Atlas of Energy Efficency

Brazil | 2023

Indicators Report

iea

Special Chapter on the Residential Sector in collaboration with the International Energy Agency

epe

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This report has a special chapter...

which provides a detailed analysis about the residential sector in Brazil, result of a cooperation between EPE and the International Energy Agency (IEA). This chapter presents a national and international analysis about the sector, with a special focus on consumption, by final energy using and consumption by incoming classes.

The IEA team that contributed for this report was:

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Objective

Objective

The main objective of this report is to track the Brazilian energy efficiency advances through an indicators analysis. In 2014 the first Energy Efficiency Indicators Report was published, with data up until 2012. Since then, this report is being updated, and in 2020 it started to be called as "Atlas of Energy Efficiency Brazil – Indicators Report". This document complements and updates, in a synthetic way, the first reports, with data up until 2022.

2014

2017

2020

Special Chapter
Energy Efficiency Benchmarking: Brazil in the Global Scenario

2021

Special Chapters

- Cement Sector in Brazil and in the World
- Covid-19 effects

2022

Special Chapter
Road freight transport and the comparison of the Brazilian case with selected countries

January 2023

Special Chapter

- Steel Sector

December 2023

Special Chapter

- Residencial Sector

Definitions

ODEX

The ODEX is an indicator that measures the energy efficiency progress. It can be combined by sector (industrial, residential, services and transport) or for the whole economy. The ODEX is being used by the European Union in the ODYSSEE database program to track efficiency gains (Enerdata, 2020).

The ODEX by sector (e.g. industry) is based on specific consumption indexes by subsector (cement, ceramics, textiles, etc.) and weighted by its share on the total energy consumption. The specific consumption by subsector can be expressed in different units to provide the best energy efficiency proxy, such as consumption per household, consumption per physical production or consumption per transport activity (measured in units such as passenger-kilometre and tonne-kilometre).

For this report, 2005 was taken as the base year (value = 100), essentially due to the data availability for most sectors from that year onwards. A decrease in the ODEX from 100 in 2005 to 80 in any given year, for example, represents a 20% gain in energy efficiency over the analyzed period. In other hand, if the ODEX increases from 100 to 120, means that the energy efficiency declined over the years.

In the case of the global ODEX, the same method is applied with weighted factors, based on the share of each sector on the total final energy consumption, in relation to the total final energy considered for all the evaluated sectors.

For this report purposes, the industrial, residential and transport sectors were considered. Other sectors (energy, services and agriculture) were not included due to the data unavailability in the appropriate format for the indicator calculation.

This edition of the Atlas of Energy Efficiency have methodological changes, in other to improve the sectors representativeness in the ODEX, as well as its calculation. Therefore, the variations in historical ODEX data in this edition, compared to previous editions, can be explained by the main changes:

- historical data series used to calculate the ODEX updates;
- use of the 3-year moving-average for the ODEX in all the sectors, in compatibility with the methodology proposed by Odyssee database;
- improvements in the indicators choice to calculate the ODEX for the residential and transport sectors.

Energy Intensity

Energy intensity refers to the amount of energy required to produce one 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 Internal Energy Supply divided by the Gross Domestic Product (GDP) of the country. This indicator is typically used to measure a country's energy efficiency. However, it's important to notice that this ratio does not necessarily express energy efficiency. It means that a country with low energy intensity may still be inefficient from an energy perspective. For example, consider the case of a small country with an economy based on the service sector. This country may have lower energy intensity than another large nation with an economy based in industrial production. However, the second country may efficiently use more energy in its industries compared to the first, which utilizes energy for developing a trade and service-based economy.

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

In this report, the indicator will be established in two ways: from the perspective of total energy supply (TESp), 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 all the energy that reaches consumption sector 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 ranged, 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 are ranged according to the Brazilian Energy Balance, except for some intensive-energy sectors, to depict better the 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, i.e., consumption from sources coming from different transformation centers, for a different economy sectors destination. 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 thermoplastics manufacture.
- **Final energy consumption** is the use of sources by sectors of the economy as energy.

INOVA-E

The INOVA-E digital platform was developed to provide information about innovation in energy in Brazil accessible to a wide range of audiences. In its investment module, the strategic information available on the platform has been arranged into a single database, presenting a relevant overview for understanding the country's investment trends in energy RD&D. This unprecedented overview provided by INOVA-E attempt to support EPE, MME, MCTI, among other government parties, private and civil society organizations, formulating and promoting public policies aimed on Brazilian energy transition. In its most recent update, the platform's RD&D investment module underwent several methodological improvements, which resulted in the expansion of mapped investments and the inclusion of projects in the investment history.

Public investment in R&D - Public investment in R&D are calculated based on expenditure on reimbursable and non-reimbursable R&D projects carried out by public institutions that promote innovation in Brazil. The statistics presented on this platform include the following federal bodies: BNDES, CNEN, CNPq, FINEP; and the state of São Paulo: FAPESP.

Publicly oriented investment in R&D - Publicly oriented investment refers to private investment driven by public policies, being compulsory for companies in the energy sector. These are resources that fall under public programs whose purpose is to induce companies to invest in RD&D. The statistics presented on this platform include R&D projects regulated by the ANEEL and ANP agencies.

For more details, visit:

Energy innovation investments in Brazil overviewing

Transport Sector

Activity

Activity in the transports sector is internationally represented by the indicators passenger-kilometer and ton-kilometer transported. Passenger-kilometer is a unit that relates the relative work to the passenger displacement over one-kilometer displacement. Similarly, ton-kilometer is the unit that represents the relative work to the displacement of a ton of cargo over one kilometer distance. It is also called as 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 is the spent fuel amount (volume) 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 ton oil equivalent [toe]).

Transport Sector

Light Duty Vehicles (by Size)[1]

Automobile

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

Light Commercial Vehicle

- **Utility Vehicle** – vehicle for freight transportation with GCVW less than 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[2]

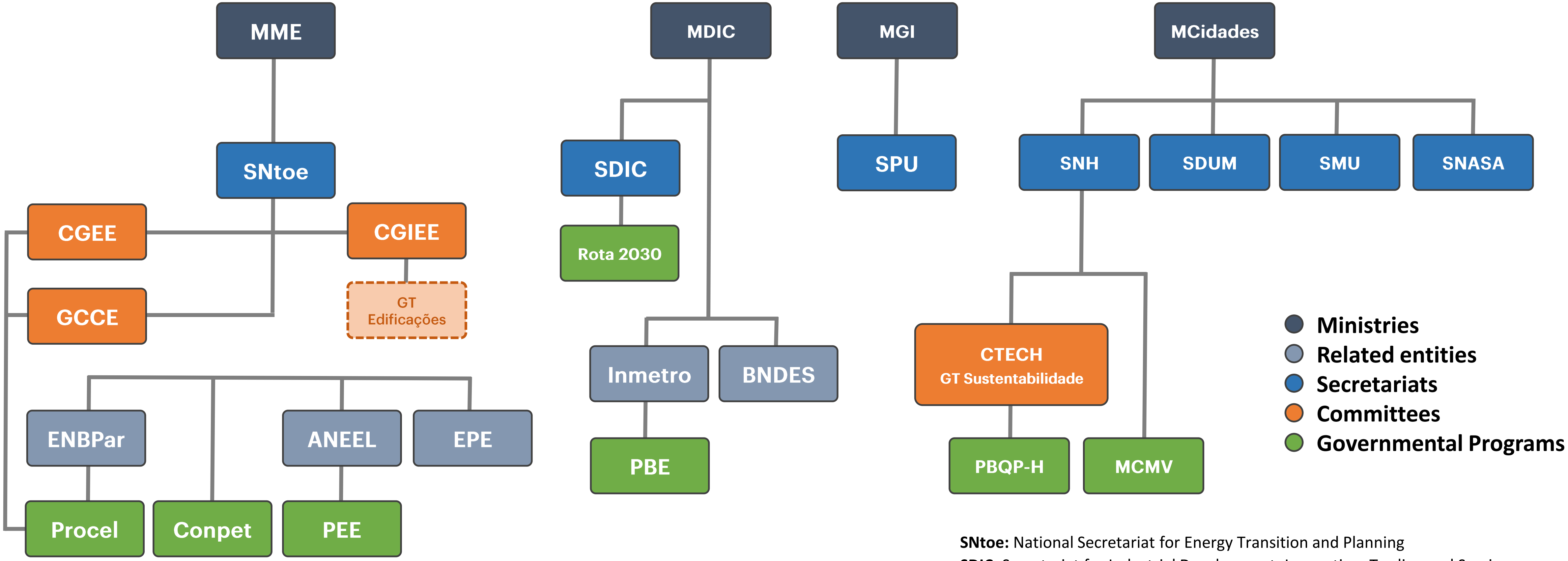
Trucks

- **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.

[1] Código Nacional de Trânsito (BRASIL, 1997)
[2] Anfavea (2023);
GCVW – Gross combined vehicle weight; MTC – Maximum Traction Capacity;
PBT – Total Gross Weight; CMT – Maximum Traction Capacity

Introduction

Institutional governance of energy efficiency in Brazil



SNtoe: National Secretariat for Energy Transition and Planning
SDIC: Secretariat for Industrial Development, Innovation, Trading and Services
SPU: Secretariat for the Coordination and Governance of Federal Assets
SNH: National Housing Secretariat
SDUM: National Secretariat for Urban and Metropolitan Development
SMU: National Secretariat for Urban Mobility
SNASA: National Secretariat for Environmental Sanitation

Energy Efficiency Policies Timeline...

