the result of complex interactions that include economic, social, technological and behavioral factors of families.

Services
(commercial and public services)

Overview: evolution of final energy consumption by source in the services sector [1]

Figure 22 – Final energy consumption in the services sector
Source: EPE (2021b)



The final consumption of natural gas by establishments grew 1.9% p.y. in the period from 2000 to 2020, with its consumption peaking in 2007. It is worth noting that part of the natural gas is used to generate electricity, which is not counted, according to Brazilian Energy Balance's methodology, as final consumption.

As of 2005, LPG consumption stabilized at the 600 ktoe level, influenced by the ANP's resolution 22/2005 Art.30, which forbids the use of LPG in:

- Saunas
- Boilers
- Swimming pool heating, except for medicinal purposes
- Engines of any kind, including for automotive purposes, except for forklift trucks and industrial cleaning equipment powered by internal combustion engines.

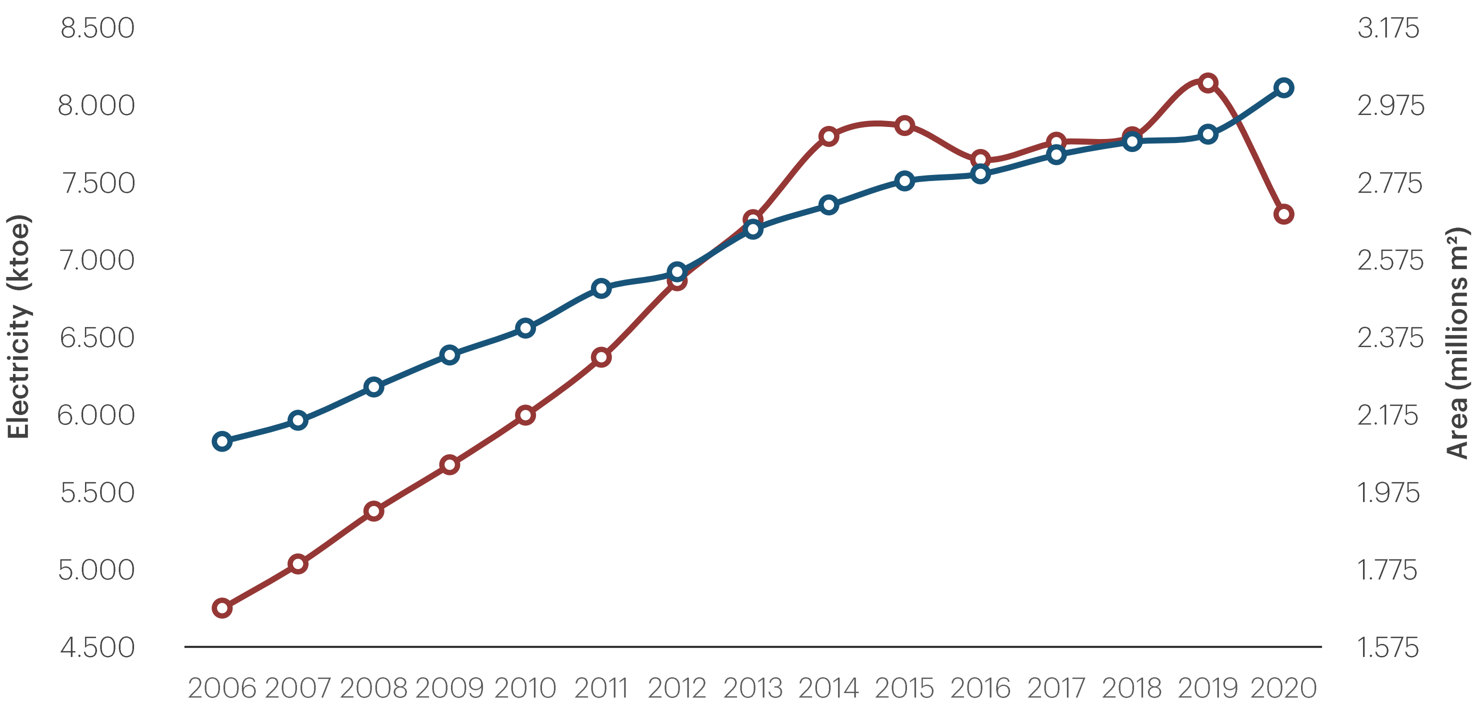
Electricity has continued to gain importance in the sector's final consumption between 2000 and 2020 and may be associated with several factors such as increased ownership of electrical equipment and appliances, increased automation and process control, and substitution of the use of secondary sources, among others. However, **between 2019-2020, electricity had a 10% decrease due to the shutdown of the sector's activities, especially those said to be non-essential in the context of the pandemic.**

[1] Commercial and public sectors according to the Brazilian Energy Balance classification

Analysis: Commercial Sector

The period 2006-2019 has seen an incremental increase in the area of commercial establishments with an average annual rate of 2.5%, while in the same period the electricity consumption of the sector shows an increase of 4.2% per year. According to ABRAVA's economic bulletin (2020), the sale of central refrigeration equipment such as chillers, VRF (variable refrigerant flow) and package units grew 9% per year between 2010-2014, and then decreased 3.4% per year from 2014-2019, corroborating for the aforementioned consumption trend.

Figure 23 – Evolution of Energy Consumption and Area in the Commercial Sector
Source: Compiled by EPE



In 2020, total area grew 4.1% year-over-year, driven by the expansion of the Hospitals, Emergency Rooms, and Information Broadcasting segments, among others. On the other hand, the paralyzation or reduction of activities led to the closure of some commercial establishments, especially bakeries, confectioneries, bars, and restaurants. It is worth mentioning that such measures, required to combat the spread of the Covid-19 virus, have led to operational adaptations in the commercial sector, intensifying implementations of e-commerce systems, delivery services, teleworking, and distance learning modalities, among others. Thus, while the area of establishments expanded by 4.1% compared to 2019, electricity consumption reduced by 10.4%.

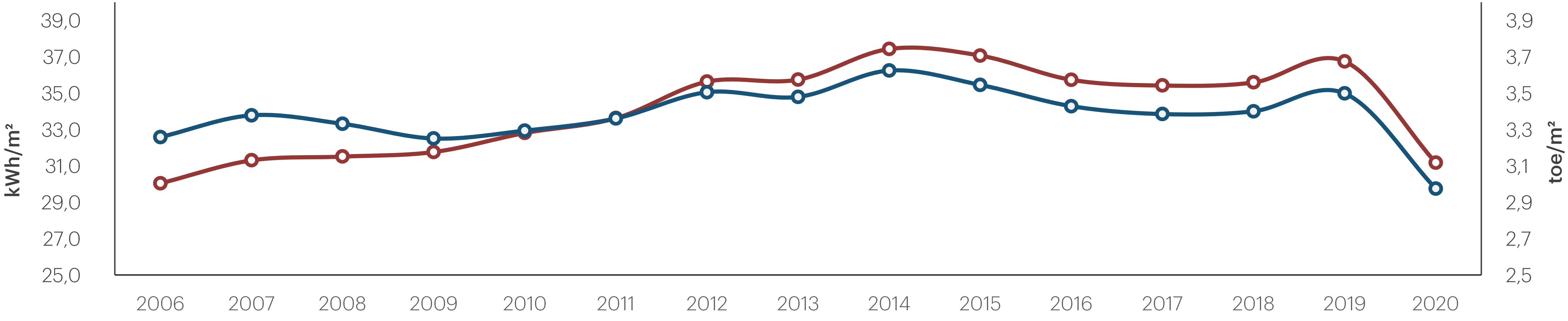
Analysis of sectoral indicators: evolution of consumption per m² of commercial and public buildings

Energy consumption per square meter in commercial and public buildings grew in the period from 2006 to 2014, especially as the ownership and use of electric appliances increased. However, from 2014 on, the indicator shows stability until 2019 culminating in a steep decline in the pandemic year of Covid-19. It is important to note that both indicators are under the effect of energy efficiency, as ongoing efficiency policies mitigate consumption growth. However, there are other contributing factors that corroborate for the illustrated trajectories, such as:

- The implementation of Aneel Resolution 414/2010 which reclassified part of the electricity consumption of condominium buildings, previously accounted for in the residential sector, to the commercial sector.
- The climate effect that intensifies/attenuates the use of environmental conditioning equipment: air conditioners, fans, among others.
- Hydric, Economic and Sanitary Crises. Economic and Sanitary crises over the last years.

Figure 24 – Consumption[1] per square meter

Fonte: Compiled by EPE

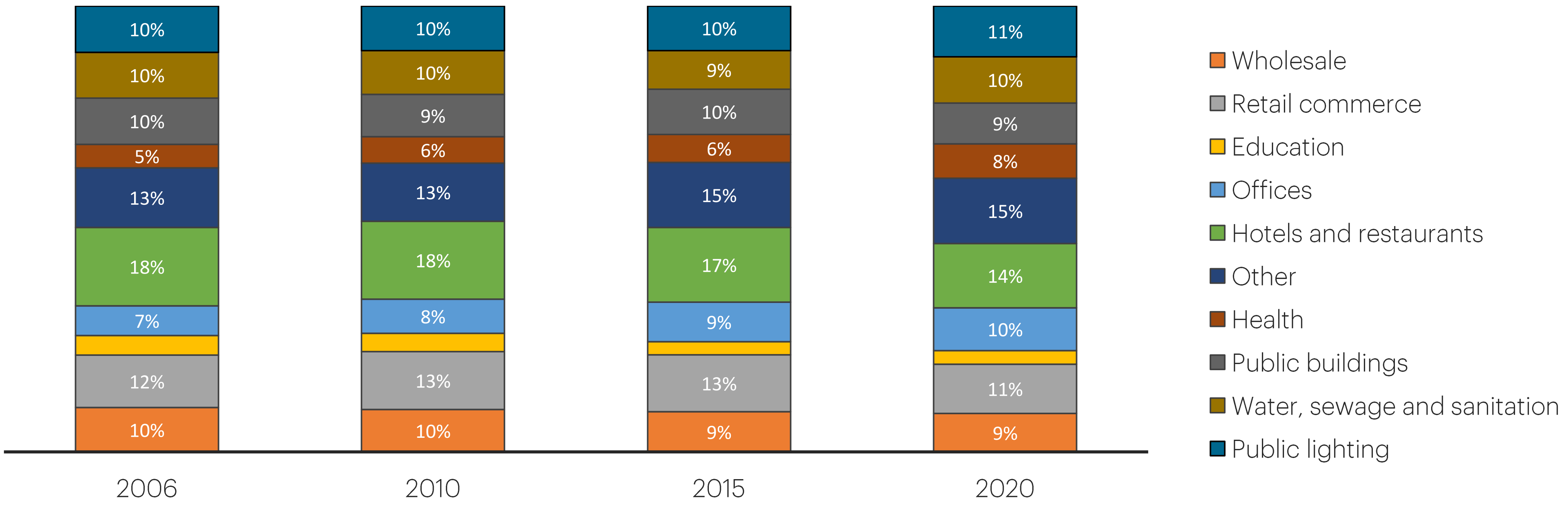


[1] Does not include consumption of the following segments: public lighting, water, sewage and sanitation.
The consumption in toe considers all the energy sources.

Energy consumption by segment 2006-2020

Figure 25 – Energy consumption by segment in the services sector

Source: Compiled by EPE



The services sector, intrinsically heterogeneous, presents a certain homogeneity in the annual energy amounts consumed per segment throughout the period. However, in 2020, with the Covid-19 pandemic, the healthcare segment gained share in final energy consumption at the expense of the retail, hotel and restaurant segments.

Some current energy efficiency policies

For the services sector, important energy efficiency policies drive the penetration of more efficient equipment and buildings, and in particular:

- Brazilian Labeling Program - INMETRO, created in 1984;
- PROCEL RELUZ - National Program for Efficient Public Lighting and Signaling, created in 2000;
- Energy Efficiency Program – PEE (Portuguese) regulated by ANEEL , created in 2000;
- Law nº 10.295 of 2001 - Provides for the National Policy of Conservation and Rational Use of Energy (Energy Efficiency Law);
- Technical Group for Energy Efficiency in Buildings – created in 2001 Grupo Técnico para Eficientização de Energia em Edificações – criado em 2001;
- Procel Edifica, Energy Efficiency Program in Buildings - Eletrobrás/Procel – created in 2003;
- PROCEL SANEAR - Energy Efficiency Program in Environmental Sanitation, created in 2003;
- PROCEL Annual Resource Plan, Law No. 13,280/2016;
- Procel Label for appliances/equipment (1993) and buildings (2020);
- ABNT/NBR 15220/2005 - Brazilian Thermal Performance Standard for Buildings;
- ABNT/NBR 15575/2013 - Performance for residential buildings, residential buildings of up to five floors;
- INMETRO, Technical Regulation for Quality (RTQ, in Portuguese) for Energy Efficiency of Commercial, Services and Public Buildings, Technical Regulation of Quality for Energy Efficiency Level of Residential Buildings - RTQ-R, RAC - Requirement of Conformity Assessment for Buildings and its Complementary Ordinances;
- SLTI Normative Instruction no. 02/2014 of MPOG.

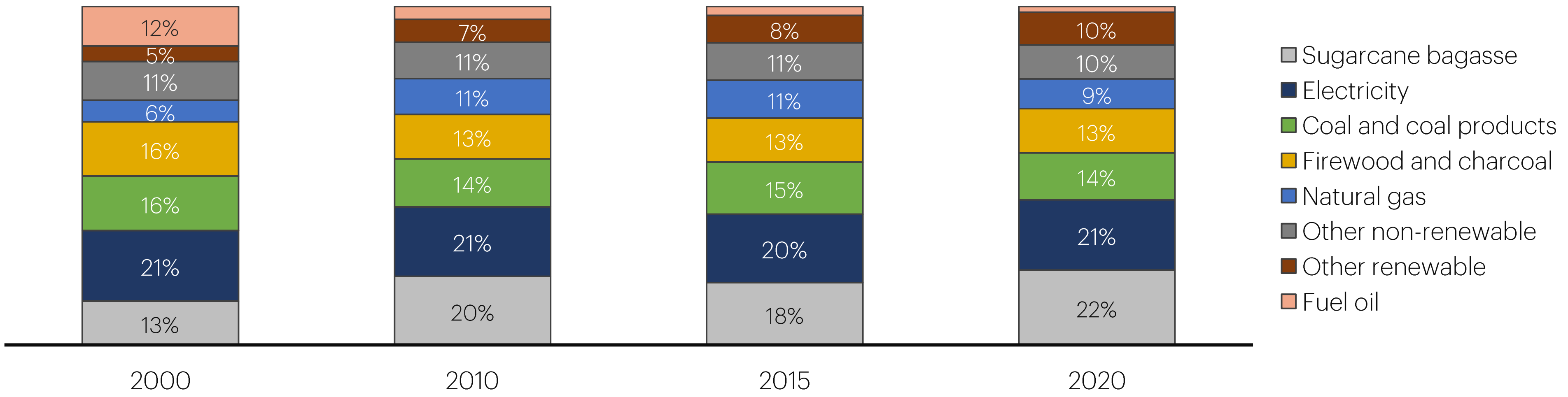
Industry

Industrial sector overview: evolution of energy consumption by source

The industrial sector was strongly impacted by the decrease in industrial economic activity, especially in 2020 due to the restrictions imposed by the pandemic. The industry has replaced a large part of fuel oil with different types of fuels such as natural gas (in several segments, such as chemicals and food and beverages) and petroleum coke (in the cement industry), reducing its share from 12% to 2% over the analyzed period. Sugarcane bagasse and other renewables (mainly black liquor) gain relevance, associated with the sugar and pulp industry, respectively. Electricity maintains its participation around 21%.

Figure 26 – Final energy consumption by source

Source: EPE (2021b)



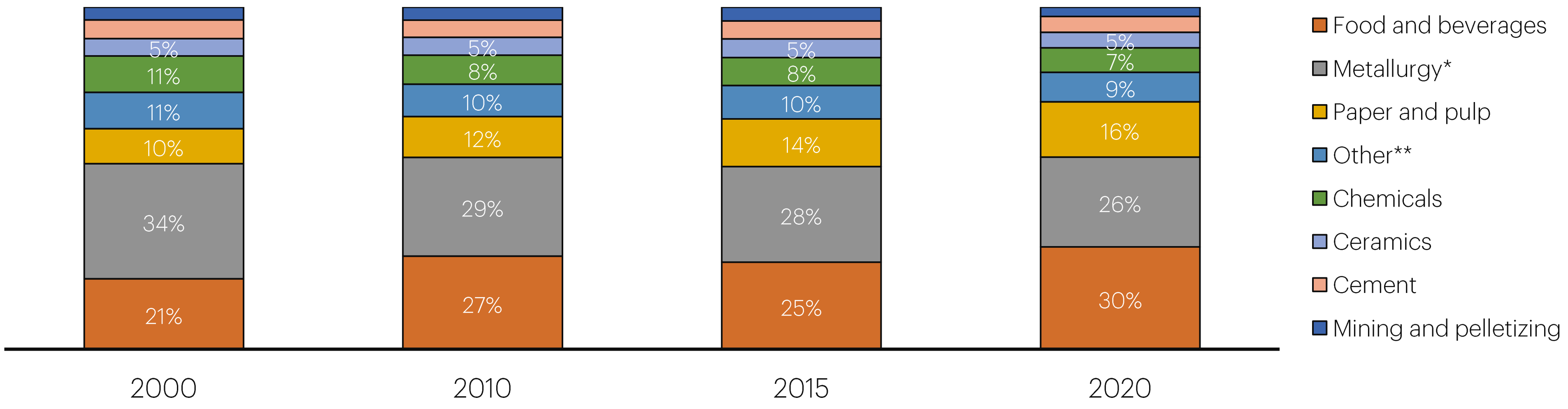
Between 2015 and 2020, the main industry sources that stood out, in order of relevance, were: sugarcane bagasse, electricity and other renewables. In 2020, the reduction in consumption of sources such as natural gas, other non-renewable and fuel oil portrayed the high level of idleness of several industrial segments.

Industrial sector overview: evolution of energy consumption by subsector

The increase in the share of the sugar and pulp production sectors ratifies, respectively, the increase in the share of sugarcane bagasse and other renewables in industrial consumption. A decrease in the share of fuel oil is observed, gradually displaced by petroleum coke (notably in cement production) and by other renewables (in paper and pulp production).

Figure 27 – Sectorial shares of final energy consumption in industry

Source: EPE (2021b)



> The sum of final energy consumption in only three sectors (including metallurgy, food and beverage and pulp and paper) corresponds to 72% of the total consumed by industry in 2020. Compared to 2015, there was an increase in the participation of the food and beverage sectors (+5%.), especially sugar, and paper and cellulose (+2%), while the participation of metallurgy decreased by -2%.

*Metallurgy includes steel, ferroalloy, non-ferrous and other metallurgy

** Other includes textiles and other industries

Evolution of energy consumption, value added and intensity of the Brazilian industry

- Between 2001 and 2013 there was a growth trend in industrial activity and energy consumption in industry, interrupted occasionally during the energy crisis (2001) and the global recession caused by the international financial crisis (2008/2009). The energy intensity remained relatively stable, especially between 2005 and 2010.
- Between 2010 and 2013 the economy recovered, with growth of up to 10.9% of GDP, and reduction in industrial intensity.
- Between 2014 and 2019, however, this trajectory was reversed. A retraction of the industrial GDP per capita by 3.9% per year was confirmed by the reduction in the production of domestic industrial goods due to the economic crisis, which was associated with the deteriorated domestic scenario.
- Likewise, the idleness level of the manufacturing industry was boosted, and with a greater share of energy-intensive industries, there was an increase in energy intensity of 1.3% per year during this period.
- Throughout 2020, the world and national economies were impacted by the Covid-19 pandemic, which led to isolation measures and restrictions on mobility. The expectation of reduced demand impacted the operation of industrial plants, and consequently the drop in energy consumption and industrial value added, especially in the first half of the year.

Figure 28 – Total Energy Supply, final industrial energy consumption and industrial value-added

Source: Compiled by EPE, using EPE (2021b) and IBGE (2021)

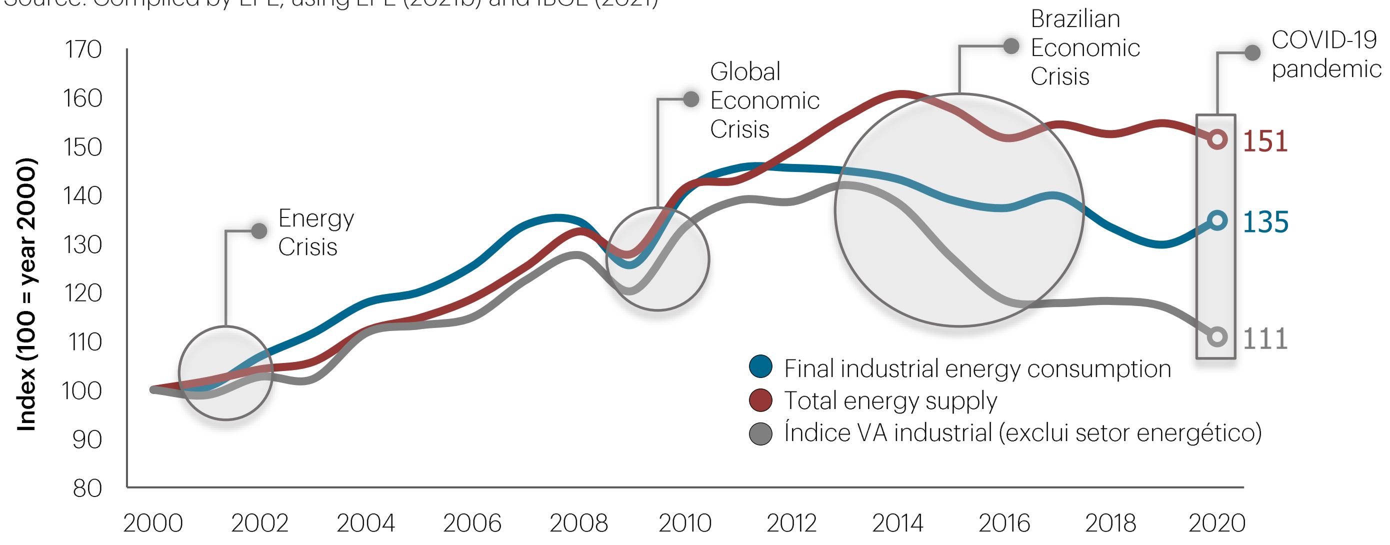
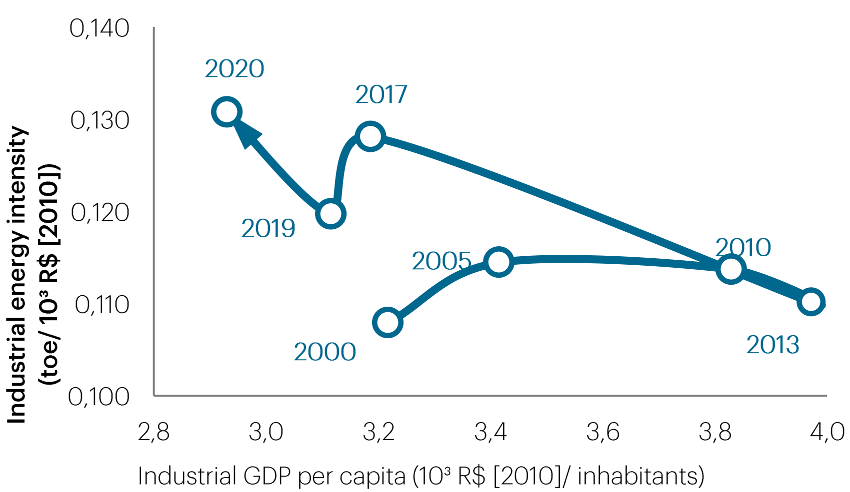


Figure 29 – Path of energy intensity and GDP per capita in industry

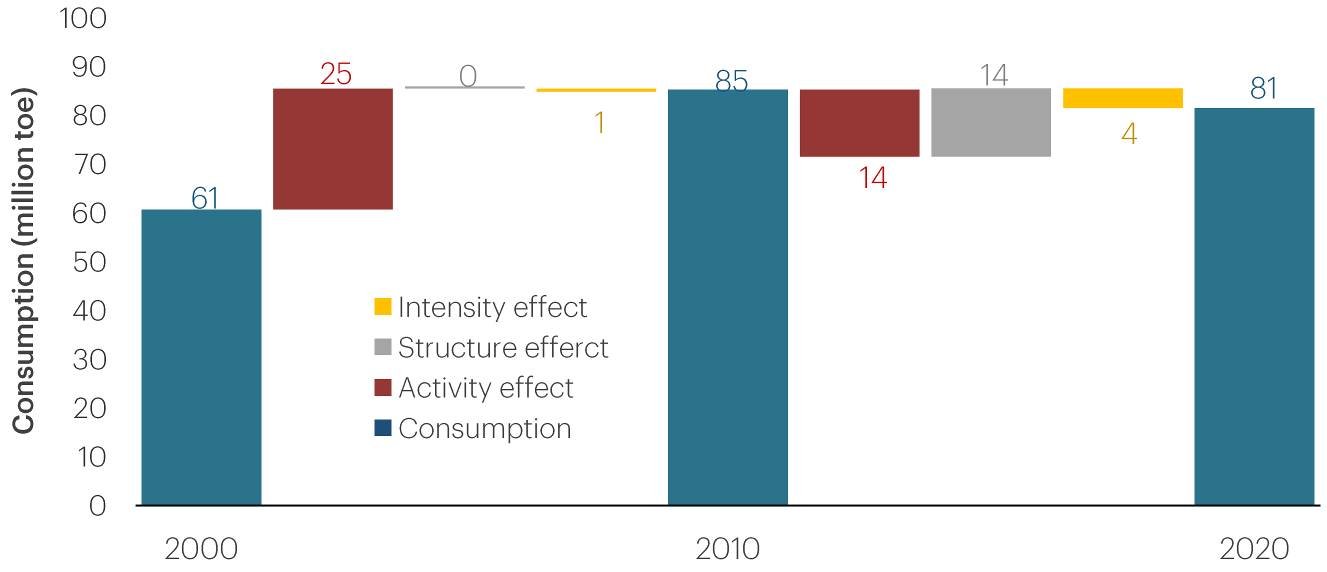
Source : Compiled by EPE, using EPE (2021b) and IBGE (2021)



Decomposition analysis: between 2000 and 2020 industrial energy consumption increased by 1.5% per year...

Figure 30 – Breakdown of changes in industrial energy consumption

Source: Compiled by EPE, using EPE (2021b) and IBGE (202)



The variation in industrial consumption can be explained by three main effects: variations in activity level (value added), changes in structure (relative share of industrial segments) and intensity of each segment.

Between 2000 and 2010 there was a large increase in industrial activity, and the structure and intensity effects were small and offset each other. The industries that grew most in the period were food and beverages, mining and pelletizing, and pulp and paper.

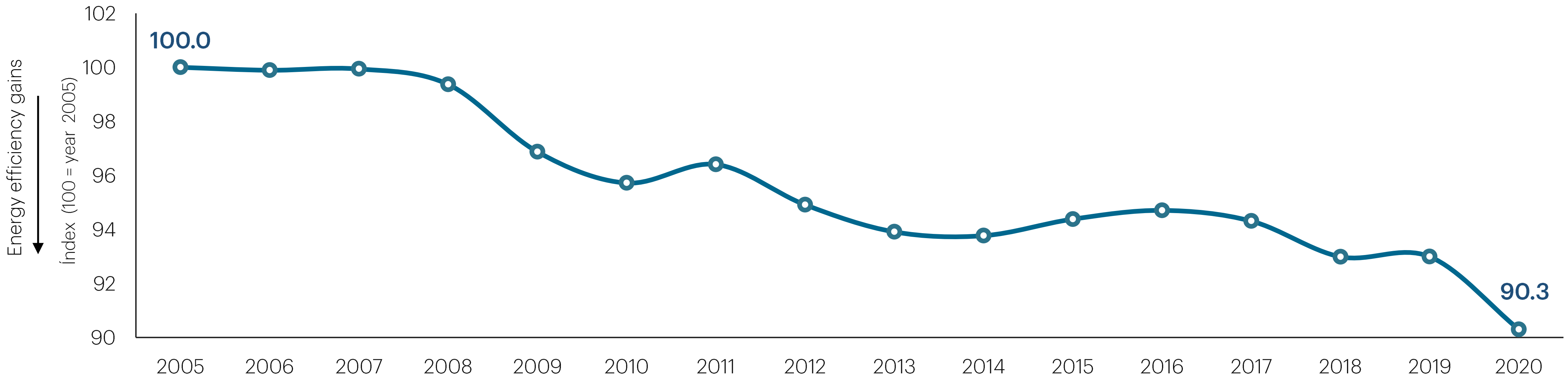
Between 2010 and 2020 industrial consumption fell due to reduced industrial activity (due to the various economic crises that have impacted the industrial sector since 2014), and also due to energy efficiency gains. However, part of the reduction is offset by the structure effect.

The food and beverages and paper and cellulose industries stood out for growing throughout this period. However, in the first period, practically all the segments grew, with little structural variation. In the second period, several industries reduced their activity and lost share, especially textiles and other industries, with energy-intensive segments predominating - increasing the intensity of the national industry.

Industrial ODEX

Specific consumption was examined for the steel, paper and pulp, cement, and sugar sectors, while energy intensity was examined for 'other food', textiles, chemicals, ceramics, ferroalloys, 'other metallurgy', mining, and 'other industries', based on available information.