1981
Ordinance MIC/GM46
CONSERVE Programme
Industry and imported energy sources substitution

1982
Decree 87079
PME: Energy Mobilization Programme

1984
PBE | INMETRO
PROGRAMA BRASILEIRO DE ETIQUETAGEM

1985
IO[1] 1877
Establishes PROCEL

1990
Decree 99656
CICE – Internal Commission for Energy Conservation (withdraw by Decree 10473/2020)

1991
Federal Decree 07/18/1991
Establishes CONPET

1993
Federal Decree 12/08/1993
Efficiency seal

1997
Law 9478
National Energy Policy Council (CNPE) and ANP

2000
Law 9991
PEE ANEEL: Investments in R&D and energy efficiency
ANEEL – Agência Nacional de Energia Elétrica

2001
Law 10295
Energy Efficiency Law
(MEPS - Minimum Energy Performance Standards)
Decree 4059 and republished by **Decree 9864/2019**
CGIEE/ Buildings Technical Group

2002
Procel Industry

2003
Procel EDIFICA
Procel SANEAR

2004
Law 10847
Decree 5184
Establishes EPE

2005
Conpet Seal

Notes: (1) IO = Interministerial Ordinance
(2) Three-phase electric motors, compact fluorescent lamps, refrigerators and freezers, gas stoves and ovens, air conditioners, gas water heaters, sodium-vapor and metal-halide lamps, incandescent lamps, distribution transformers, ceiling fans.

... over the years to the present day

2007

PNE 2030

2009

Vehicle and Commercial Building Labeling

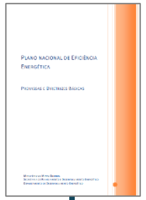
Decree 6996 (withdraw)
Decree 11158/2022 (in force)
Tax reduction (IPI) for products with energy efficiency levels A and B

2010

Residential Label

2011

Ordinance MME 594
NEEP: Energy efficiency targets



2014

NI[1] 02 MPOG
Requirements for Federal Public Buildings and Procurement

Procel Seal for Non-residential Buildings

2016

ProEESA: Energy Efficiency in Water Supply Systems Project

Law 13280
Reallocation of resources from PEE to Procel

Nationally determined contribution (NDC)

2017

Law 13576
National Biofuels Policy (RenovaBio)

Aliança Programme (industry)

2018

Decree 9557
Rota 2030 Programme (transport)

2019

Brasil Mais Produtivo – Eficiência Energética Programme (B+P EE) (industry)

2020

Procel Seal for Residential Buildings

Energy Efficiency Networks for Industry and Public Buildings

2021

Decree 10791
Establishes ENBPAr

PotencializEE Programme (industry)

2022

FGEnergia
Guarantee Fund for Energy Efficiency (BNDES and PROCEL resources)

2023

Energy Efficiency Website (MME)

Note: (1) NI = Normative Instruction

Political Integration Viewing

ENDORSEMENT SEAL
Rewards the most efficient products

PROCEL Seal
1985

ENCE
Comparative label that
rates energy performance

ENERGY EFFICIENCY LAW
Regulates minimum energy performance standards (MEPS) and the establishment of energy efficiency requirements for buildings

Minimum Energy Standards
Law Nº 10,295/ 2001

Energy Efficiency

Brazilian Labeling Programme
INMETRO (1984)

Implement the policies and develop the market

Energy Efficiency Programmes
PEE/ANEEL
PAR PROCEL

Research, Development and Innovation Programme (PDI)
ANEEL

Law nº 9,991/2000 delivers the rules about the investments in RD&D (currently PDI) and EE for the electric utilities. Currently 0.5% of the utilities' Net Operating Revenue (NOR).
After Law No. 13,280/2016, which amends Law No. 9,991/2000, 20% of the EE resources are destined for Procel and 80% for the PEE/ANEEL.

Share of renewables in the Energy Mix

Historically, Brazil is known as a country with a high percentage of renewable energy sources in its internal supply, when compared worldwide. In the last 20 years, the renewables energies share in Brazilian matrix has remained stable, over 40%, which is big challenge for the country. Recently, between 2011 and 2014, there was a reduction in the renewable energies share due a decrease in hydraulic supply, associated with less rainfall. Since 2015, renewable sources recovered the growth trajectory because of the expansion of sugarcane derivatives, wind and biodiesel supply, reaching 47% in 2022 also associated with the favorable hydrological situation.

Figure 1: Share of renewables in the Total Energy Supply (TES): international comparison
Source: EPE (2023b)

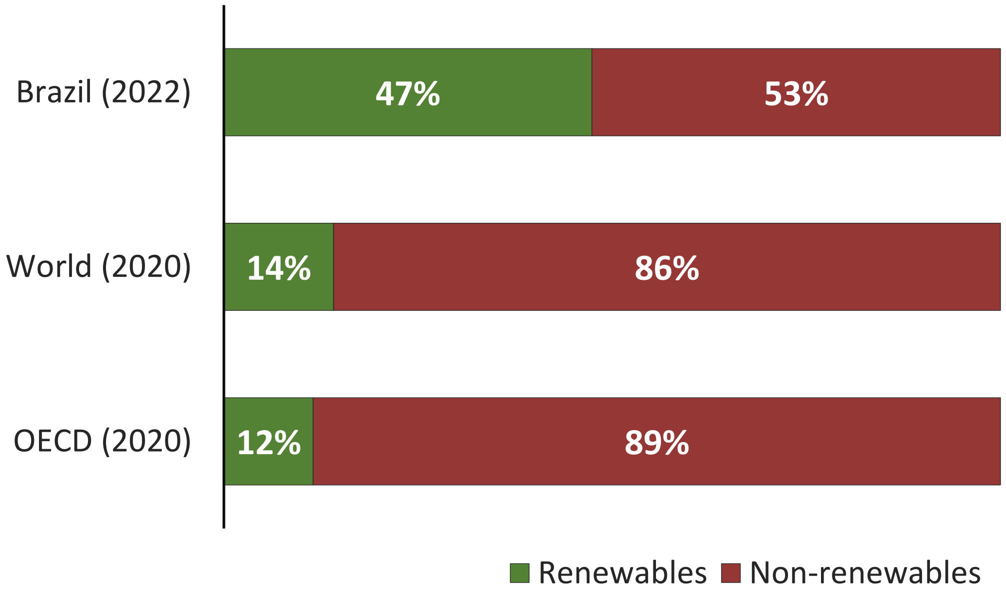
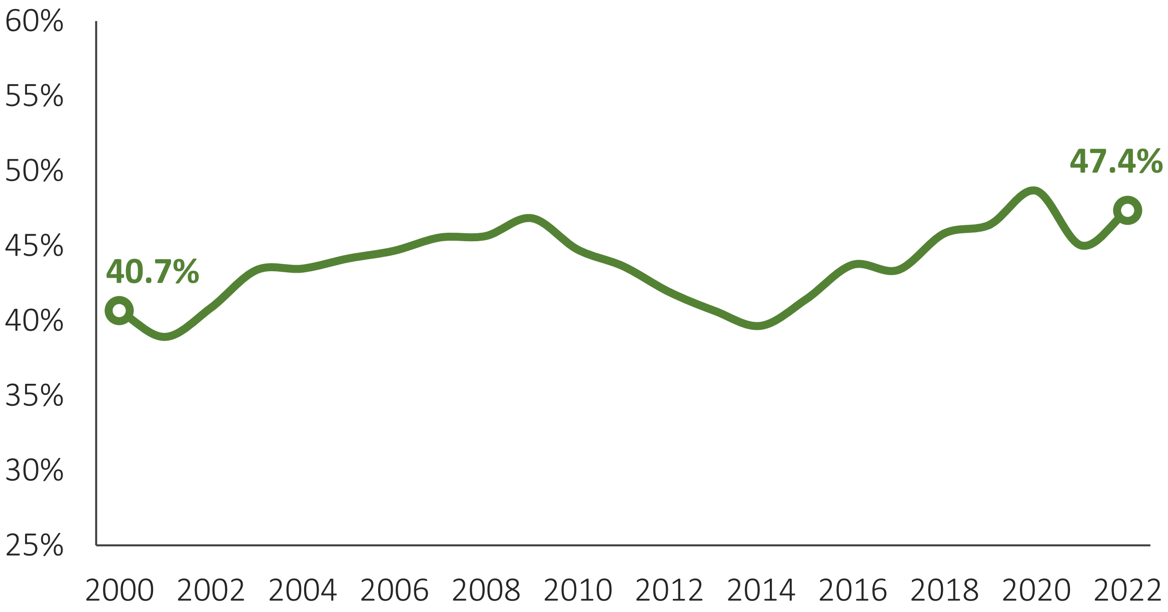


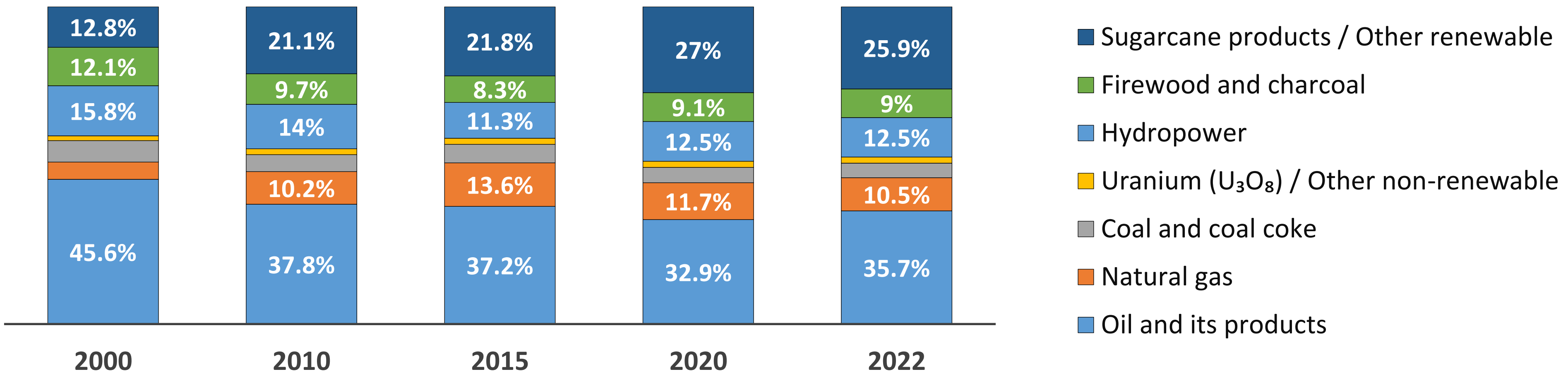
Figure 2: Evolution of the renewable sources' share in the Total Energy Supply (TES)
Source: EPE (2023b)



Evolution of Total Energy Supply (TES) by source

In the field of non-renewable energies, oil and its derivatives are still the largest share. However, natural gas has been the spotlight, with its share rising from 5.4% in 2000 to 10.5% in 2022 due to its use in basic thermoelectric plants and the extension of the pipeline network, which has made it possible to use it in industries as well as in residential, commercial and public buildings.

Figure 3: Total Energy Supply (TES) by source in selected years
Source: EPE (2023b)

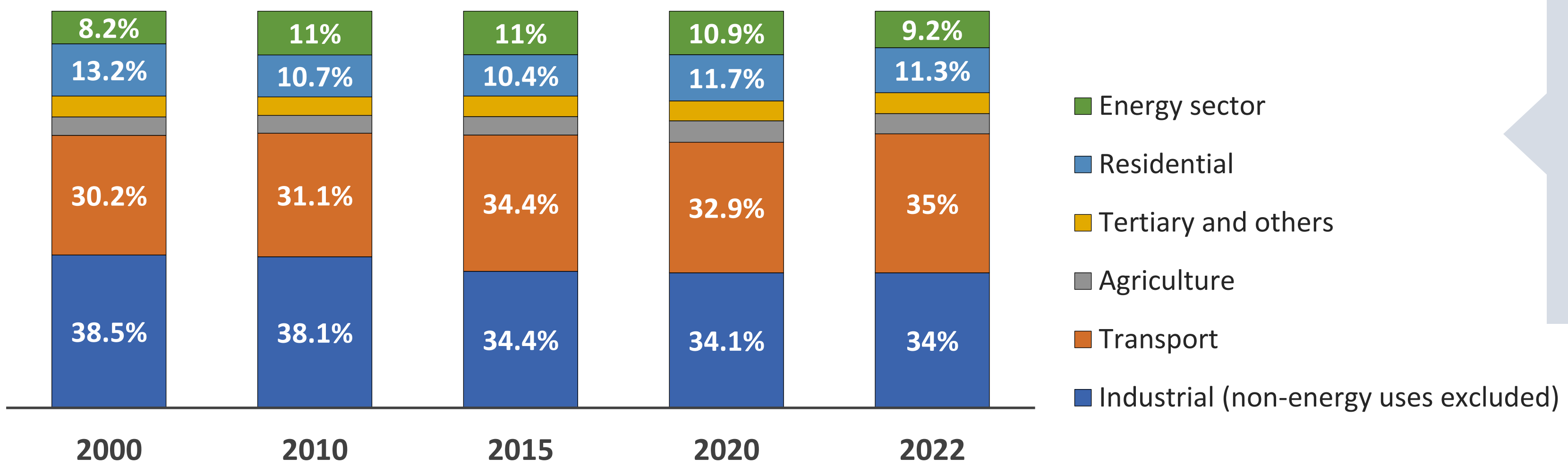


Renewable sources grew in a fast pace due to sugar-alcohol sector expansion and other renewable sources strong insets, such as wind, bleach and biodiesel. With a negligible share in 2000, wind energy has shown increasing participation in the energy matrix, reaching 2.3% of the Internal Energy Supply in 2022. Bleach, directly associated with the cellulose industry, contributed 3.7% of OIE in 2022. Biodiesel has been favored because of the policies of adding this fuel to fossil diesel. In 2022, the percentage added (in volume) was 10% throughout the year. Brazil is the world's second largest producer of biodiesel, behind the United States, and the raw material most used to make it in the country is soybean oil.

Evolution of energy consumption by sector

The main noted movement in this period was the decrease in the industry share, in contrast to the advance of the transport sector, which overtook industrial consumption in 2018, 2019 and 2022. The transport sector grew up in an average rate of 2.9% per year (2000-2022), and more sharply between 2000 and 2015, with a road sector growing share. In 2020 the sector was impacted by the Covid-19 pandemic and the consequent repercussions on the economy and restrictions on travel, especially by air, but it recovered and in 2022 it had the highest energy consumption among the others.

Figure 4: Energy consumption by sector in selected years
Source: EPE (2023b)



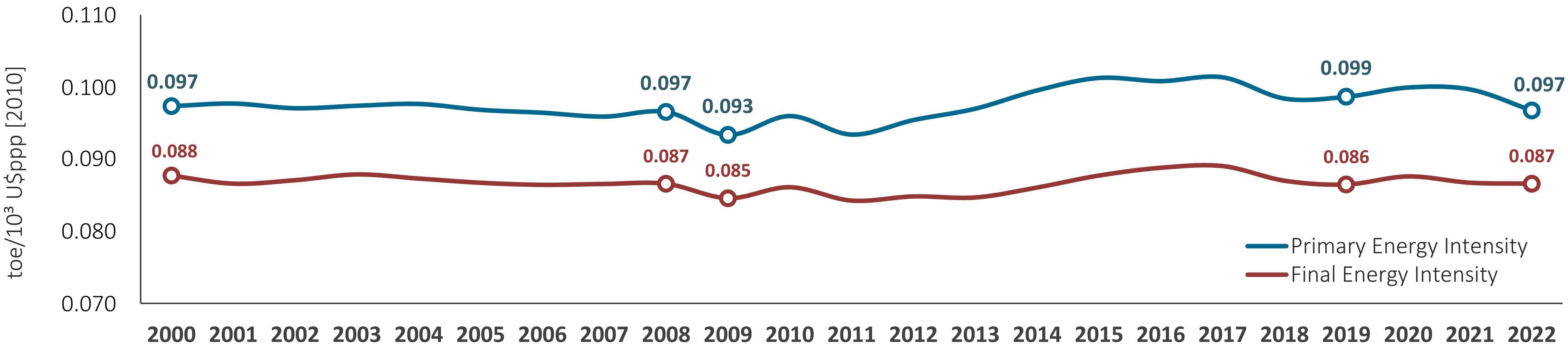
In industry, **the most stood out the segments** were pulp and paper (4.1% per year), food and beverages (2.75% per year) and ferroalloys (2.6% per year). It should be noted that pulp and sugar production are energy-intensive and use the co-products bleach and sugarcane bagasse, respectively, which are renewable.

Cement/steel aggregate has reduced its industrial consumption share from 29.9% to 23.7%. The cement industry, in addition to the gradual reduction in the clinker/cement ratio from 73.2% in 2000 to 68.2% in 2022 (clinker is energy intensive). The energy sector is driven by oil and ethanol production, which grew up in an annual rates of 4.1% and 4.3% over the period. Ethanol production, however, fell by 13.3% between 2020 and 2022.

Energy Intensity

From 2000 to 2008, primary energy intensity remained stable at around 0.097 toe/10³U$ppp[2010]. Likewise, the final intensity stabilized at around 0.087 toe/10³U$ppp[2010]. In 2009, the effects of the international crisis on industry contributed to a reduction in primary energy intensity to 0.093 toe/10³U$ppp[2010]. More inefficient units with higher intensities were shut down.

Figure 5: Evolution of energy intensity in Brazil
Source: EPE (2023b)



Between 2010 and 2022, the primary and final intensities grew up on rates of 0.07% and 0.05% per year, respectively, reflecting OIE growth over the GDP growth. Between 2014 and 2022, primary energy intensity fell at a rate of 0.4% per year. Final consumption intensity, over the same period, grew at a rate of 0.1% per year. The upward trend in energy intensity may be associated with the growth in the production of low value-added energy-intensive products production growth, related to other manufactured products.

Brazil is investing in Energy Efficiency

Competitive sectors such as industry depend on energy efficiency in their production processes and regular working days. Without it, many businesses could become unviable. Technological changes is one of the main sources of wealth creation and long-term economic growth.

According to the INOVA-E platform[1], between 2013 and 2022, Brazil invested almost R$ 5 billion in researches, development and demonstration (RD&D), in energy efficiency projects from public or publicly oriented investments[2]. From this amount, more than a half came from the BNDES (National Development Bank), while ANEEL (National Electricity Agency) and Finep (Financing Agency for Studies and Projects) accounted for 13% and 11% respectively.