Figure 31 – Industrial ODEX
Source: Compiled by EPE

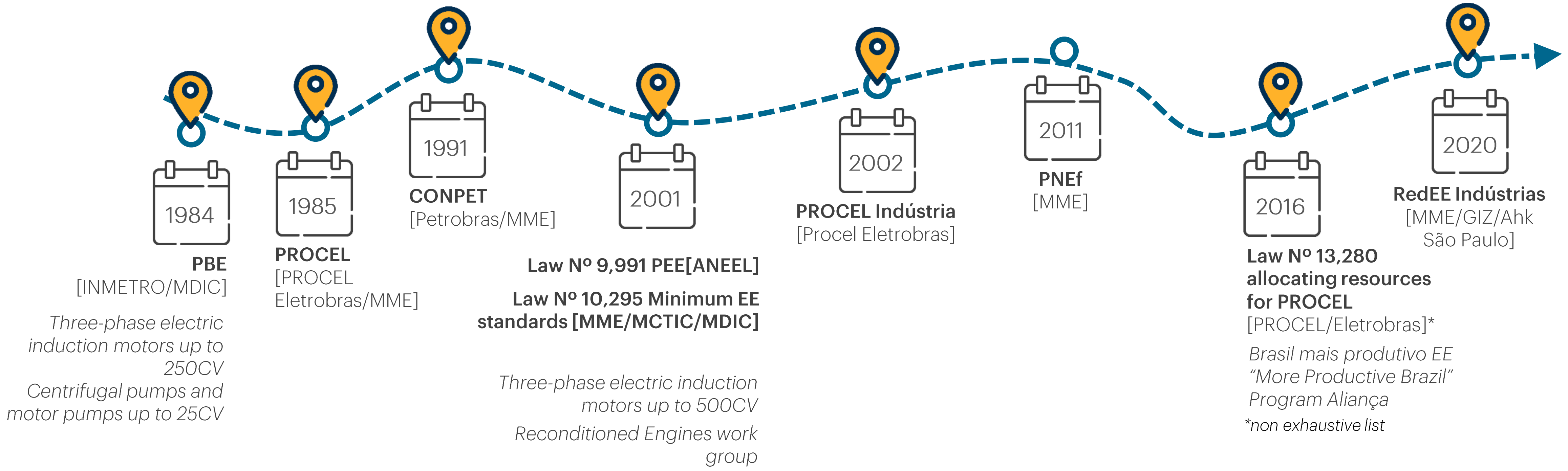


In 2020, ODEX for industry was 90.3, which is to say it was 9.7% lower than the ODEX for 2005, with an average reduction of 0.7% per year. The segments with the highest efficiency gains in the period were metallurgy and mining and pelletizing. From 2019 to 2020, the chemical and cement industries contributed the most to the improvement of the indicator.

Timeline: current energy efficiency policies

Figure 32 – Main highlights of energy efficiency policies related to the industrial sector

Source: EPE. Images; Icons made with Freepik - www.flaticon.com



For the industrial sector, important policies have boosted gains in technological innovation, both in the use and in the production of products related to the energy efficiency market. These policies have driven the penetration of more efficient equipment and processes and also take advantage of energy efficiency opportunities, besides representing a driver for gains in competitiveness.

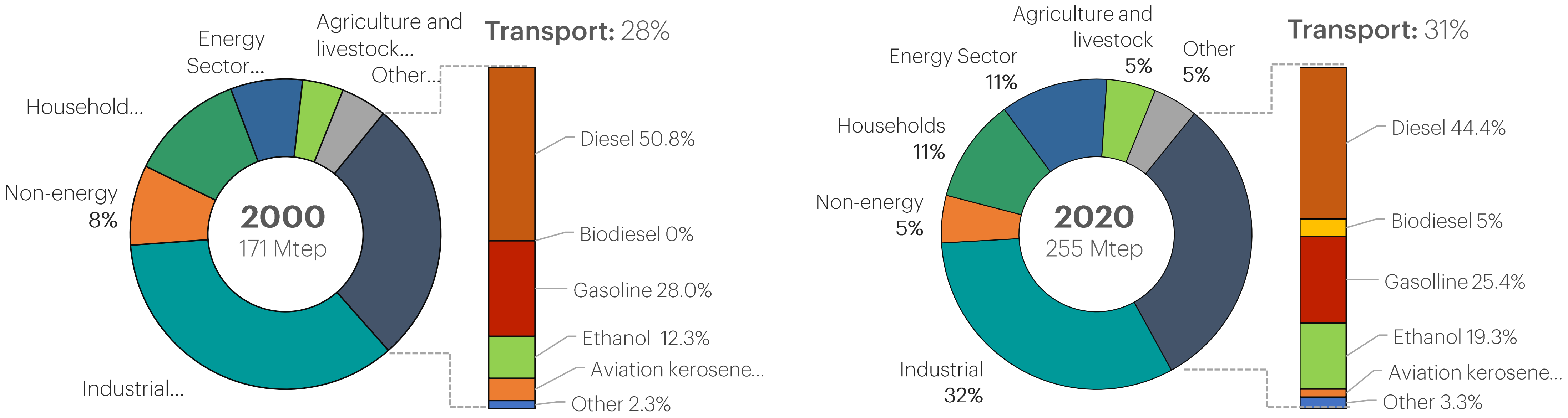
Transport

Evolution of energy consumption in the transport sector

In 2020, national energy consumption fell by 2.0% compared to 2019, a lower rate than the reduction in GDP, 4.1%. The effects of the Covid-19 pandemic reflected on the performance of the various sectors intensively. However, many recovered quickly, particularly food, export-oriented, and freight transport. As for the transportation sector, there was a decrease of 6.4%, with the share of passengers remaining small for most of the year, which explains the loss of share of the total transportation sector from 33% in 2019 to 31% in 2020.

Figure 33 – Final consumption and the transport sector in Brazil in 2000 and 2020

Source: Compiled by EPE, with data from EPE (2021b)



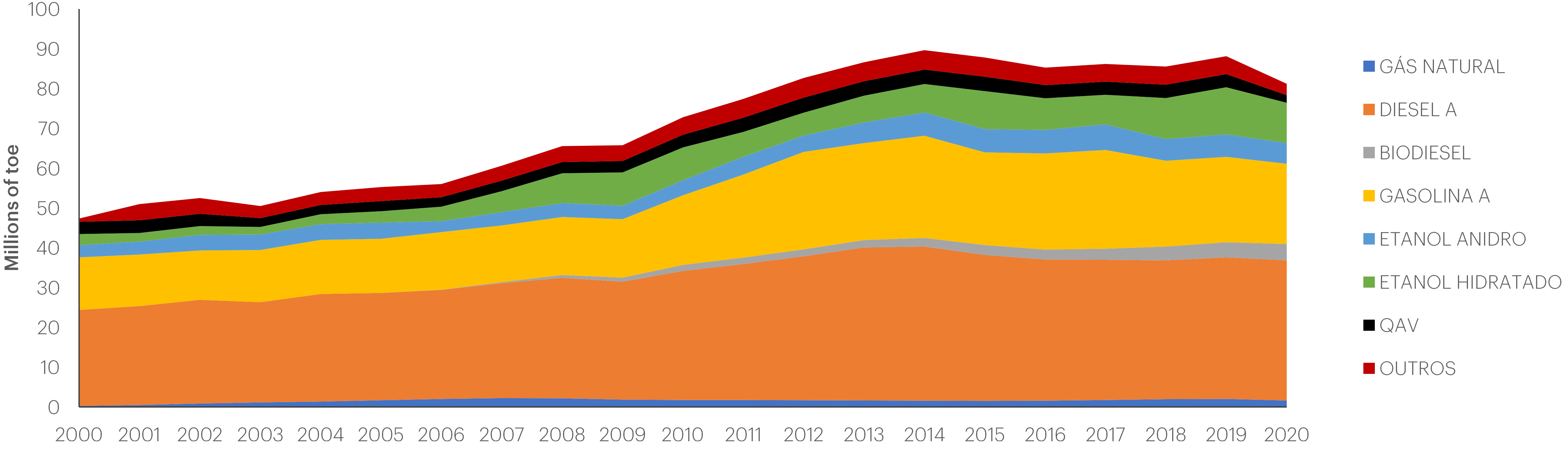
Evolution of the share of energy consumption in the Transport Sector

The Transport sector grew 2.9% per year between 2000 and 2020, when an increase in passenger and cargo transport was observed, due to the rise in the consumption of goods, the mobility of the population, and agricultural and industrial production. In the same period the national energy consumption grew 2.2% per year, in line with the GDP growth, which was 2.0% per year.

The air transport and passenger transport sectors were hit particularly hard, which explains the drop in the share of aviation kerosene, gasoline and ethanol from 2019 to 2020. Nevertheless, when compared to 2000, individual passenger transport gained relevance over the period, fostered especially by the increase in ethanol production.

Figure 34 – Transport sector consumption by energy source (million toe)

Source: Compiled by EPE, with data from EPE (2021b)

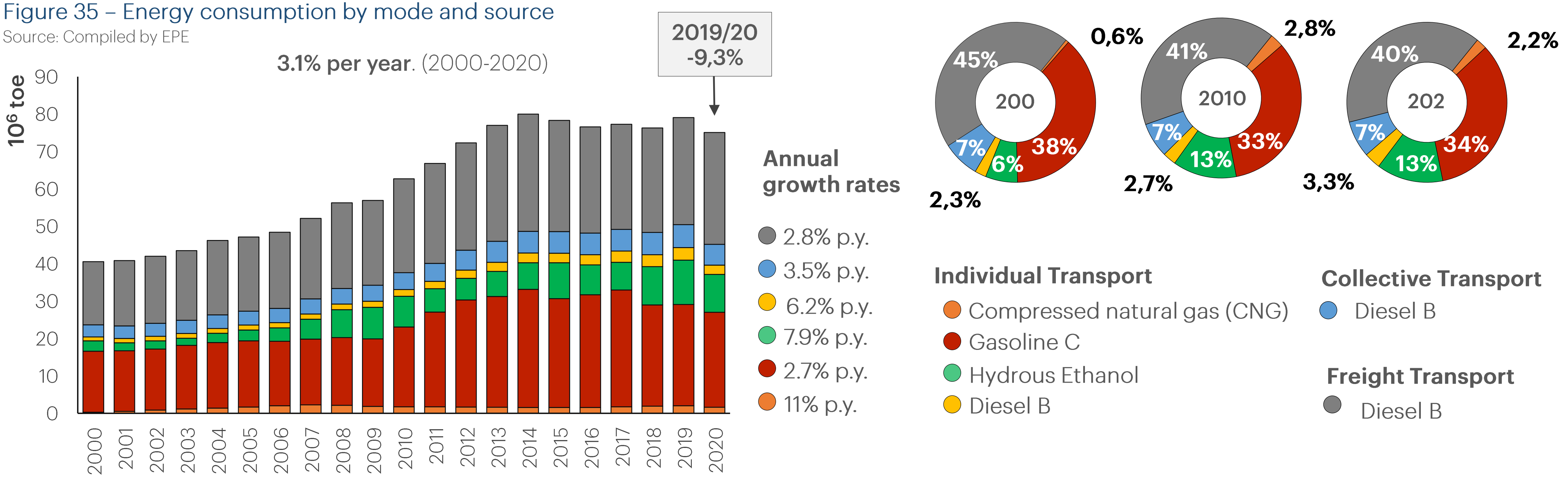


Evolution of energy consumption in road transport

Between 2000 and 2020, passenger transport demand increased by 3.3% p.a., and freight transport demand grew by 2.9% p.a.. The greater advance of individual transport has reduced potential systemic efficiency gains obtained through public transport. In 2020, passenger transport demand fell by 10.4%, while freight transport demand increased by 4.5%.

Figure 35 – Energy consumption by mode and source

Source: Compiled by EPE



The growth in the share of CNG and hydrous ethanol as energy sources in the road transport mix is noteworthy. Both have a higher specific consumption than gasoline vehicles, and therefore have limited the sector's efficiency gains. However, they have reduced transport emissions and Brazil's imports of fossil fuels. In 2020, both CNG and hydrous ethanol showed drops of 17.5% and 14.7% when compared to 2019, respectively, and lost share in the mix against gasoline, whose demand fell by 6.4%. It is estimated that there will be a reversal of this recent loss of market share.

Passenger Transport

Individual transport gained importance over the first decade of the 2000s, in line with greater income distribution, and at the expense of the sector's overall efficiency. The reduction in efficiency was intensified in 2020, with declining use of public transport and partially mitigated by the decline of the more energy-intensive air transport.

- Efficiency in the air mode has increased over the past two decades. However, in 2020, the reduction in aircraft activity and occupancy impacted this indicator. The decrease was mitigated due to cancellation of longer flights and flights with lower demand and occupancy.
- The share of the metro-rail transport has grown over the years with the entry of new infrastructure projects. The pandemic, however, discouraged the use of this mode, especially due to home-office adoption and increased unemployment. This should reverse itself with the normalization of the health situation.
- In recent years, the collective road transport became less efficient with the introduction of biodiesel and the growing use of air conditioning in the fleet of large cities. Throughout 2020, the lower use of this mode caused an increase in energy intensity, a condition that began to be reversed at the end of the year.
- The total energy intensity of passenger transport has decreased by 2020 as individual transport increases over public transport. To improve this indicator in the future, incentives to use public transport need to be prioritized.

Figure 36 – Energy intensity by mode [toe/(10^6 p.km)]

Source: Compiled by EPE

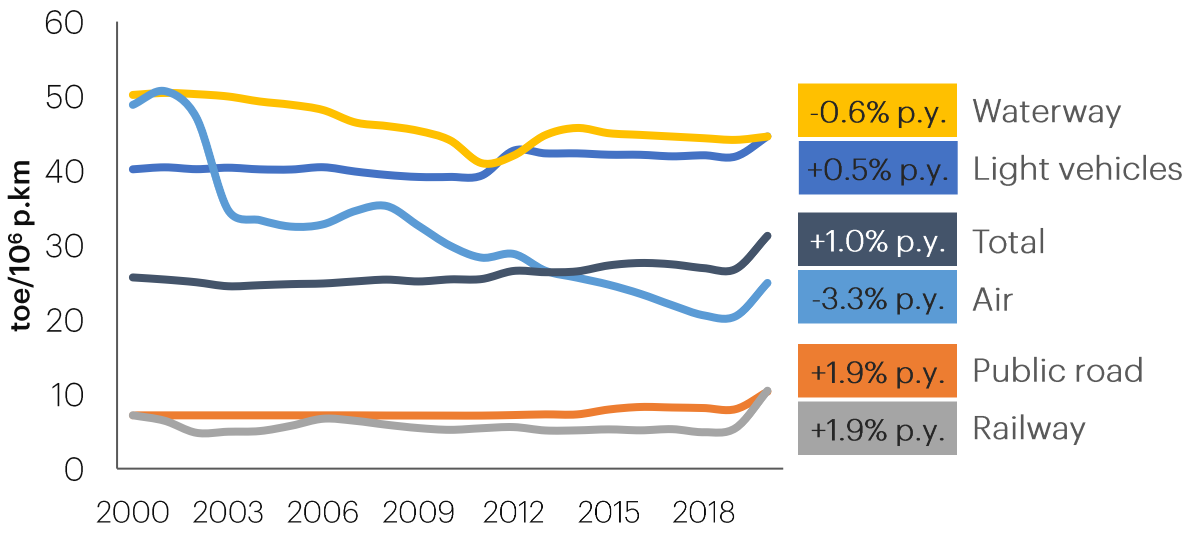
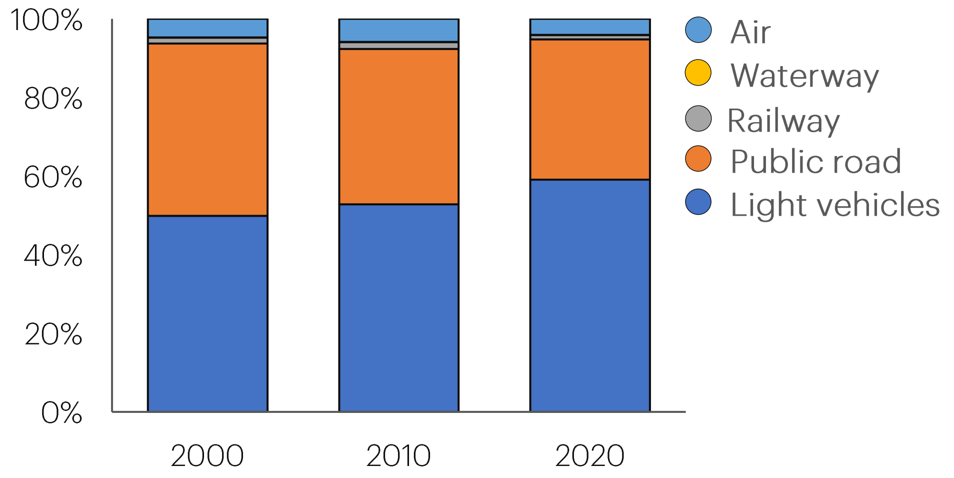