Figure 6: Evolution of RD&D investments in Energy Efficiency
Source: EPE (2023c)

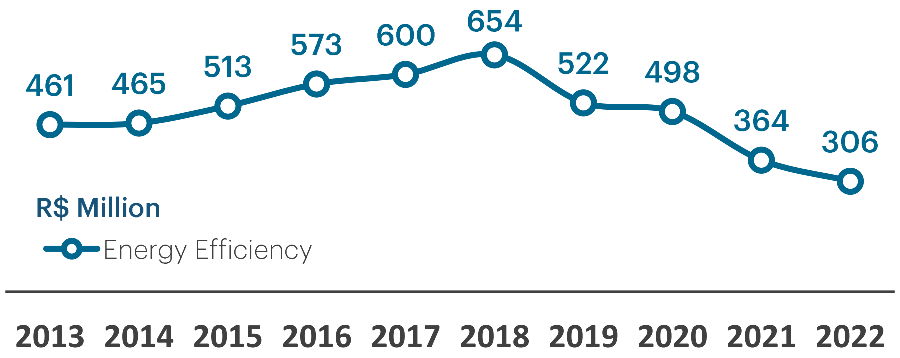
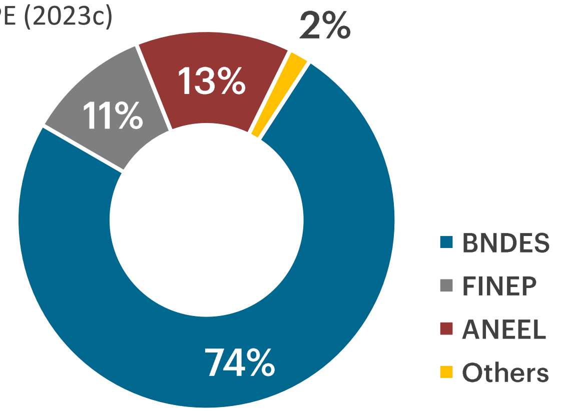


Figure 7: Source of resources (%) for Energy Efficiency RD&D investments
Source: EPE (2023c)



Based on INOVA-E, the previous version of the Atlas showed a 56% share of BNDES funding for energy efficiency. However, the methodological improvements presented in the current version of the platform included, in the energy efficiency category, several projects from the BNDES' funding. The history for the other sources of funding remained unchanged.

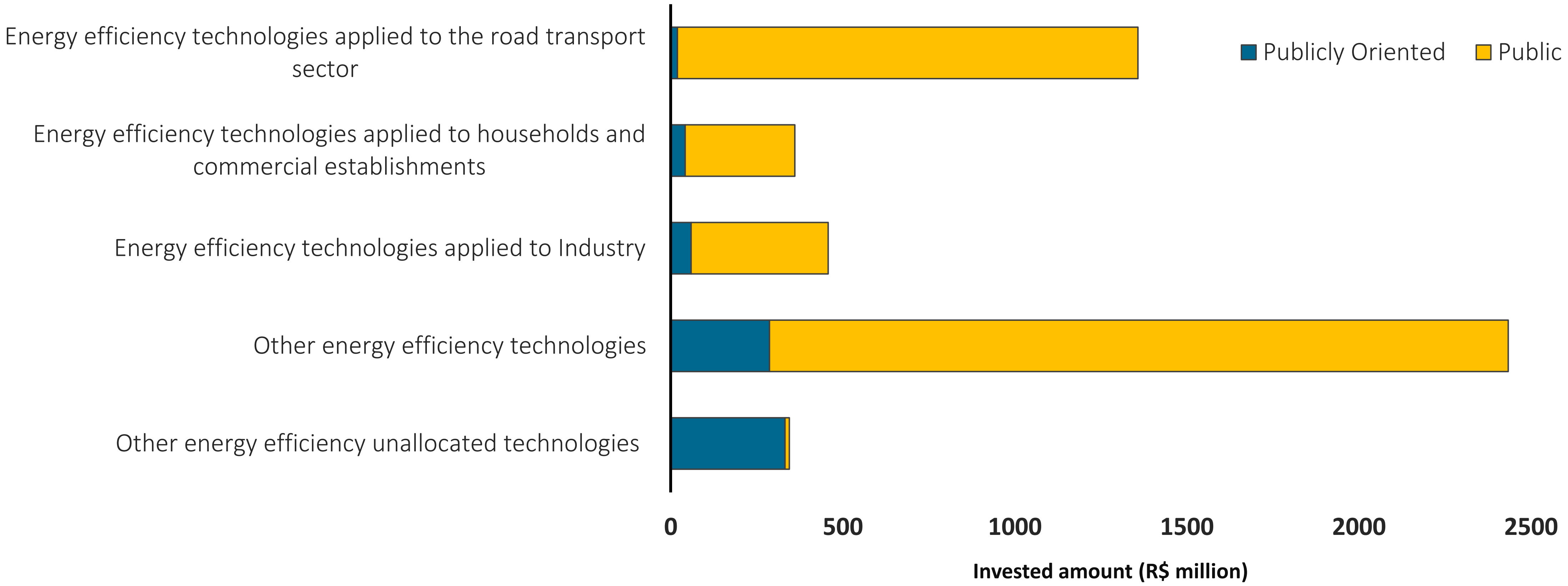
inova e BRASIL

Data from INOVA-E shows an average annual investment of around R$ 495 million over the ten-year time series, considering public and publicly oriented resources in R&D projects in Brazil.

Note: For information on INOVE-E and the meaning of the expressions "public investments" or "publicly oriented" go to Definitions.

RD&D Energy Efficiency Investments

Figure 8: Nature and modality of investments, in millions of reais - 2013 to 2022
Source: EPE (2023c)

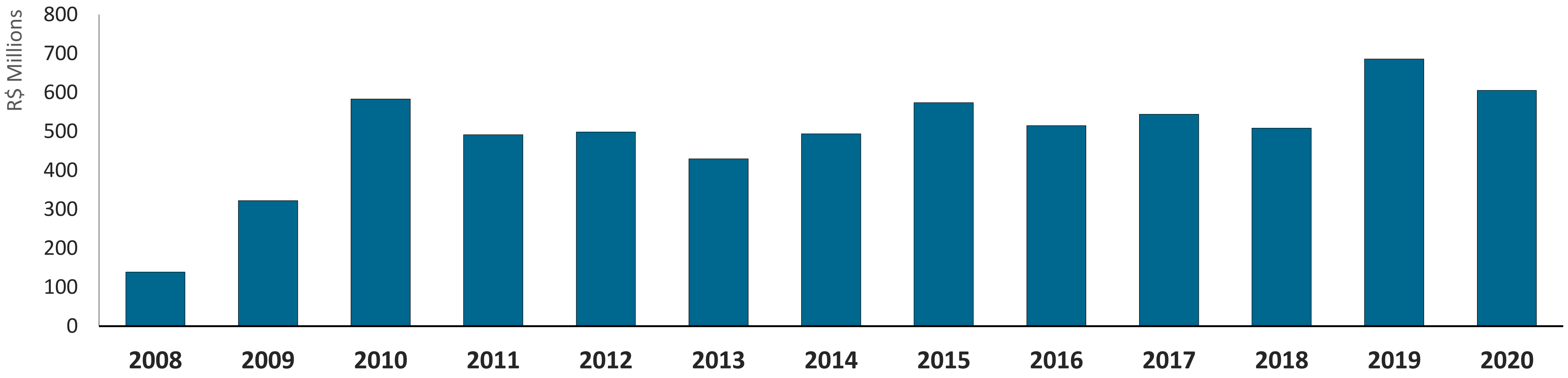


Notes: Investments are classified according to the INOVA-E methodology. It should be noted that particularly demonstration projects, by their nature, may be assigned to more than one technological category and/or include other items of the project, depending on the funder's criteria. For example, investments in energy efficiency through BNDES Finem may include items such as: studies and projects (including energy diagnosis), civil works, acquisition of machinery and equipment, etc.

Investments in the Energy Efficiency Programme regulated by ANEEL

Electricity distributors invest 0.4% of their Net Operating Revenue (NOR) in the Energy Efficiency Programme regulated by ANEEL, based on Law No. 9,991/2000[I]. In 2020, R$ 605 million was invested, which makes a total of R$ 6.4 billion since 2008.

Figure 9: Investment made by electric utilities through PEE/ANEEL - 2008 to 2020
Source: ANEEL (2023b)



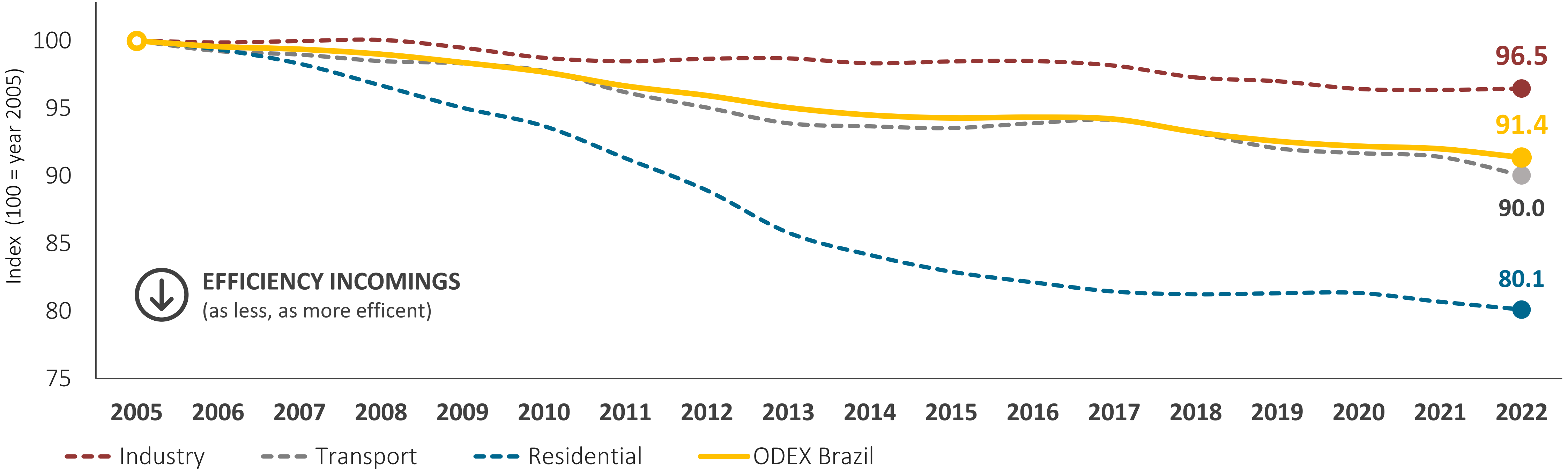
Low-income projects received most of the funding (55%), followed by the residential sector (17%) and public authorities (9%) (ANEEL, 2023a)[2].