Figure 37 – Activity by mode [p.km]

Source: Compiled by EPE



Individual passenger transport

Figure 38 – Light Vehicle fleet and specific consumption - 2000 to 2019

Source: Compiled by EPE

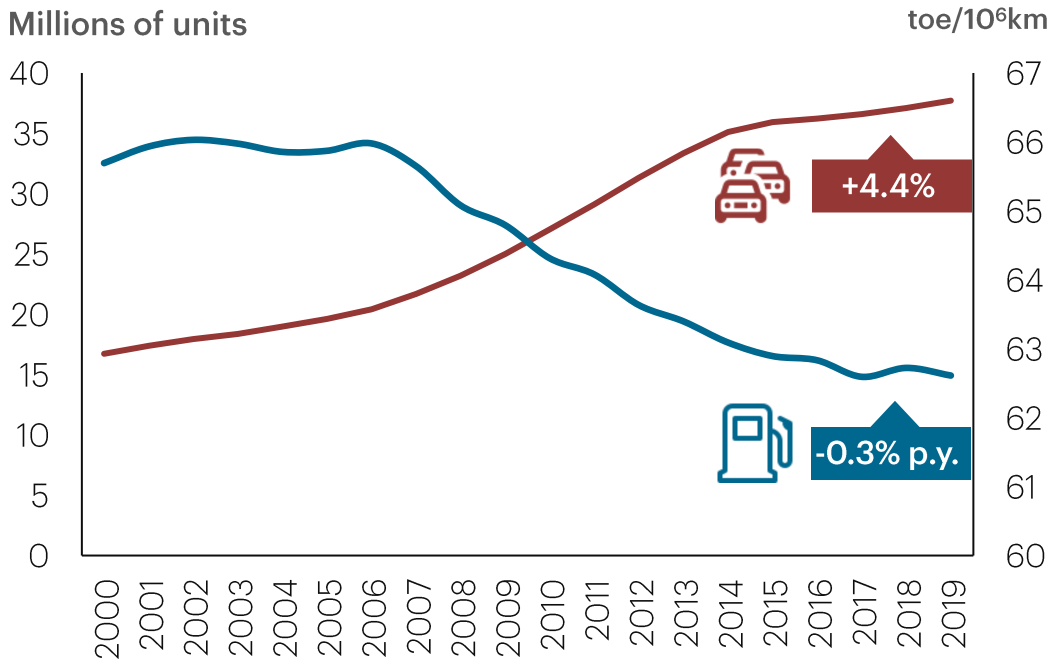
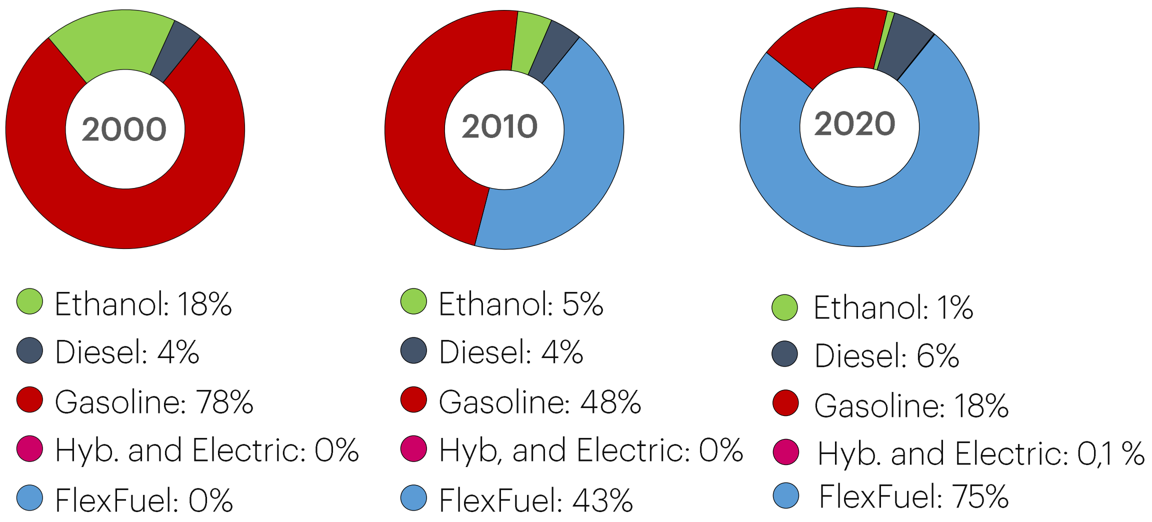


Figure 39 – Light Vehicles fleet per fuel type – selected years

Source: Compiled by EPE



Car sales kept pace with the growth of Brazilian per capita income throughout the 2000s.

The Brazilian Vehicular Labeling Program, Inovar Auto and Rota 2030 promoted the improvement of energy efficiency of new vehicle engines.

Since 2003, the introduction of flex fuel vehicles has made it possible to choose between hydrous ethanol or gasoline C at the time of refueling. Their share in the fleet advanced rapidly, which had an influence on the average efficiency of the light vehicle fleet, since they presented lower efficiency than their dedicated analogues. The increase in the licensing of SUVs also increased the fleet's specific consumption, since they are less efficient vehicles.

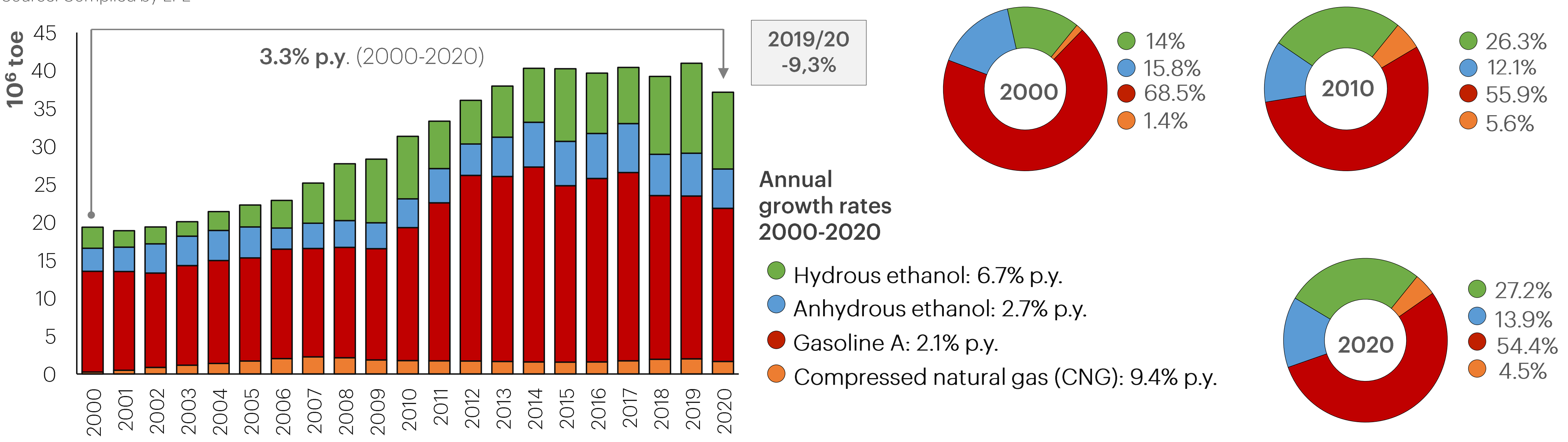
A 27% retraction in light vehicle licensing was observed in 2020 compared to 2019. For hybrid/electric vehicles, the increase was 67% in this same period.

Otto cycle and individual road transport

The expansion of the flex fuel vehicle fleet has allowed an increase in demand for hydrous ethanol.

Figure 40 – Energy consumption by source

Source: Compiled by EPE



In 2020, the pandemic and measures to restrict mobility caused a significant reduction in demand for transport by all modes, including individual transport. The demand for gasoline shrank by 6.4% in the year and hydrous ethanol had an even more significant drop, of 14.7%, with a reduction in Otto-cycle ethanol of 9.3% in the year. The ethanol supply was greatly impacted by the rise in sugar prices and the exchange rate, with an increase in the attractiveness of sugar production and export, which caused mills to reduce ethanol production, with a reduction in supply. With the return of greater mobility, sales of gasoline C increased due to the lower competitiveness of hydrous ethanol at the service stations.

Freight transport

Between 2000 and 2020, waterway and railway transport grew by 5.0% per year and 4.2% per year, respectively, more than doubling their magnitude in the country's activity, improving the efficiency of the sector as a whole (systemic efficiency). Waterway transport grew 10.6%, with the pandemic favoring cabotage, and with the increase in agricultural exports through the Arco Norte.

Despite this, the road transport mode gained importance in the period. Given the growth in consumption of agricultural products and civil construction and the dependence on road transport, the mode grew by 5.4% per year. The mode suffered losses due to mobility restrictions at the beginning of the pandemic. But, its recovery occurred quickly, especially with increased agricultural production, exports, and e-commerce development. Road transport activity increased by 6.2% in 2020.

Despite the increase in activity, the increase in energy efficiency of road transport is noteworthy, due to the increase in the fleet of trucks with more modern technologies, both at the beginning of the decade and in the last year, as well as road works. The increase in the transport of non-mineral or agricultural products and the containerization of cargo reduced the energy intensity of rail.

Figure 41 – Energy intensity by mode [toe/(10⁶ t.km)]

Source: Compiled by EPE

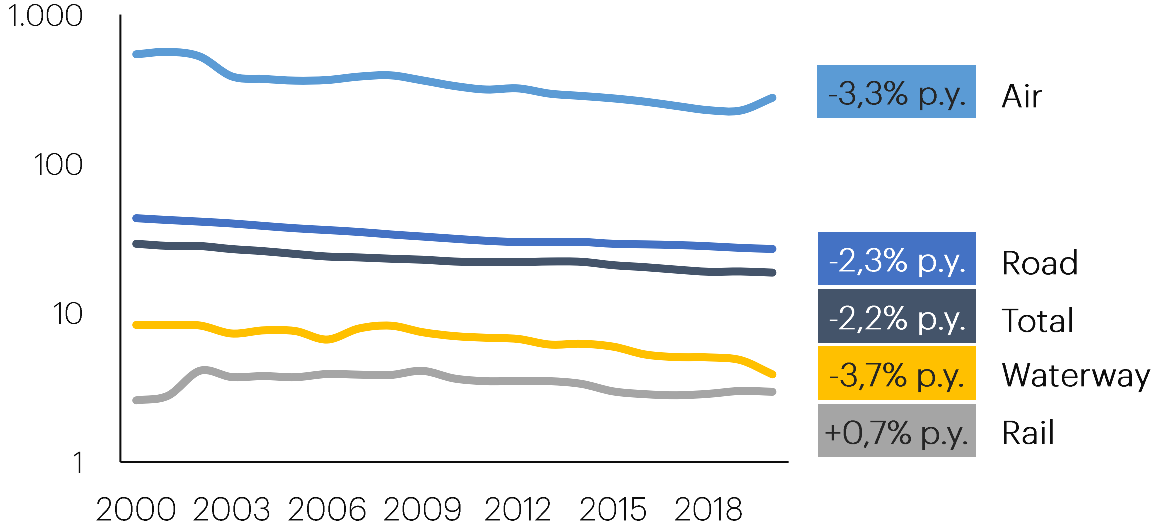
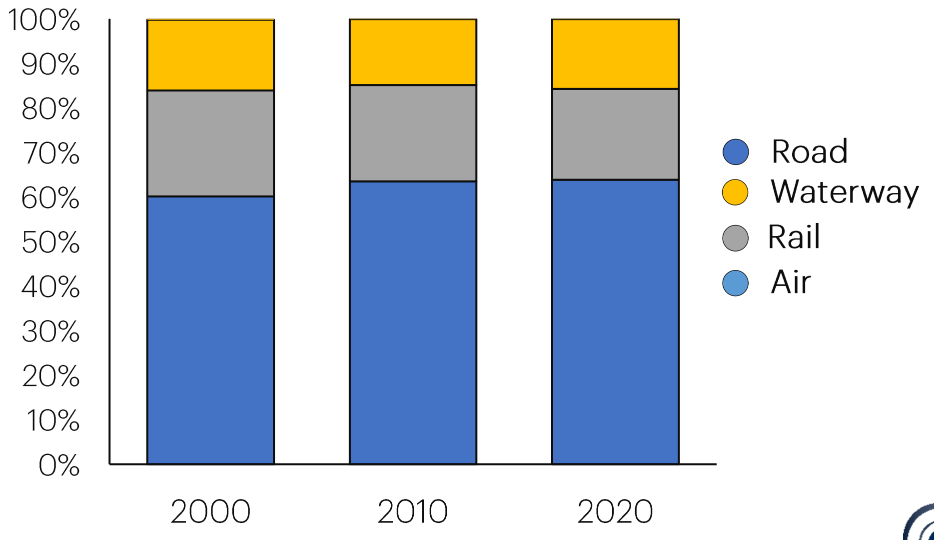


Figure 42 – Activity by mode [t.km]

Source: Compiled by EPE



Road freight transport

Figure 43 – Truck Fleet by Category (millions of units)

Source: Compiled by EPE

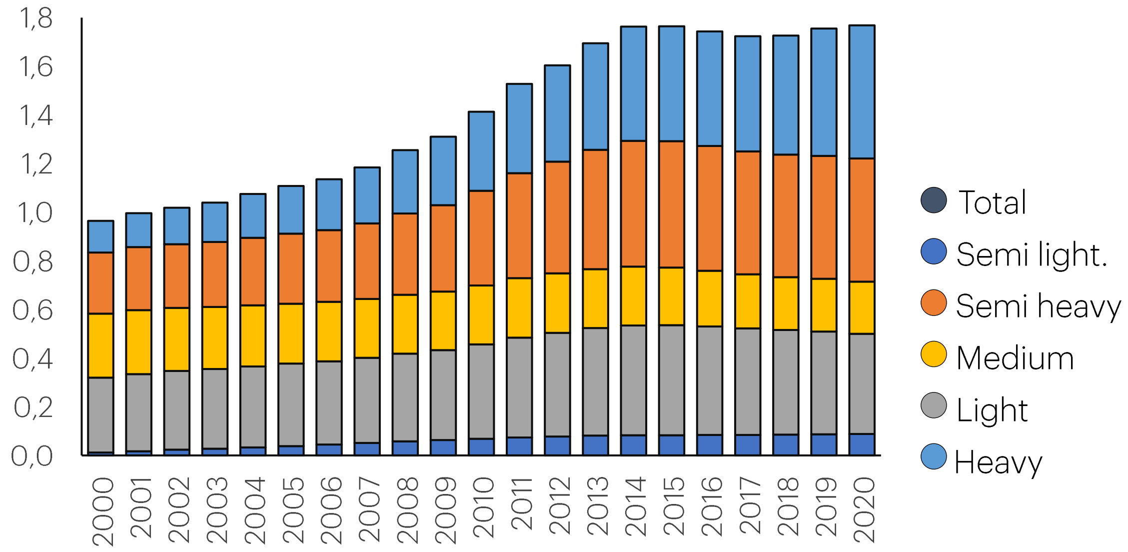
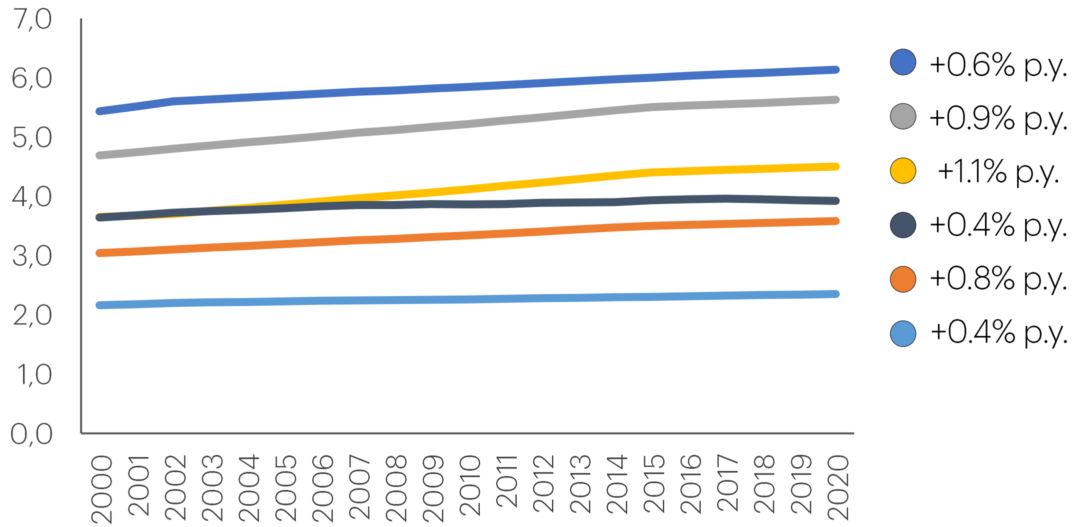


Figure 44 – Average energy efficiency of new vehicles sold (loaded) [km/L]

Source: Compiled by EPE



The truck fleet grew over the first 15 years of the century, becoming stagnant since the beginning of the crisis at the end of 2014. However, the expansion of agricultural production and protests by self-employed truck drivers have pushed sales, especially of heavy vehicles by transport companies, back to record levels in 2019. Grain production increased 4.2% in 2019/20 and 4.7% in 2020/21. Even with the effects of the pandemic disrupting assembly lines, approximately 90,000 trucks were licensed in 2020.