Notes:
(1) Since 2016, the percentage due for the application of the Energy Efficiency Programme went from 0.5% to 0.4% of the utilities' ROL, in accordance with Law No. 13,280 of 05/03/2016.
(2) Results based on a sample of 1,485 projects that had the data in the Observatory of the Energy Efficiency Programme (OPEE) necessary for accounting the results.

ODEX

In this report, 2005 was set as the base year (100), covering the industrial, residential and transport sectors, and Brazil as a whole. During the term, all the analyzed sectors showed efficiency gains, with emphasis to the residential and transport sectors, the biggest gains, with 20% and 10% efficiency gains in the period, respectively. The ODEX calculated for 2022 shows that the country will be around 8.6% more energy efficient than it was in 2005.

Figure 10: ODEX Brazil
Source: Compiled by EPE



Note: Clarifications on changes in ODEX data history are available at Definitions

Buildings

Evolution in Buildings' consumption: residential, commercial and public sector

The main source of energy used in buildings is electricity[1]. In 2022, households used 46% electricity, 22% LPG and 26% firewood, while commercial and public buildings mostly use electricity with a 90% share.

Figure 11: Total energy demand in buildings
Source: EPE (2023b)

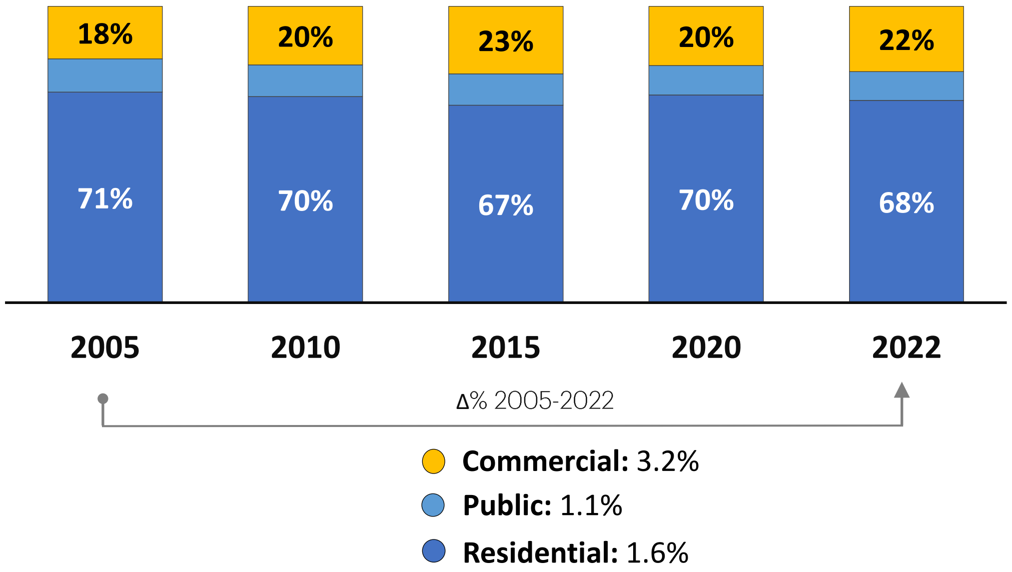
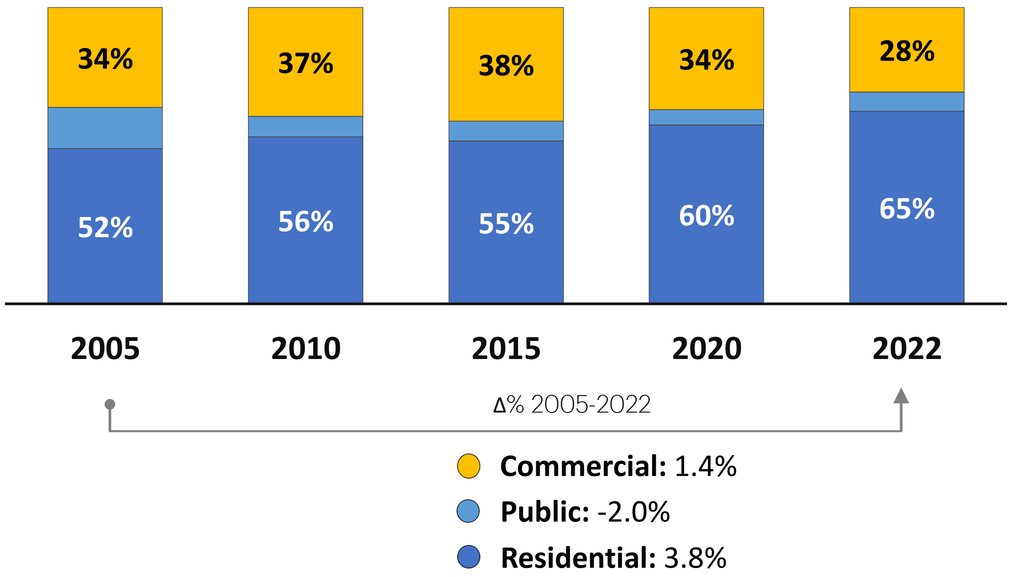


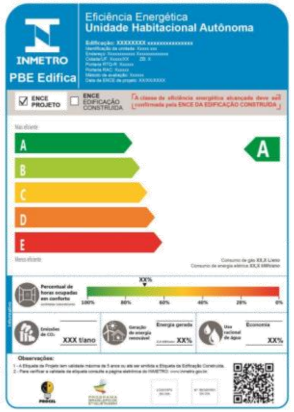
Figure 12: Electricity demand in buildings
Source: EPE (2023b)



In 2022, buildings consumed 239 TWh, which represents 41% of the country's electricity. Considering the attendance of buildings in electricity consumption, this sector can be considered to have the biggest potential for electrical efficiency.

Note: the public sector includes public lighting and sanitation services.
[1]According to the historical series, electricity has been the main source since 2008.

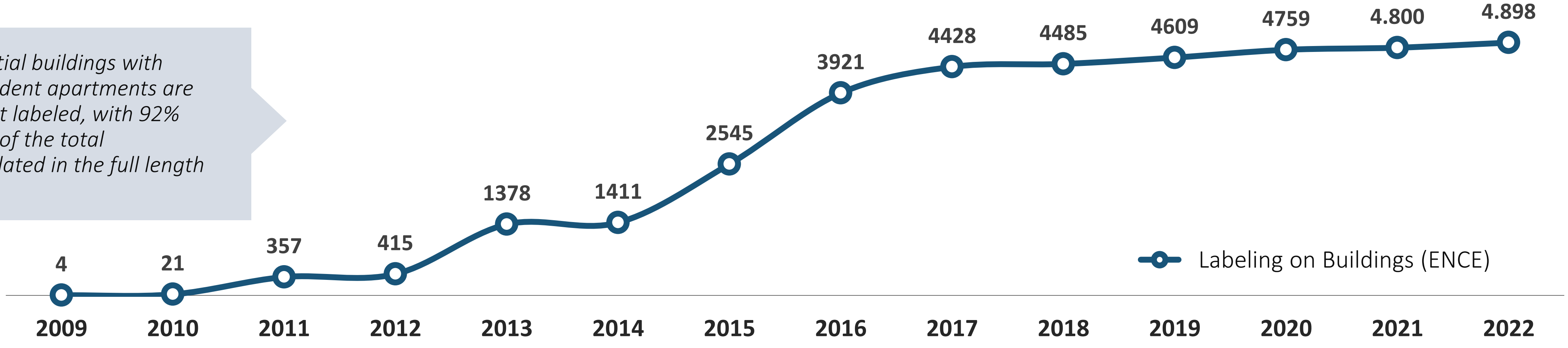
Building Labeling Evolution – Brazilian Labeling Programme (PBE Edifica)



PROCEL EDIFICA - the National Programme for Energy Efficiency in Buildings - is 20 years old this year and building labeling in Brazil is 14 years old, through the publication of methodologies to classify the energy efficiency level for commercial, service and public buildings in 2009 and for residential buildings in 2010. The label can be applied to during the design phase, as well to the constructed building. The figure shows the buildings addition cumulative data about this policy, which informs the building's performance requirements.

Figure 13: Evolution of the National Energy Efficiency Label for Buildings - ENCE (number of issued labels)
Source: INMETRO (2023)

Residential buildings with independent apartments are the most labeled, with 92% sharing of the total accumulated in the full length of time.



In September 2022, the new assessment method for residential, commercial, service and public buildings was approved. The methodology applying will be mandatory from May 1, 2024 onward. This new methodology brings important advances and enables PBE Edifica to be aligned with the Brazilian Standard for the residential buildings performance, NBR 15575/2021, and allows consumers to have the building potential consumption information, or residential unit, and how much energy can be saved as well, compared to a standard building.