The introduction of new phases of the Vehicle Emission Control Program (Proconve) stimulated the adoption of more efficient engines to meet the new emission limits.

In terms of km/l, despite a 15% increase in the payload capacity of new trucks sold between 2003 and 2020, the efficiency of heavy trucks had a negligible increase. In 2020, the average capacity of the trucks sold was 30 tons against a historical 26 tons in 2003.

Diesel and biodiesel consumption

Figure 45 – Diesel and biodiesel consumption by trucks (10^9 liters)

Source: Compiled by EPE

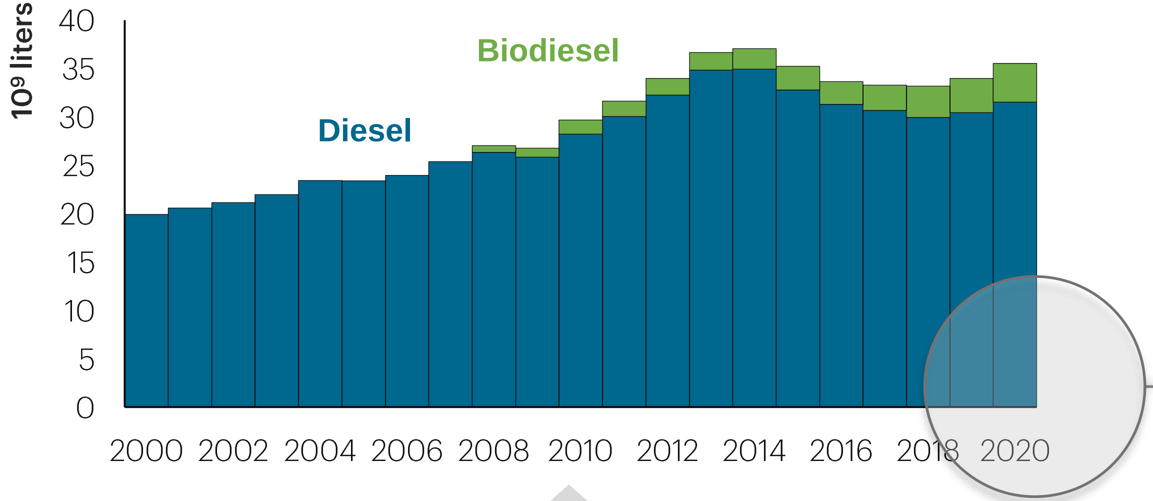
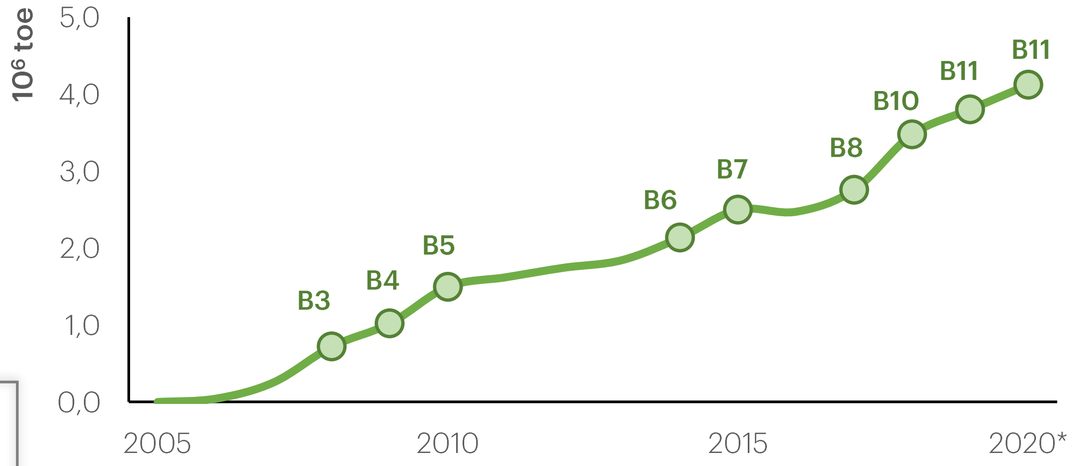


Figure 46 – Evolution of biodiesel consumption and its addition percentages

Source: Compiled by EPE

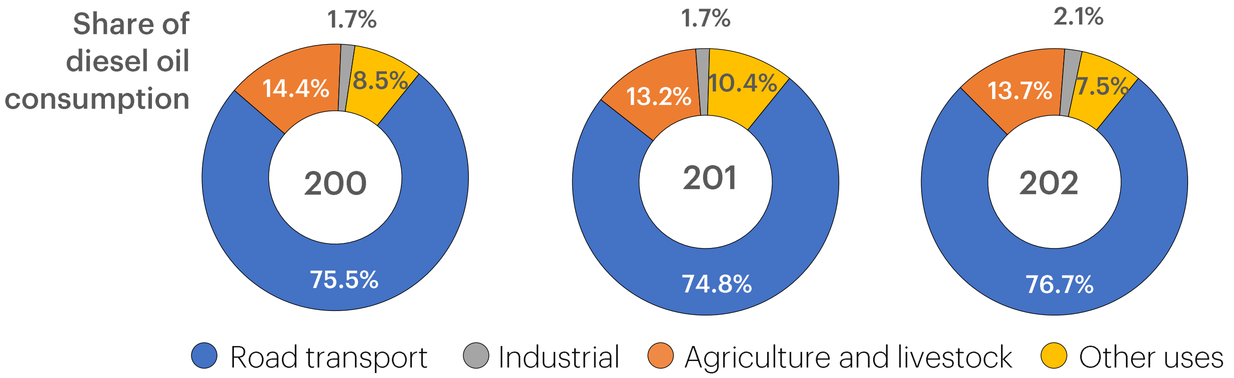


* As a preventive measure to ensure the supply of the domestic market, the ANP carried out three temporary mandatory percentage reductions throughout 2020. These actions were also required in the year 2021.

Truck diesel demand grew by 2.8% per year between 2000 and 2019. And despite the pandemic, which reduced industrial production and consumption, and restricted the free movement of truckers at the beginning of the pandemic, the demand for diesel fuel by trucks registered an increase of 4.6% in 2020 compared to 2019.

The increase in the mandatory biodiesel blend in B diesel in 2020 provided an increase in its demand of 8.4% when compared to 2019, which resulted in the growth in demand for mineral diesel of only 3.6%.

The lower energy content of biodiesel, compared to diesel, provides a slight reduction in the mileage traveled per vehicle with the same volume of diesel B. However, the environmental gains and the efficiency of new trucks, especially heavy trucks sold in 2020, offset this slight drop in energy content.



Additional remarks – transport

Because of the pandemic, the Transport sector lost its position as the country's largest energy consumer to the industrial sector in 2020. However, by the end of this year, the demand for diesel returned to pre-pandemic values and the demand for gasoline C and aviation kerosene (rapidly expanding with the end of restrictions on mobility) could take the consumption of oil products to levels above those recorded before the pandemic.

The energy demand of passenger transport is predominantly associated with the fuel consumption of automobiles. In the first half of 2020, the pandemic significantly reduced the movement of people. However, by the end of the year, the demand for individual transport returned to historical values, although many are still working remotely or in hybrid mode. This year saw a 27% retraction in the licensing of light vehicles, with hybrid/electric vehicles increasing by 67%.

In 2020, the Otto cycle share of gasoline A rose from 52.4% to 54.2%, with hydrous ethanol falling from 28.9% to 27.2%. This is justified, above all, by the increased attractiveness of sugar on the international market and the variation in the Brent spot price which, among other factors, resulted in an increase in the PE/PG ratio.

Over the years, road transport has been predominant in the Brazilian mix. Despite the increased activity in this sector, from the use of railroads and waterways, with improvements in systemic efficiency, most of the increase in freight transported has been by road. The increase in exports and e-commerce has further promoted the use of trucks, with developments in logistics operations and in the country's economy.

The mandatory participation of biodiesel in diesel B allowed the increase in its demand to be largely supplied by the biofuel, despite its lower energy intensity. Furthermore, the efficiency of the truck fleet improved in 2020, due to increased sales of new heavy trucks that are more efficient than the Brazilian average.

Road Freight Transport in Brazil and International Benchmarking

Introduction

Energy efficiency is a critical tool to cut carbon emissions and air pollution in the transport sector, and forms part of a package of sustainability measures including modal shift and use of alternative fuels.

The transport sector is responsible for 31% of final energy consumption in Brazil (EPE, 2021a), and this demand is linked to a number of environmental, socio-economic, and technological aspects. Freight transport represents approximately 40% of this energy demand and is based mainly on roads. Growth of the truck fleet - at a rate of 3.5% a year between 2005 and 2018 has led to diesel consumption increasing from 20 million toe to 30 million toe, an increase of 3.2% a year. In São Paulo, over 60% of the main air quality pollutants (PM, NO_X and SO_2) are due to freight vehicles (São Paulo, 2017).

This chapter aims to present the transport sector in Brazil, the evolution of national road transport, its importance, and the various reasons that explain the significant dependence on this mode and its high share in the country's transport and energy mix. Brazil is then benchmarked with other countries along key indicators, with examples offered of leading technology and policy options to advance energy efficiency, carbon mitigation and air quality improvements of the sector.

Energy consumption of freight transport in Brazil

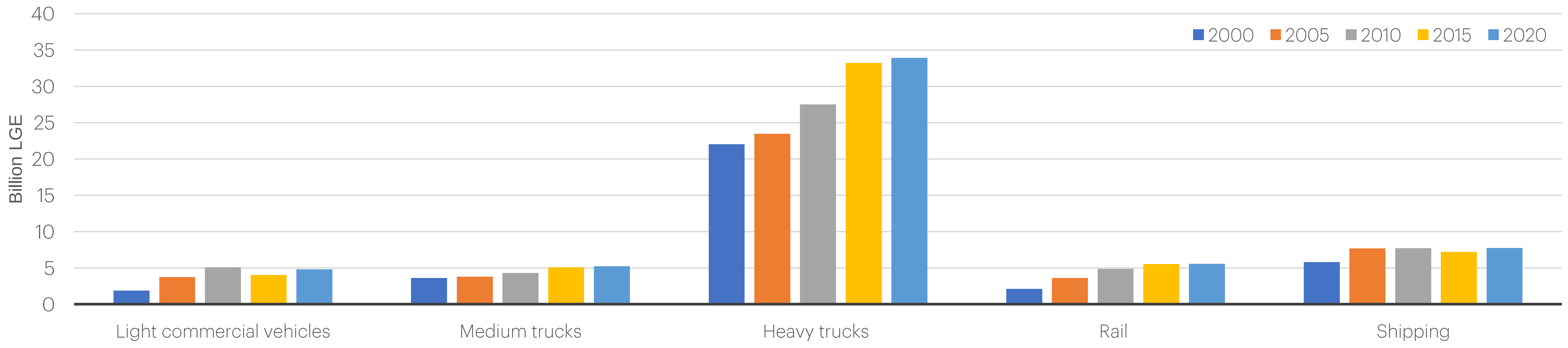
In Brazil, heavy trucks play a significant role and were responsible for most of the increase in energy consumption in the transport sector, representing an increase of 219% between 2000 and 2020.

This increase in Brazil's energy use by heavy trucks reflects:

- an intense period of economic growth between 2000 and 2015, where domestic consumption also increased significantly
- a strong commodities boom that favored the agricultural and mining sectors
- the location of these heavier commodities, which are typically located in Brazil's heartland, with goods transported longer distances as a result

Figure 47 – Brazil Freight Energy Use by Mode over time

Source: IEA, (2021a).



Freight energy use across regions

In Brazil, heavy trucks are responsible for approximately 27% of tonne-km driven and 60% of freight energy use. In other countries, the proportion of freight energy used by heavy trucks tends to be lower.

Brazil's strong emphasis on roads and vehicles and less emphasis on rail is a result of its industrialization process. For most of the second half of the 20th century, the automotive sector was incentivized to attract more manufacturers to Brazil. This process included investments in the road network, to the detriment of investments in other transport modes. This scenario has changed over the past two decades, and there is now an emphasis on attracting private investments in concessions for railways and ports to increase the use of these modes.

Comparing energy intensities of different modes across countries, Brazil has the least difference between road and rail efficiency. This reflects the fact that, historically, its energy efficiency efforts have focused on the former rather than the latter. The greatest variation across the countries is with light commercial vehicles.

Figure 48 – Freight transport percentage energy use (billion liters gasoline equivalent) by mode in 2020

Source: IEA (2021a).