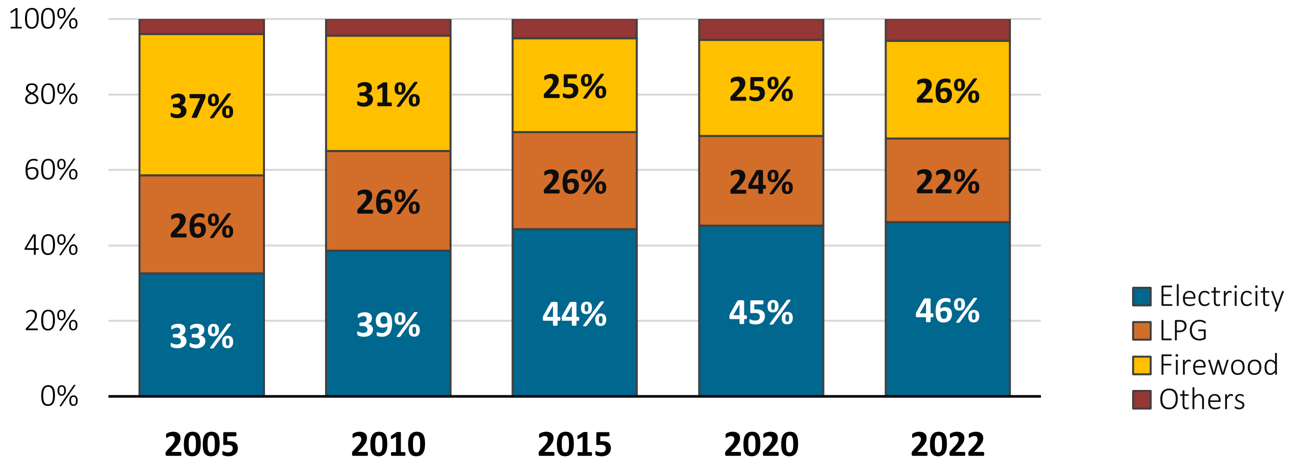
Note: PBE is the Brazillian Labeling Programme

Residential Sector

Evolution of energy consumption in Households by source

Electricity is still widely most used energy source in Brazilian households, with an increase in its energy share around 13.6% between 2005 and 2022. It is broadly used in homes and can be used for air conditioning, food conserving, cooking and preparing, water heating, lighting, laundry, entertainment, communications, personal beauty and in electrical and electronic equipment.

Figure 14: Evolution of energy consumption in Households by source
Source: EPE (2023b)



Liquefied Petroleum Gas (LPG) keeps up as an intermediate share (22% in 2022), and its main use is associated with food cooking.

Natural Gas (NG) is included in Other category (see the Figure) and is used for food cooking and water heating, mainly in urban country areas with distribution grid.

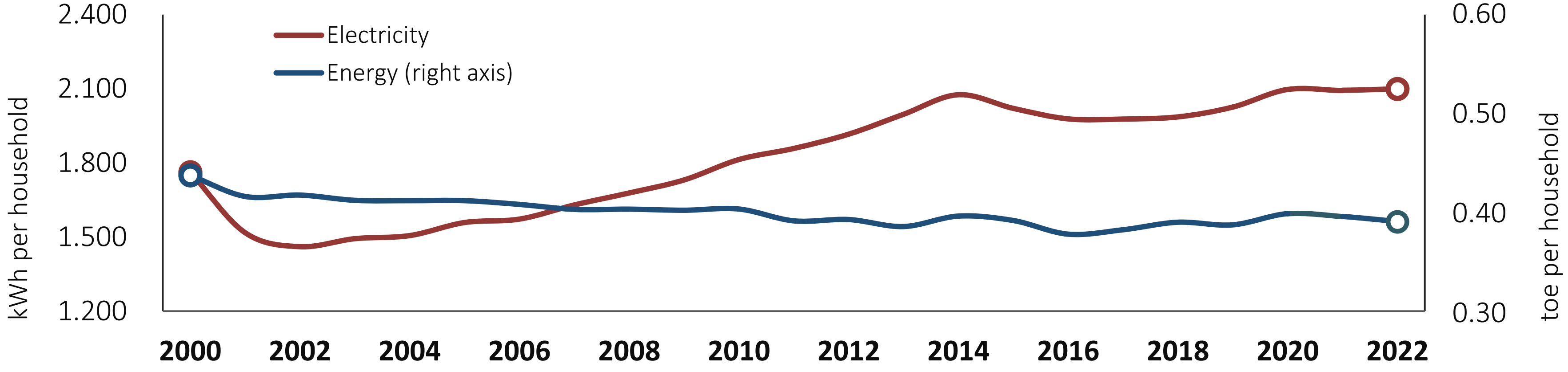
Solar thermal energy is also included in Other category and is used for water heating.

There is a reduction in the firewood use for cooking from 2005 to 2015, due to the improvement in families' economic conditions. Since 2015, the energy share of firewood is remaining around 25%.

Evolution of electricity and energy consumption in households

While energy consumption per household fell by 10.7% (0.5% down, per year) from 2000 to 2022, electricity demand per household grew up by 19% (0.8% up, per year) in the same period. Energy and electricity demand sharply felt in 2001 due to the country's electricity rationing, which stimulated a change in habits and promoted energy efficiency measures in Brazilian households.

Figure 15: Evolution of electricity and energy consumption in households
Source: Compiled by EPE



Electricity demand increased from 2000 to 2022 due to the economic progress of families, the advance of credit for the household appliances purchase, government electrical connection policies, mainly in rural areas, and housing program and incentives to reduce the Brazilian housing deficit. On the other hand, energy consumption fell over the period owing of the reduction in the less energy-efficient sources using (traditional biomass - firewood and charcoal) and the consequent replacement by more modern sources (LPG, NG and electricity). It's important to note that energy consumption per household started to rise in 2014, due to the return to the use of traditional biomass for cooking food, replacing LPG, which is relatively more expensive, especially in poorer families in a consequence of the economic crisis.

Effects of energy efficiency policies on households

Energy efficiency policies can include minimum energy efficiency indexes (or maximum consumption indexes), comparative labeling (compulsory or voluntary) and endorsement seals.

These initiatives have been introduced in the country since 1984, with the establishment of the Brazilian Labeling Programme (PBE), headed by INMETRO, which began to produce comparative labels for equipment's energy performance, providing consumer education and stimulating more efficient products manufacture from industry.

In 1993, the PROCEL (for electrical equipment) and CONPET (for products that use derived fuels from oil and natural gas) seals were created to emphasize the most energy-efficient devices.

There are complementary actions aimed at reducing energy demand in homes, including performance standards (ABNT NBR N0 15.220 and N0 15.575), labeling standards (PBE Edifica) and endorsement seals (Procel Edifica) for buildings, as well as encouraging the use of alternative energy generation systems in social housing (HIS).

It is estimated that the average annual consumption per **air conditioner** reduced about 15.3% between 2005 and 2022 (-1.0% per year), because of the minimum energy efficiency index, regulations initiated by MME/MCT/MDIC IO n° 364/2007 and revised the IO n° 323/2011 and by the IO n° 2/2018.

In the case of **refrigerators**, it is estimated that the average annual consumption per appliance reduced about 11.5% between 2005 and 2022 (-0.7% per year), because of the minimum energy efficiency index regulations initiated in 2007 by IO MME/MCTI/MDIC n° 362/2007, which was revised by the IO n° 326/2011 and by the IO n° 01/2018.

Following on the new policies from Law N0 10.295 of 2001, known as the Energy Efficiency Law, it is important that the regulations about minimum energy efficiency ratings be extended to other household appliances, prioritizing those with the highest average consumption per appliance.

IO = Interministerial Ordinance

Solar Heating Systems (SHS) ingress in houses

The exchange from the sun's energy into thermal energy is based on the absorption of solar radiation and its transfer, as heating, for an element that will provide a certain energy service.

Solar water heating systems are made up of solar collectors and a thermal storage, where the heated water is stocked. SHS have an extra heating equipment, that can use electricity or gas, and are activated during periods of low solar intensity, such as nights and cloudy days. The collectors and tanks are standardized by the Brazilian Labeling Programme (PBE), coordinated by INMETRO.

From the consumer's point of view, the use of SHS can

total energy spending. For the electrical sector, their use can reduce consumption on the grid, peak demand in critical periods and the technical losses in the system as well, helping to postpone new investments in generation, transmission and distribution. Finally, from an environmental point of view, the use of SHS can help to reduce GHG emissions.

Residential solar thermal energy is mostly used to heat water for showers and swimming pools, which can be located inside houses or in buildings leisure areas. It was estimated that the energy consumption avoided in the country's homes will be 806,000 toe in 2022 using SHS.

Figure 16: Solar Heating Systems (SHS) ingress
Source: Compiled by EPE

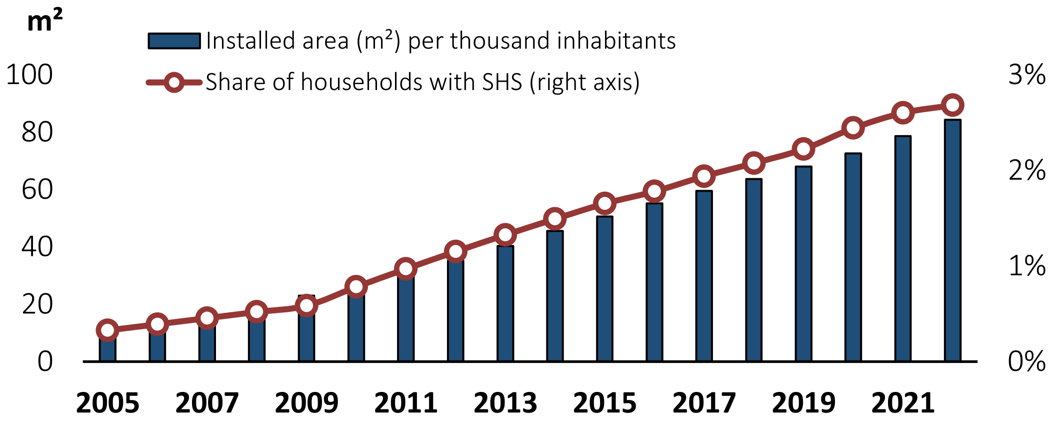
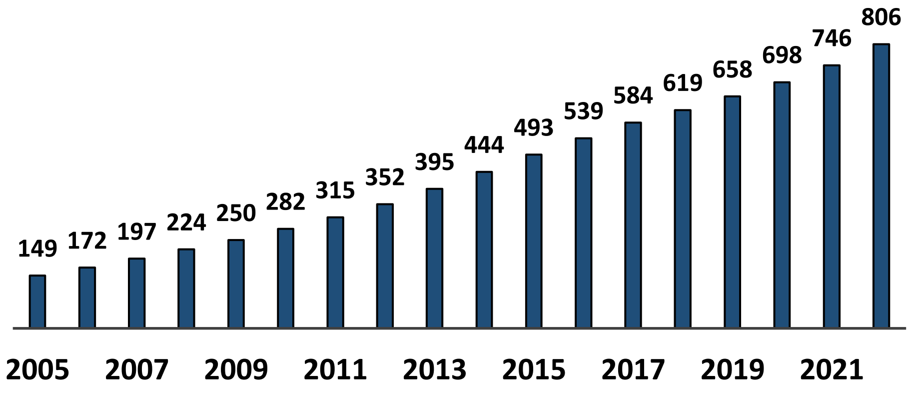


Figure 17: Avoided Residential Energy Consumption (thousand toe)
Source: Compiled by EPE



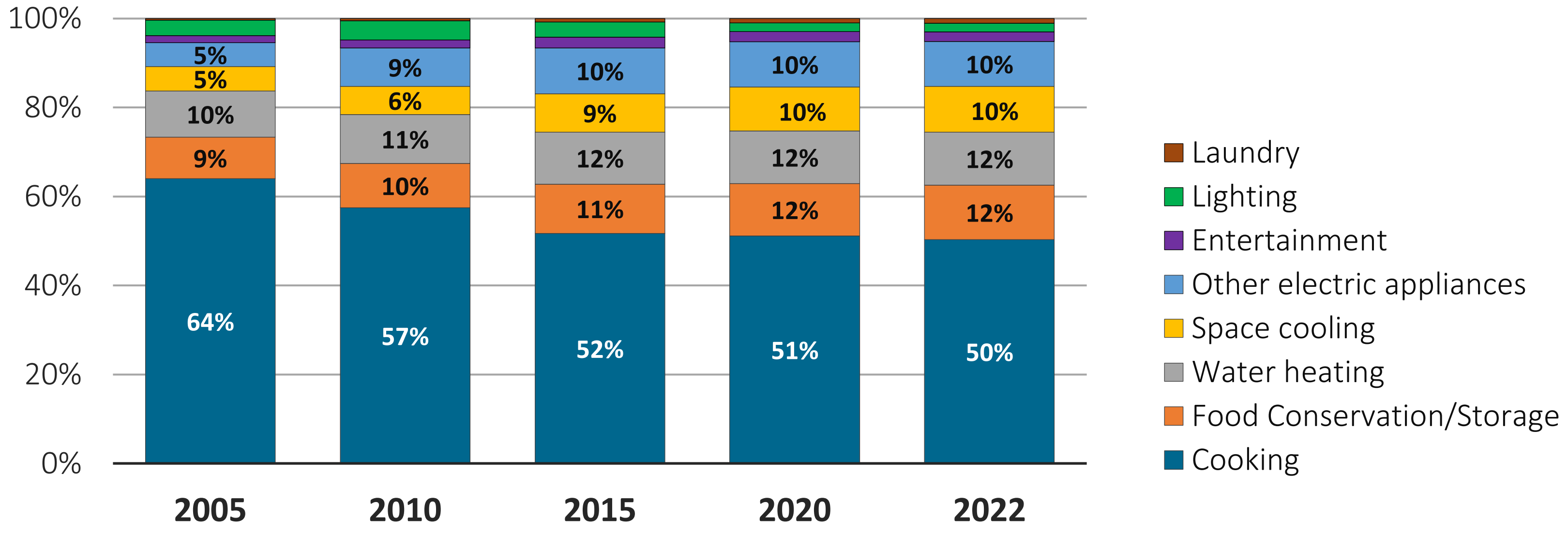
Energy share evolution of the final consumption in the residential buildings

The main final energy use in Brazilian homes is cooking, followed by food preserving and water heating. The reduction in the energy share of food cooking between 2005 and 2022 can be explained by the energy transition process of the most economic disadvantaged families, which have been replacing the consumption of traditional biomass by modern and efficient fuels, as they economically progress. Lighting, on the other hand, has been losing share over time due to the increasingly use of efficient light bulbs, especially compact fluorescent and LED technology.

The increase in the electrical and electronic equipment share can be explained by the increase in the families' possessions and resources, which follow a technological and habits transition.

Figure 18: Evolution of the energy share of end uses in the residential energy demand

Source: Compiled by EPE



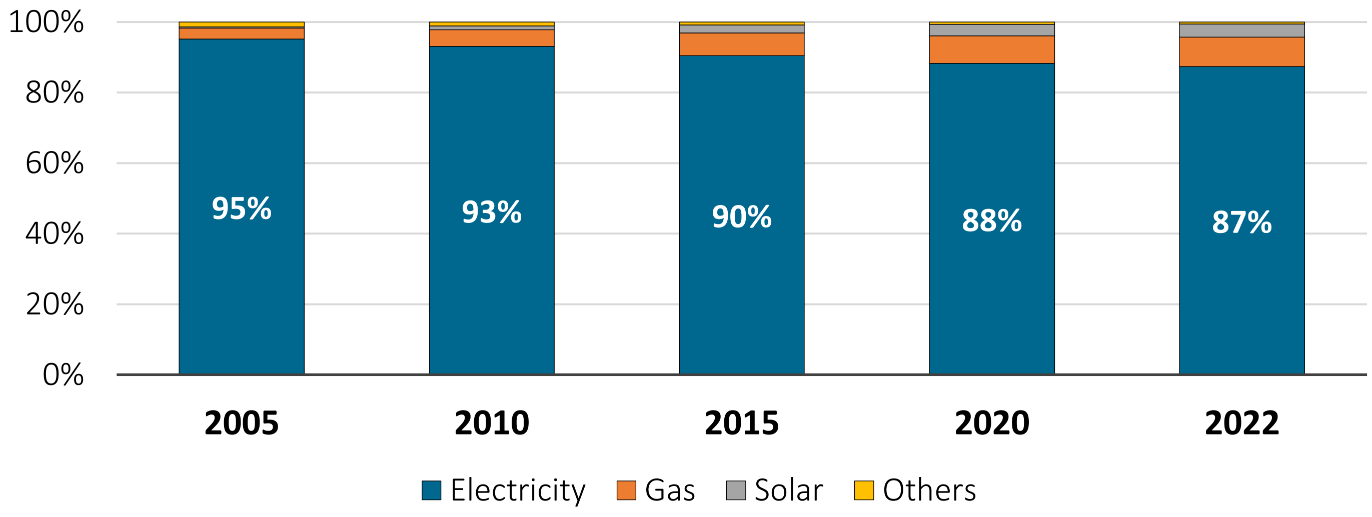
Conditioning air has become more popular due to the increased use of equipment's by families, as they are able to afford them, replacing fans and air circulators, which are relatively cheaper and use less energy. This may also happen due to the increase of warmer days average occurrence over the years.

Heating water houses percentage evolution by energy source

Electricity is the biggest energy source used by Brazilian households to heat water, because of the electric showers. It is estimated that in 2022 the country has an average of 0.71 electric showers per house and the percentage of households using electricity to heat water reached 87.3% in the same year. In addition, the households with solar thermal energy for water heating reached 3.6% of all heating water households in 2022.

Figure 19: Evolution of the share of households that heat water by energy source

Source: Compiled by EPE



Water gas heaters, which can be tankless or storage tank, are alternatives to electric showers, especially in urban areas with gas distribution grid. It is estimated that around 8.4% of households are using gas to heat water.

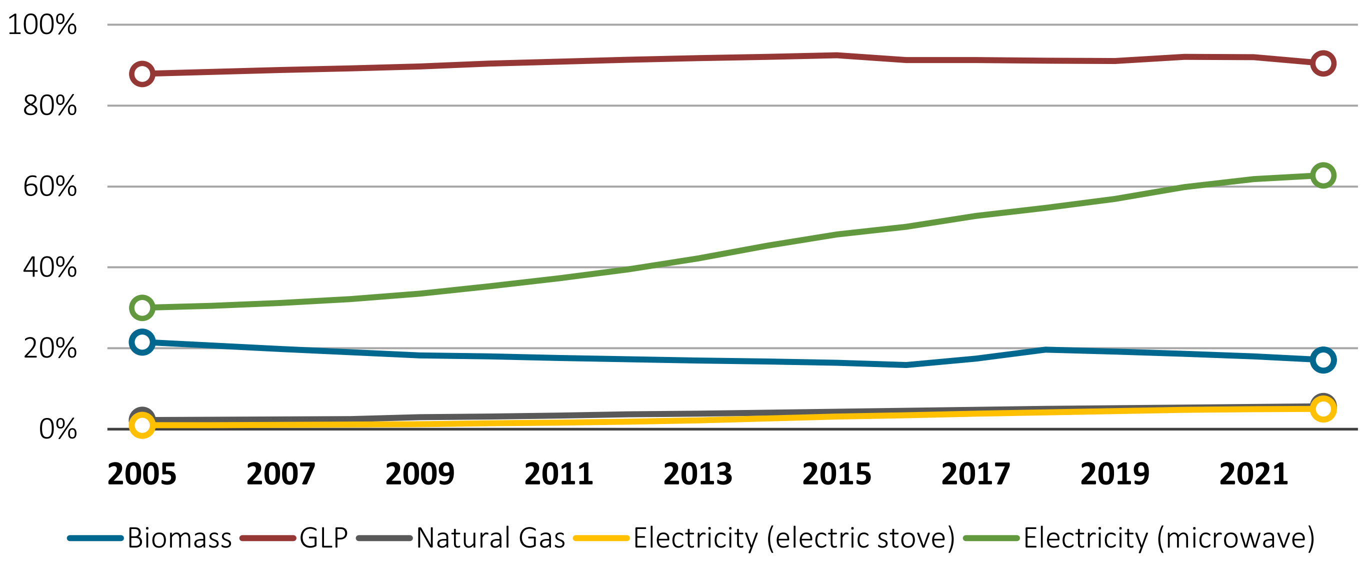
This equipment is standardized by the Brazilian Labeling Programme (PBE), coordinated by INMETRO. There are also regulations for minimum energy performance standards for gas heaters, which started with the MME/MCT/MDIC Interministerial Ordinance No. 298/2008 and was reviewed in 2011 by the Interministerial Ordinance No. 324.