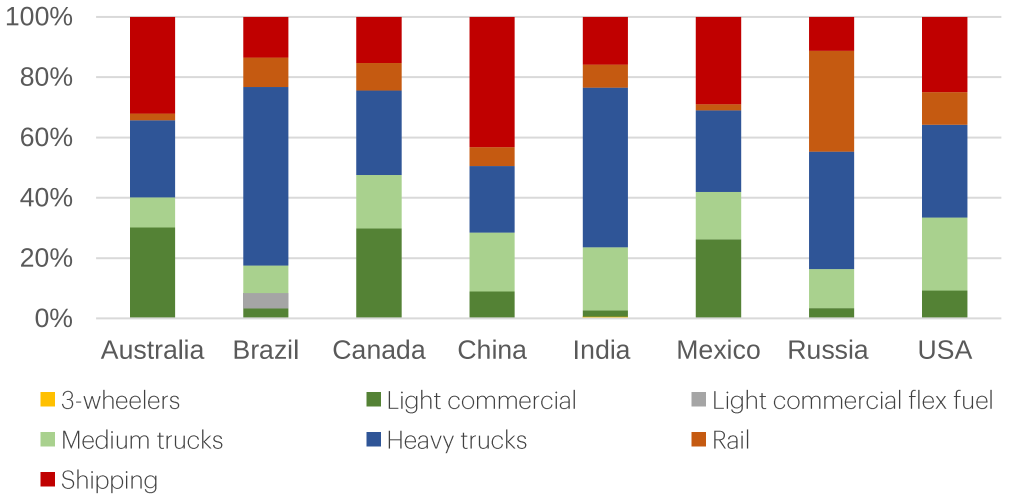
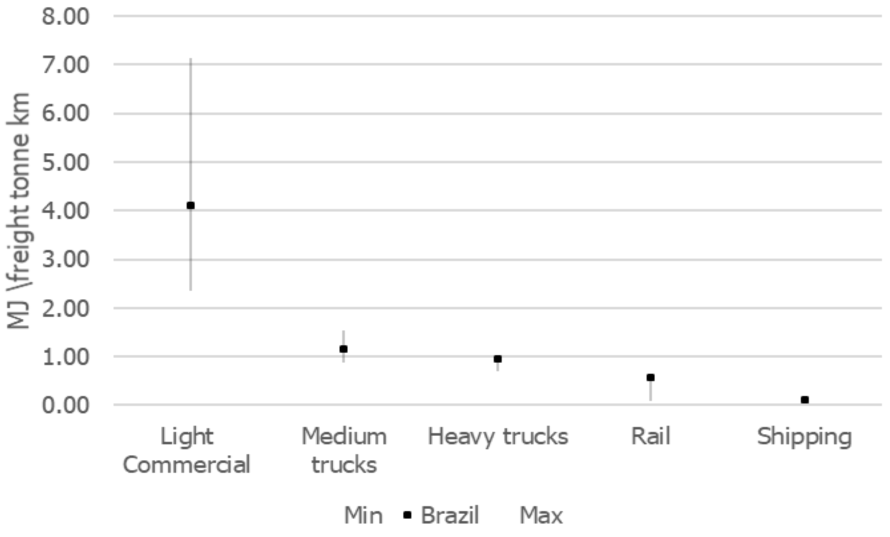


Figure 49 – Range of energy intensities of freight transport across selected countries by mode

Source: IEA, (2021a).



Truck size and types in the world

Brazil has one of the largest truck sizes and weights in the world. Brazil's "road trains" have a gross combination vehicle weight of 74 t, up to nine axles and a length of 25 m to 30 m. In 2016, Brazil approved the use of trucks up to 91 t with special authorizations. In the United States, federal truck size limitations can be more restrictive, with these limitations applying to interstate highways, where the majority of freight transport takes place.

Table 1 – National Weight Limits for Various Countries

Sources: Unescap, Comt, 2019. ITF, 2019. NHVR, IEA, 2017.

Country	Articulated vehicle five or more axes	
Argentina	Weight (t)	Lenght (m)
Australia	75	25.25
Brazil	122.5	≤ 53.5
Canada	74/91	30
China	62.5	27.5
India	49	20
Mexico	55	
Russia	47.5	23
USA	44	20
Argentina	40	

Figure 50– Regulation of Heavy Cargo Vehicles

Source: www.luz.mg.gov.br

Efficiency of new trucks

The increase in energy use occurred despite improvements in average payload capacity, which increased by 15% between 2003 and 2020, bringing greater efficiency gains in terms of tonne-km carried. The average energy efficiency of new vehicles sold (km/l) also increased. Over this period, the efficiency of heavy trucks increased 0.6% per annum, while that of semi-heavy trucks increased 0.7% per annum. It is important to note that in terms of definitions EPE´s use of heavy and semi heavy vehicles are equivalent to IEA´s use of heavy.

Figure 51 – Average energy efficiency of new vehicles sold (loaded) km/l

Source: Compiled by EPE

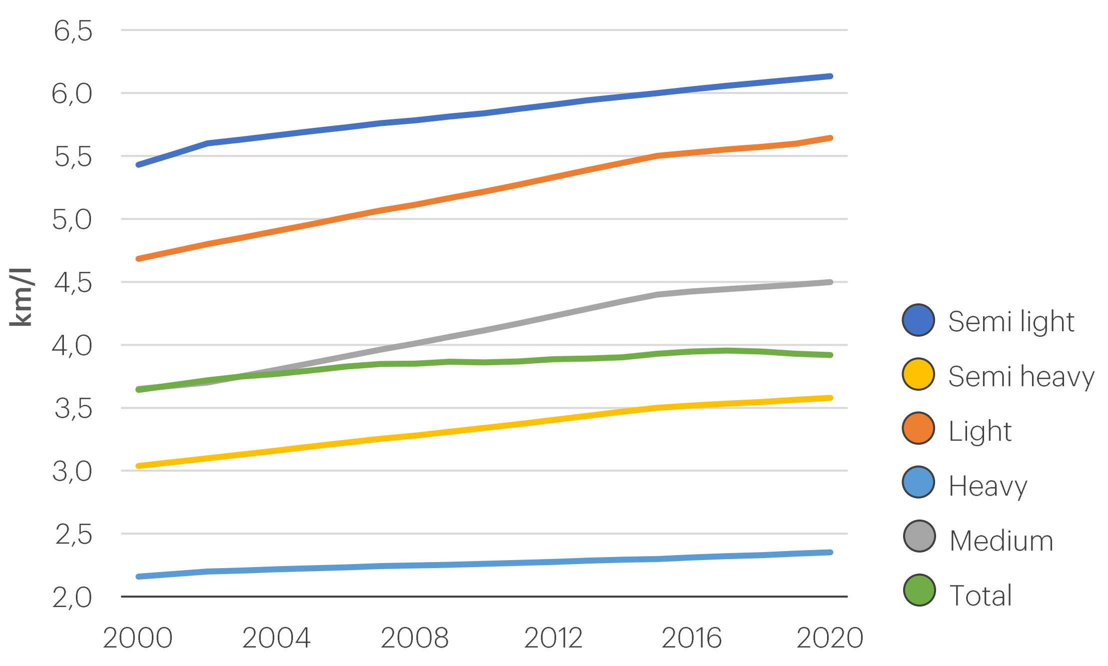
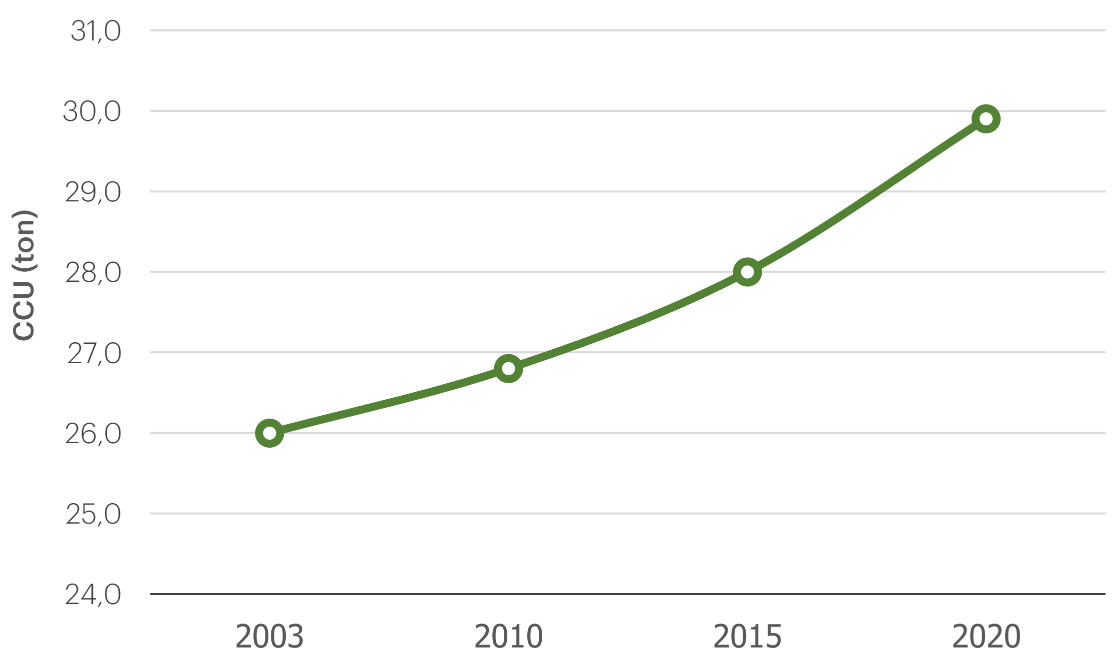


Figure 52 – Heavy trucks – average payload capacity over time

Source: Compiled by EPE



Vehicle age in diferente countries

In terms of fuel economy, the age of the vehicles can also play a crucial role. Older vehicles typically are less efficient and more polluting. The graphs bellow highlight the average age of vehicles when retired. Brazil's average age for heavy trucks is on par with Mexico, lower than China and India, and higher than Canada and USA. It is important to note that the average age can hide variation. Figure 54 highlights Brazil's estimated active truck fleet by age, with 6.1% of Brazil's truck fleet being over 30 years old.

Figure 53– Average age of vehicles when retired (years)

Sources: IEA, (2021a).

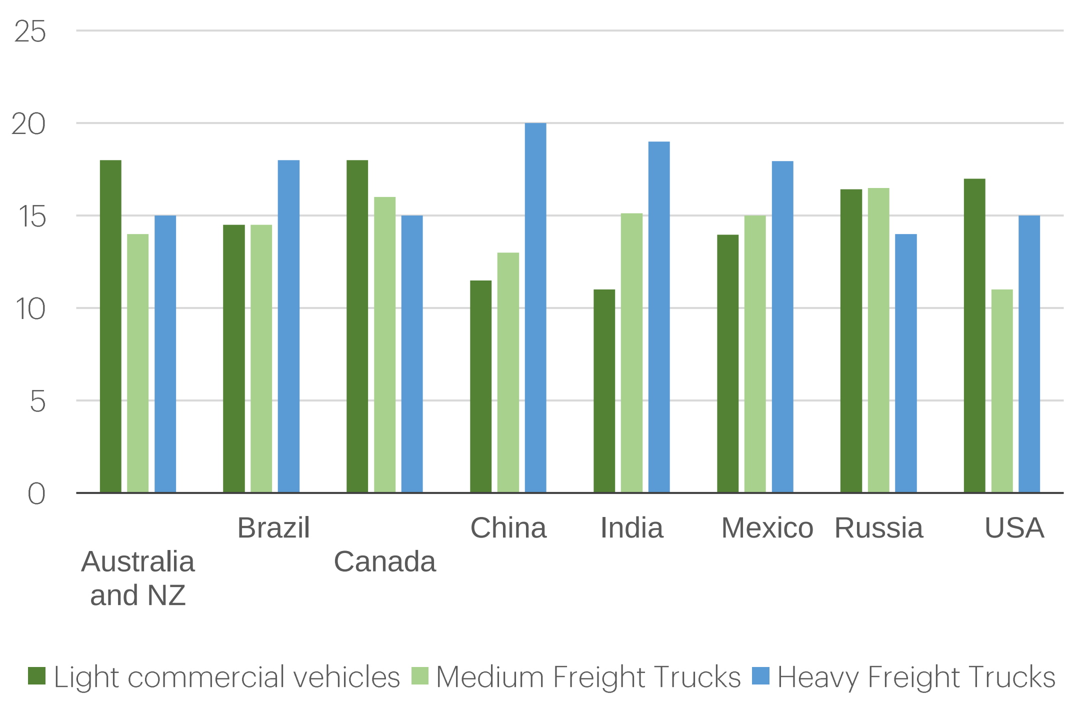
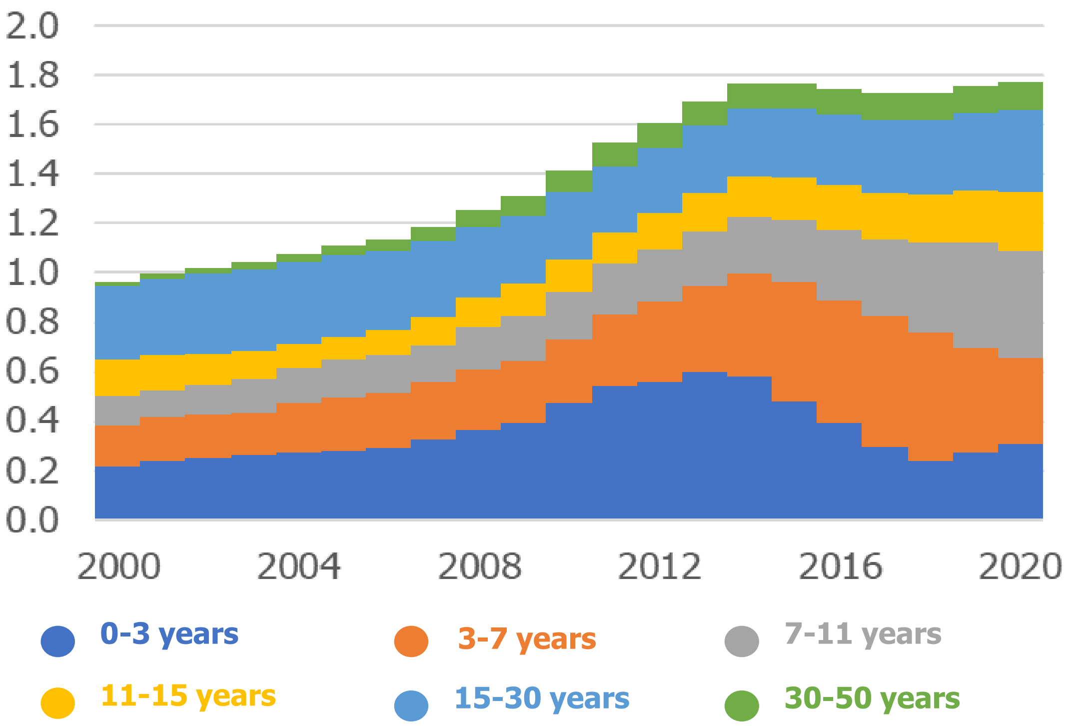


Figure 54 – Estimated truck fleet by vehicle age (million units)

Source: EPE (2021b)



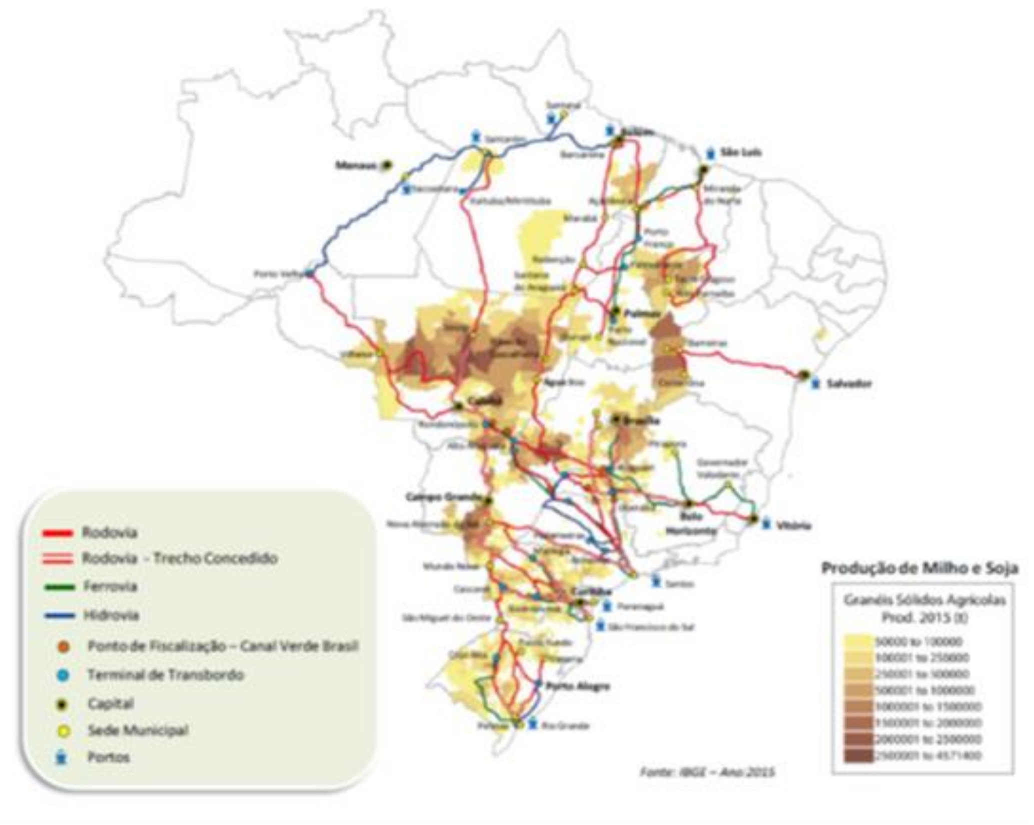
The Brazilian geography and its impact on freight transport

Commodities can be geographically anchored, which in turn influences distances travelled. An illustration is soya beans, which make up over 11% of Brazil's trade exports and whose production is centrally located, resulting in longer distances travelled to ports for shipping.

For example, soy production in Mato Grosso is centred in Sorriso, located 2 200 km away from Paranaguá (Brazil's main soy export port) and 1 300 km away from the nearest railway junction. In comparison, the freeway connecting the state of Mato Grosso to the Amazon rivers (BR-163), that are used as waterways, had its pavement completed at the end of 2019. Since then, the time for a truck to traverse the final 936 km of the road was reduced from an average of 10 days to 4 days. Operational freight costs were also reduced by 13% (Brazil, 2020e). This example highlights the differences and opportunities presented by the modes.

Figure 55 – Brazil's soybean production by municipality and transport infrastructure

Source: Brazil (2017d)



Infrastructure spending in selected countries

Countries differ by infrastructure spending, with clear variation by country and over time. Russia, where rail plays a key role, has a high share of infrastructure spending on rail. Rail spending in Brazil had been increasing. However, with the end of the concession contracts looming, companies stopped investing, which explains the decrease since 2015. Many concessions were renewed in 2020, which partly explains the favorable forecasts for the sector.

It is important to note that infrastructure spending covers passenger and freight transport. Brazil is not considered alongside other countries in Figure 57 because data on rail infrastructure spending originates from a different source. The OECD data in Figure 57 includes spending on new transport construction and the improvement of the existing network.

Figure 56 – Rail share of infrastructure spending (road and rail) – Brazil

Source: CNT (2021)

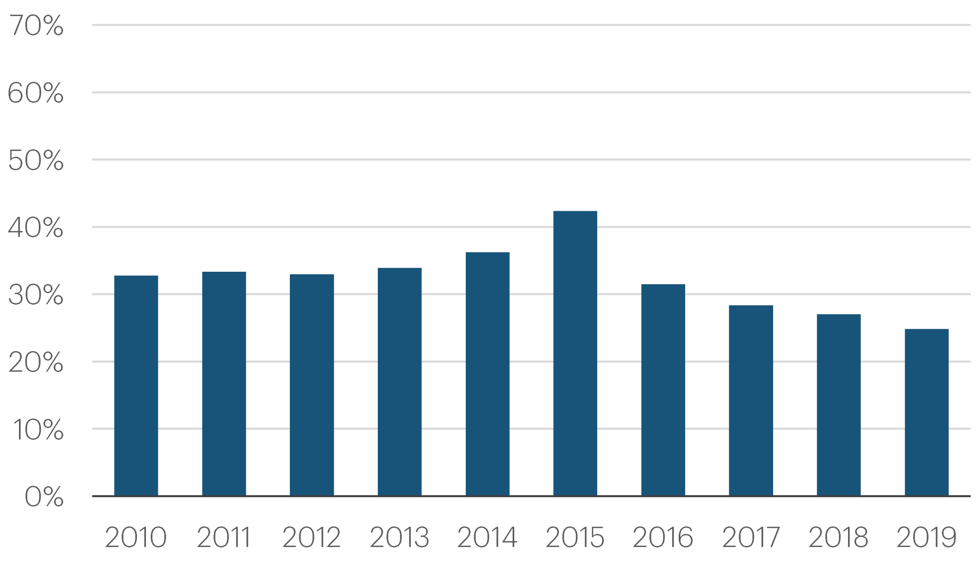
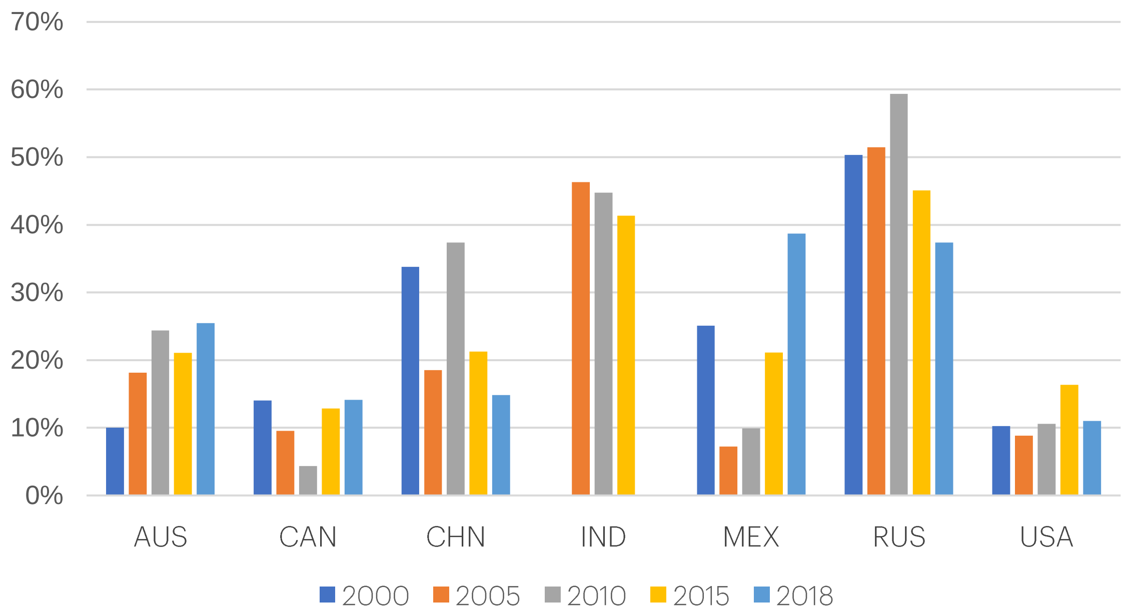


Figure 57 – Rail as a proportion of infrastructure spending (road and rail)

Source: OECD (2021)



Quality of the roads and its impacts on energy efficiency

Globally, Brazil is ranked 103rd out of 137 in terms of road quality (WEF, 2017). In comparison, the US is ranked 10th, Mexico 52nd and Russia 114th. Brazil's score is 3.1 with the scale going from 1 being extremely poor to 7 being extremely good. The US score is 5.7, Mexico is 4.4 and Russia is 2.9. Brazil's road quality has improved over time.

Road quality can directly influence vehicle fuel consumption. Studies show fuel consumption can increase between 2.5% (MIT, 2018) and 5% (Bartholomeu, 2006). Thus, it is relevant to assess impacts of different load types and spacing on the wear and tear of roads.

Figure 58 – Road Quality Ranking and Rating in 2017

Source: World Economic Forum (2017)

Ranking
10
22
35
42
52
55
96
103
114

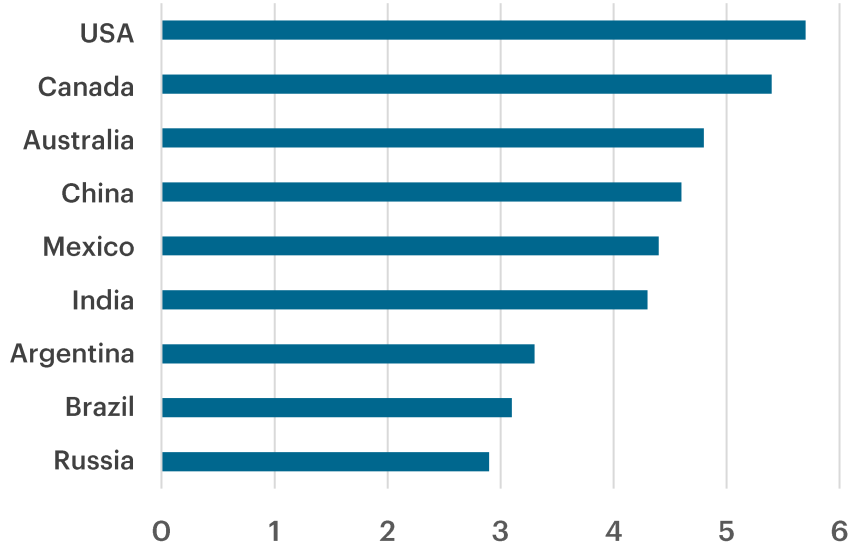


Figure 59 – Traffic interrupted by the weather

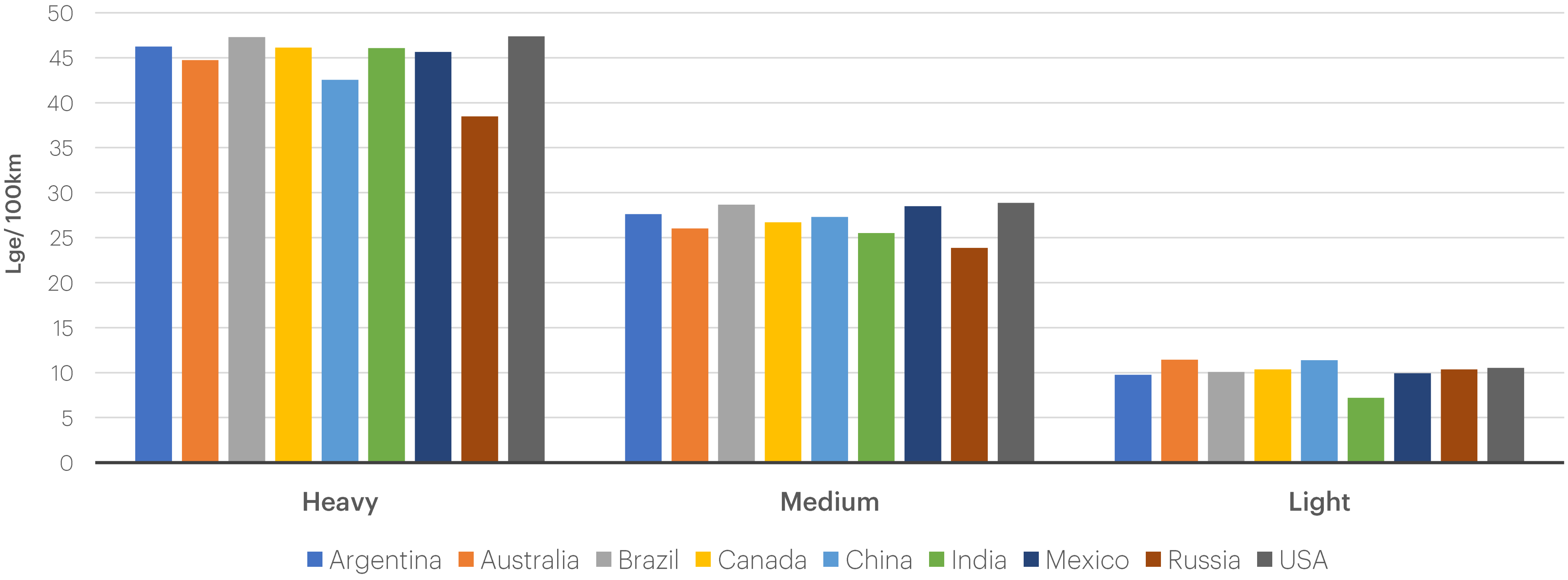
Source: Agência Brasil (2019)

Fuel economy of trucks in Brazil and selected countries

Brazil has one of the highest fuel uses (LGE/100km) for heavy trucks reflecting the road quality, loads carried and size and type of vehicle. For medium and light vehicles Brazil's energy use is in line with other countries.

Figure 60 – Average Fuel Economy in 2020

Source: IEA, (2021a).



Brazilian public policies reflected in the energy efficiency of the transport sector

The increase in diesel demand over the last 20 years has led Brazil to implement various programs and policies to increase the efficiency of the transport sector.

Fuel economy

- **Inovar Auto**
  R&D incentives for automakers
- **Rota 2030**
  Incentives to stimulate R&D and energy efficiency
- **Inov@BR**
  Modernization of the road infrastructure

Emissions

- **Proconve P7**
  Euro V emissions standard as of 2013
- **Proconve P8**
  Euro VI emission standard as of 2023

Funding

- **Finame**
  Fund for the acquisition of machinery and equipment
- **Procaminhoneiro**
  Loans at reduced rates for the self-employed
- **PSI**
  Economic subsidy for equipment financing

Fuel

- **PNPB**
  Mandatory addition of biodiesel to diesel
- **RenovaBio**
  Fossil fuel credits to encourage ethanol
- **Combustível do Futuro**
  Promote clean and advanced fuels
- **PNH2**
  Development of the industry and a market for hydrogen

Modal Shift

- **PAC**
  Recursos públicos para o desenvolvimento de infra-estrutura
- **PPI**
  Public Private Partnerships to stimulate investments in infrastructure
- **BR do Mar**
  Incentives for cabotage and reduction of bureaucracy
- **Pro Trilhos**
  Facilitate railway authorizations
- **Gigantes do Asfalto**
  Assistance to independent truckers

Information Technology

- **Portolog**
  Collect truck data to optimize port logistics
- **Porto sem Papel**
  Online cargo declaration prior to arrival at ports
- **DT-e**
  Integrated and electronic documentation for truck drivers
- **Canal Verde**
  Electronic surveillance of important highways

Brazilian public policies reflected in the energy efficiency of the transport sector

Fuel efficiency

Rota 2030

Rota 2030 is a program of tax subsidies to foster research and development and consequently the efficiency and security of the auto industry. It follows the program Inovar Auto, using the same strategic approach. Companies must be eligible for these tax incentives, and have to agree to minimal investment levels (Brazil, 2020a).

Inov@BR 2020

Modernization program for the federal road infrastructure to improve security, flow, efficiency and technology (Brazil, 2020b).

Brazil's heavy duty vehicles have no fuel efficiency targets yet. Data on fuel efficiency is currently being collected, and targets for 2032 will be developed once this is completed, which is expected by 2027 (Brazil, 2018a). The government is discussing with the Automotive Engineering Association (AEA) procedures to measure the energy efficiency of heavy duty vehicles through the use of Vehicle Energy Consumption Calculation Tool (VECTO).

Emissions (air quality)

Proconve

The next Proconve phase (P8) will push forward the maximum emissions standards from 2023 (Brazil, 2018b). Proconve P8 is equivalent to the European Emission standard EURO.

Brazilian public policies reflected in the energy efficiency of the transport sector

Fuels

PNPB

The Biodiesel production and use program (PNPB) (MAPA, 2019) continues to be the instrument to promote renewable energy and reduce GHG emissions in the sector. The proportion of biodiesel is currently 13% (Brazil, 2021c), this will keep increasing until B15 in 2023 (Brazil, 2020d).

RenovaBio

RenovaBio is another program to incentivize biofuel use and reduce greenhouse gas emissions by creating a carbon trade system in the fuel distribution sector in Brazil (Brazil, 2021d).

Combustível do Futuro

The Future Fuels program (Combustível do Futuro) has been created and is being structured so as to incentivize clean fuels, especially drop-in biodiesel and drop-in jet fuel (SAF). The program considers that vehicle electrification will occur gradually in Brazil, especially because of the high use of biofuels. The focus is on developing electric-vehicles powered by ethanol using fuel-cell technology (Brazil, 2021e).

Brazilian public policies reflected in the energy efficiency of the transport sector

Modal shift

There has been a push to increase concessions and investments in railways, waterways and ports. Investments are expected to play a key role, with EPE's Business as Usual Scenario for Brazil considering the construction of over 600 km railway a year until 2030 (EPE, 2021b). The last time Brazil built this many railway km was over 100 years ago (EPE, 2018).

These investments may avoid an extra 276,000 trucks, with the shift from road to rail saving an estimated 11.5 billion LGE between 2020 and 2030. The envisioned railway investment reflects the emphasis on rail since 2000, with many projects that have started still to be concluded.

Information technology has been key to helping Brazil to better manage trucking logistics and its interaction with ports and ships. This includes:

- The Portolog system which lets ports collect data from trucks to improve logistics management within the port area (Brazil, 2017a)
- The introduction of the 'Porto sem Papel Progam', which lets ships declare all of their cargo and availability online before arriving at ports (Brazil, 2017b)
- The centralisation and digitalisation of information provided by truckers before they start a trip. This has facilitated the control of cargoes on highways and access to ports (Brazil, 2021a)
- These actions have been facilitated by the Canal Verde Program, which implemented electronic surveillance on some of the most important highways in Brazil (Brazil, 2021b). Data is collected and, associated with other data, allows governments to control the flow of goods, and ports to control the access including the flow of trucks.

All of these measures have allowed the government to better manage the modal shift between trucks and ships, reducing congestion in ports. Further action has been to encourage cabotage (Brazilian Government, 2020c), e.g. reducing requirements for domestic national crews and enabling access by foreign ships.

Policy measures in other countries that affect energy efficiency in the transport sector

Different countries use policy instruments to set a framework for and to facilitate modal shift. Among the policy instruments are target setting and use of intermodal corridors.

Table 2 – Selected policy instruments chosen by different countries to facilitate modal shift

Source: Kaack et al (2018), Chen et al (2020), Brasil (2021f)

Country	Selected current and planned policy instruments
India	▪ Government of India (GOI) targets a rail share of 50% by 2031-32 ▪ Initiation of large multi-modal infrastructure projects ▪ Building of Dedicated Freight Corridors (DFC) ▪ GOI plans to subsidise water shipments and develop India's first modern inland waterway on the Ganges River
North America	▪ Intermodal policies have been key since the 1990s, with policies mostly targeting: corridor development, infrastructure financing, and development and employment of intelligent transport systems.
China	▪ Development of a high capacity freight network with intermodal corridors and hubs ▪ Three-year action plan for advancing modal shift ▪ Work plans for air pollution prevention ▪ Overlord control on road transport ▪ Ban of road for transporting of coal in Tianjin
Brazil	▪ The programme BR do Mar aims to incentivise cabotage in Brazil. ▪ The objective is to encourage new players to enter - to increase competition, and reduce freight costs. ▪ The program aims to reduce the bureaucracy of the sector, allows temporary contracts for the use of port infrastructure, and reduces the requirements for companies to register as a Brazilian vessel, even if only temporarily. ▪ The proposal is currently being discussed in the legislature. ▪ The latest national logistics plan forecasts the share of rail increasing from 33% to up to 36% by 2030, if all rail projects are considered.

Heavy duty vehicle scrappage in Brazil

Scrappage is a means of providing incentives for freight operators to retire their older and more polluting vehicles and in turn allow them to purchase newer, more efficient vehicles. These schemes are becoming increasingly common internationally.

Brazil's federal government has introduced financing for individual truckers to exchange their older trucks for new ones, for particular situations. However, these have not been accompanied by commitments to scrap older units, which were resold and continued operating (Brazil, 2015; BNDES).

At the state level, a few schemes have been introduced, for example in Rio de Janeiro, São Paulo and Minas Gerais. However, these had limited budgets and stringent rules, usually only granting discounts on future property taxes, or financing for the acquisition of new vehicles without giving credit for the scrappage of older vehicles, which disincentivized individual trucker participation (AB, 2013; São Paulo; Detran MG).

Case study examples of heavy duty vehicle schemes are shown in Table 3. Best practices could include:

- Schemes need to be designed to ensure that they remove only older vehicles that are still being driven and replace these with more efficient and lower emitting vehicles.
- Subsidies should be introduced in tandem with tightening emission and fuel economy standards to maximize potential.
- Accountability mechanisms should be leveraged to prevent reselling. However, recycling programs of scrap metals should also be leveraged to take advantage of ancillary environmental benefits and job creation opportunities.
- Policy finance structures play important roles in providing greater access to smaller companies and individual truckers. Factors to consider include enhanced credit access, flexible payment plans, relaxed verification requirements of tax paying, and lower interest rates.

HDV scrappage scheme – selected countries

Table 3 – HDV scrappage scheme – case study examples

Source: ICCT (2015)

Country	Scrappage scheme	Years of operation	Truck criteria	Premium offered	Other policy design components	Success factors	Limitations
Chile	Cambia tu camión (Change your Truck)	2009	> 10t GVW; >25 years old	USD 8 000-24 000	Targeted micro and small business owners with revenue below a minimum threshold of roughly USD$25,000 per year. Subsidised payments represented about one-third of the price of the new one.	Program required proof that the vehicles were in regular operation Program applicants had to apply through their regional or provincial government office --> more input from local/regional authorities	The difficulty accessing credit lines particularly affected small operators. Vehicle owners typically lacked financial documents, complete tax information and have little credit history. No additional funding opportunities were set up through municipal government offices
México	Esquema de Sustitución y Renovación Vehicular "Program to Modernize Federal Road Transportation"	2003-2018	> 10 years old	15% toward the trade-in of a new HFT	Financing setup allows for credit access, preferential interest rates, and 1-5 year payment plans contingent on owners showing enough cash flow for credit access and proof of tax-paying (contingencies exclude small business owners)	The program requires that vehicles receiving subsidy be removed from circulation and that the vehicle has been in circulation at least one year before requesting the incentive. Successfully reduced average age of federal transport fleet from 13.3. years to 11.39 years between 2007-2012	Offers flexible financing, but exclusionary to small businesses Difficult to reach small family business with fewer than 5 vehicles.
China	Old-Swap-New	2009-2010	Between 10 and 15 years old	USD 1 400-2 400	Main vehicles targeted for early retirement are Euro 0 gasoline vehicles (pre-2000) and Euro 0, I, and II diesel vehicles (pre-2008). These vehicles, which are known in China as "yellow-label vehicles"—because there is a parallel effort to affix yellow environmental labels to their windshields—emit a disproportionately large share of total emissions	The national scrappage program requires vehicles to be dismantled. Local level programs supplementary and independent provide further incentives and emission reduction potential	Initial per-vehicle subsidies ($980 for heavy duty truck) did not incentivize scrapping, so had to increase subsidies ($2,940 for heavy duty truck) 6 months after program implementation

Fuel economy standards in the world

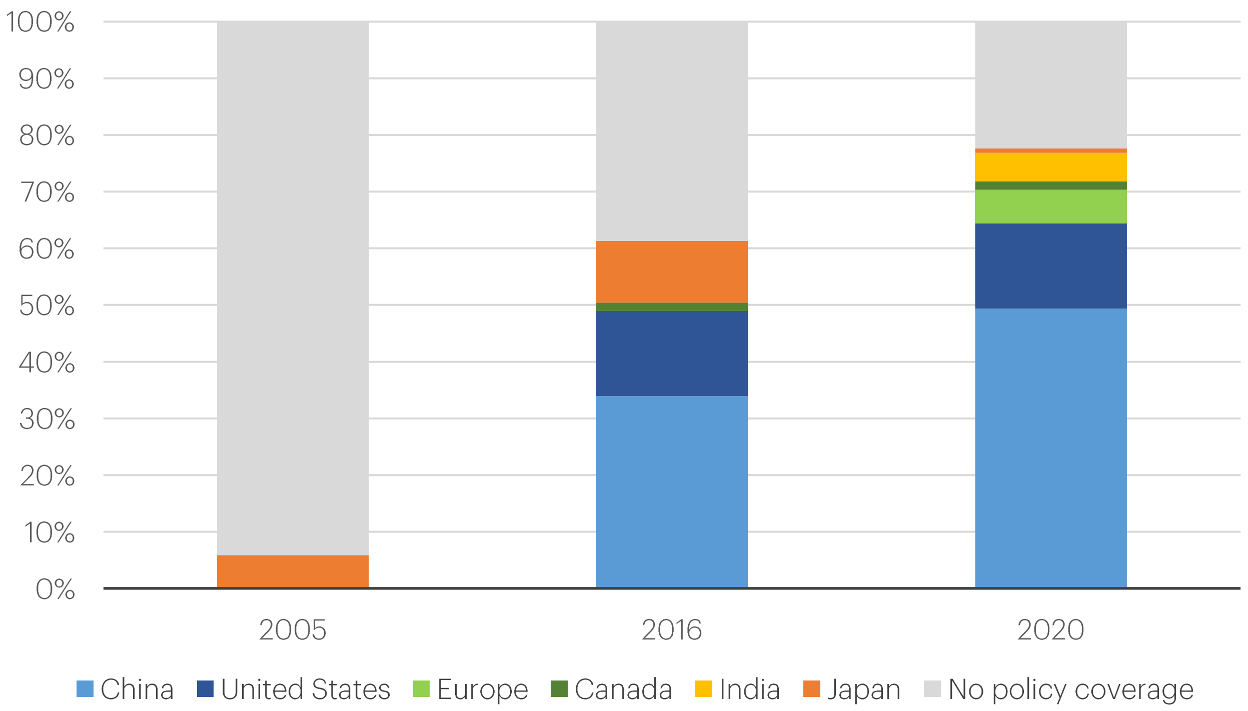
Vehicle efficiency regulations now cover nearly 80% of HDVs sold globally, this share is in comparison to 2016 when coverage had already reached nearly 85% of light duty vehicles but only 50% of heavy duty vehicles. Recently, substantial progress has been made in establishing vehicle efficiency and CO2 emissions standards. For example, China's phase III fuel efficiency standards were implemented in 2019, while Japan updated its fuel efficiency standards for trucks and buses in March 2019, setting 2025 as the target year and 2015 as the base year.

These schemes can bring high benefits. For example, in Canada, the net benefits are estimated to be 18 billion Canadian Dollars. Overall savings are 24 billion CAD from a combination of fuel savings, GHG reductions and other environmental and economic benefits. The costs for developing and implementing new efficiency technologies were 6 billion CAD (ICCT, 2018c). In the EU, savings at the pump are estimated to be around EUR 25 000 for the first five years of use for a new lorry bought in 2025, increasing to around Euro 50 000 when a lorry is bought in 2030 (EU, 2019).

Brazil's heavy duty vehicles have no fuel efficiency targets yet. Data on fuel efficiency is currently being collected, and targets for 2032 will be developed once this is completed, which is expected by 2027 (Brazil, 2018d). However, Proconve emission targets indirectly mean that Brazil will have some fuel efficiency savings through these standards in the shorter term.

Figure 61 – Heavy duty vehicle sales in countries with adopted fuel economy (and/or GHG/ CO_2 standards 2005-2020

Source: IEA, (2020). All rights reserved



Fuel economy standards in selected countries

Countries differ in key aspects in relation to fuel economy standards, such as vehicle coverage, certification approaches and whether flexibilities or incentives for zero emission vehicles are offered.

Table 4 – International comparison of fuel economy standards

Source: ICCT (2018) EU (2019)

Country	Vehicle coverage	Timeframe	Zero Emission Vehicles	Certification	Flexibilities
USA and Canada	GVWR > 3.85t 19 sub-categories, by vehicle type / duty cycle and GVW	Baseline: 2010 (Phase 1) Phase 1: 2014, 2017 Phase 2: 2021, 2024, 2027	Super credits	Component testing and simulation. Separate engine standard	Uses averaging – on a fleet average not individual vehicle basis Banking – credits can be banked once threshold reached. Trading – manufacturers can trade
China	GVW > 3.5t 66 sub-categories, by vehicle type / duty cycle and GVW	Baseline: 2010 China I: 2014 China II: 2016 China III: 2021	None	Chassis dyno (base vehicles) or whole vehicle simulation (variants).	None
Japan	GVW > 3.5t 25 sub-categories, by type (bus/lorry) and GVW	Baseline: 2002 First phase: 2015 Second Phase: 2025	None	Engine testing (map) and vehicle simulation. Second phase includes aero and tyres testing.	None
India	>12t 10 sub-categories, by GVW, axles, and type (rigid or tractor)	Baseline: 2018 (enforced by first step of standard) CSFC: 2018, 2021	None	Constant speed fuel consumption (CSFC) standards.	None
EU	Rigid and tractor trucks with a GVW exceeding 16 tonnes, and with 4x2 and 6x2 axle conFigurations	Baseline 2019	Super credits	Simulation	Banking and borrowing Exemption for vocational vehicles Allows manufacturers to balance emissions amongst different groups of vehicles

Final remarks and recommendations

Freight transport in Brazil is mostly undertaken by road, predominantly through the use of heavy and semi-heavy trucks. This is a result of the country's industrialization process, but also due to the growth of commodity exports over the past decades.

The high level of road transport, together with Brazil's geographic characteristics which result in long distance travelled; limitations of existing transport infrastructure (quality of the roads) and insufficient investment in other modes of transport result in road freight contributing to a significant portion of the growth in the national demand for fossil fuels.

Over the past decade a number of policies and programs have been implemented by Brazil in order to improve the individual and systemic efficiency of the transportation sector, with results being seen. However, the increase in transport activity has dampened these efficiency gains, reinforcing the importance of advancing efficiency policy.

In recent years, there has been an increase in energy consumption in freight transport due to the greater demand for services and the fleet profile. Replacing just 6% of the fleet – the oldest portion – could have significant energy saving and air quality benefits. It should also be noted that improvements in payload capacity have occurred, bringing greater efficiency gains in terms of ton-kilometer carried, and the average energy efficiency of the new vehicles sold has grown.

Comparing the Brazilian situation with other relevant countries, one can conclude that it is necessary to deepen the programs that have begun to be implemented in Brazil. Further investments in infrastructure can accelerate the modal diversification of the sector. Fuel economy standards play an important role in taking forward efficiency and Brazil has the opportunity to benefit from experiences from other countries. Combined with scrappage policies, it is possible to limit the increase in Brazil's energy demand, even in a context of continued growth.

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