There are very warm weather Brazilian regions, such as the North and Northeast. This may contribute to the low percentage of households that heat water for bathing, as illustrated by the Survey of Ownership and Habits of Use of Equipment - PPH 2019 (PROCEL/ELETROBRAS). The EPE calculations, using the data collected in this survey, estimate that around 35% of Brazilian households did not heat water for bathing in the country in 2019. This number of houses is much higher in the North (94%) and Northeast (88%).

Percentage evolution of households cooking food by energy source

LPG has a large grid in Brazil, reaching 90% of national households in 2022. The use of natural gas is still small (5.7% of national households), basically restricted to urban areas in cities with distribution infrastructure.

Figure 20: Percentage evolution of households that cook food by source in relation to the total number of national households
Source: Compiled by EPE



The electricity use in food cooking has been growing over time, mainly due to the increase in microwave ownership (63% in 2022).

With the technology evolution and the cost reduction, people are more likely to buy these type of electrical appliances for domestic use, because it is practical, and brings satisfactory results. It includes microwaves, electric ovens and hobs, sandwich makers, grills, toasters, electric fryers, electric pans, among other devices.

The traditional biomass (firewood and charcoal) share for food cooking in the country's houses felt down between 2005 and 2015 because of the economic progress in most of the disadvantaged Brazilian families. However, it had a growth from 2015 to 2018 due to the economic worsening scenario, with a further reduction in the following years until 2022.

Electricity - ending use, ownership and average annual consumption by equipment

Figure 21: Residential electricity consumption by end use
Source: Compiled by EPE

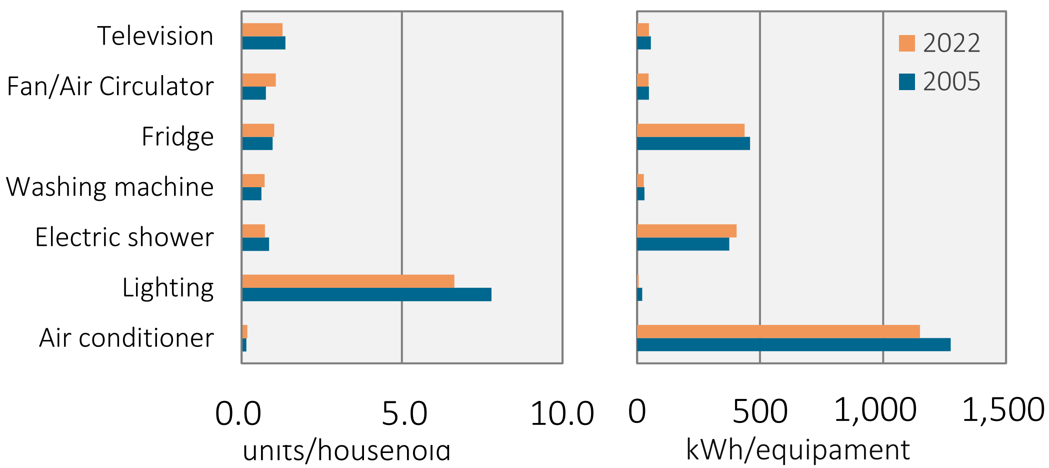
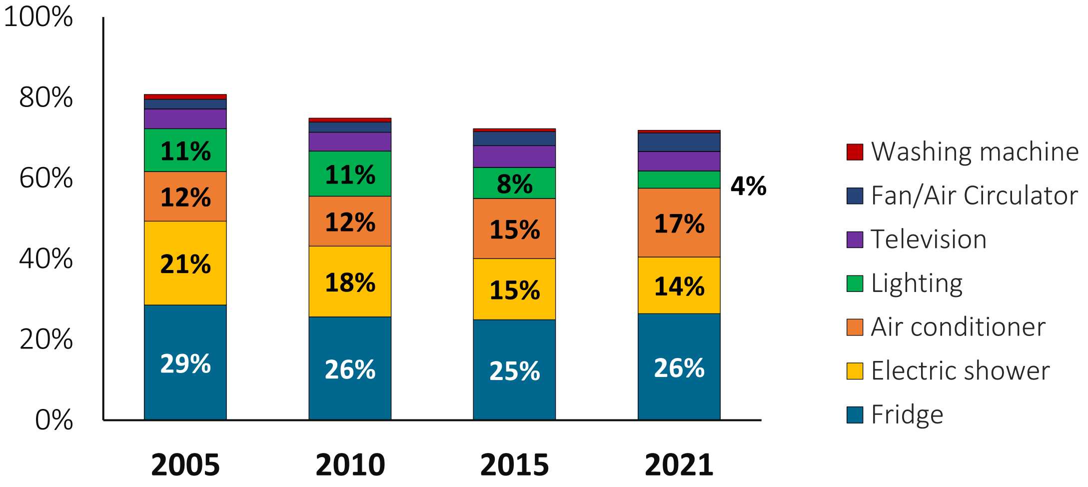


Figure 22: Electricity consumption share by equipment type
Source: Compiled by EPE



Food preservation is the highest end use consumption per household in the country, because of the refrigerators which are turned on practically in every Brazilian home, 24 hours a day, every day, all year long. It means a highly significant specific consumption.

Despite the air conditioners decrease of 0.18 appliances/house in 2022, it has the highest average consumption per appliance, that results in being the ranking second-place among the most electro-intensive appliances in 2022 (around 17% of total residential consumption in the year). Fans and air circulators have slightly more than 1 appliance/household, making them a lower-cost solution for conditioning the air.

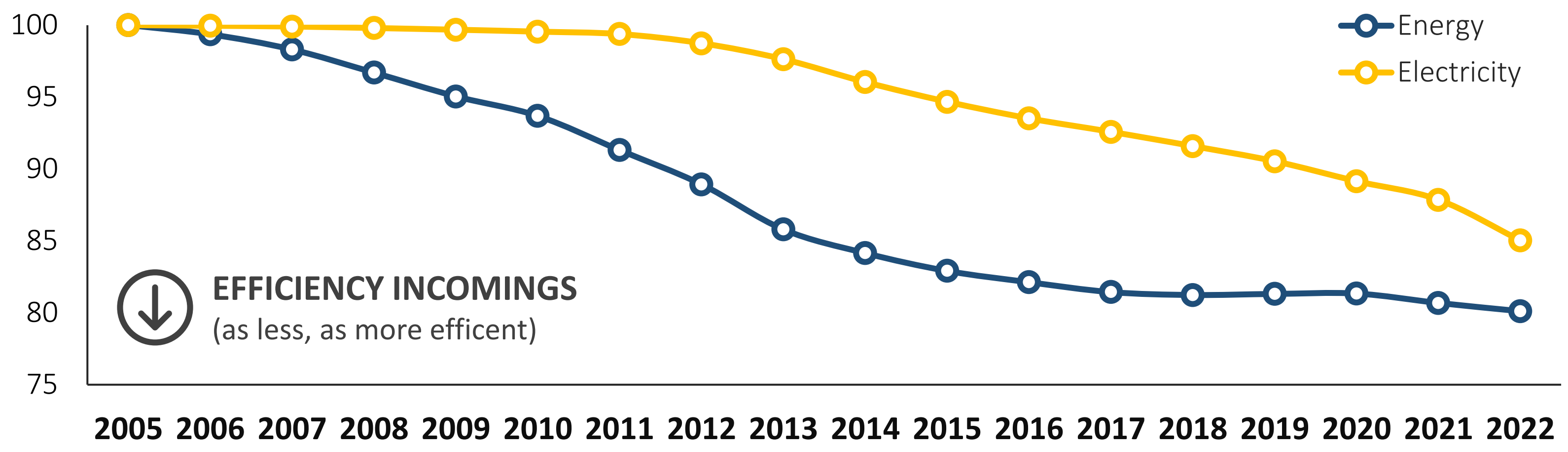
The number of electric showers felt between 2005 and 2022. In the case of freezers, the reduction is largely the result of families changing their habits in recent decades and no longer replacing equipment, that has reached the end of its lifetime and is being scrapped.

The insertion of more efficient equipment, replacing older equipment, tends to reduce the average consumption of the existing stock in the country.

Residencial ODEX

ODEX is an index that analyzes the energy efficiency improvements over a period of time. For households, this measure brings the consumption trend of the different end uses (in the case of energy), or the main electrical equipment (in the case of electricity), weighted by their total consumption.

Figure 23: Residential ODEX evolution calculated for total energy and electricity
Source: Compiled by EPE



Energy efficiency trends in the Brazilian residential sector between 2005 and 2022.

While the ODEX calculated for electricity fell by 15% (0.08% p.a.) between 2005 and 2022, the ODEX for energy fell by 20% (1.1% p.a.). In recent years, the indicator decrease has been higher for electricity, suggesting the importance of this source in the country's residential energy conservation.

For electricity, the national stock of equipment decreased in its average specific consumption. This is because of the first equipment purchase or replacement of obsolete or end-of-life appliances by more efficient ones. In other hand, when other energy sources are considered, there is a slowdown in the ODEX decrease since 2014, which can be explained by the slight increase of firewood for cooking use, due to budget restrictions and an increase of the LPG price in household expenses, especially for low-income families.

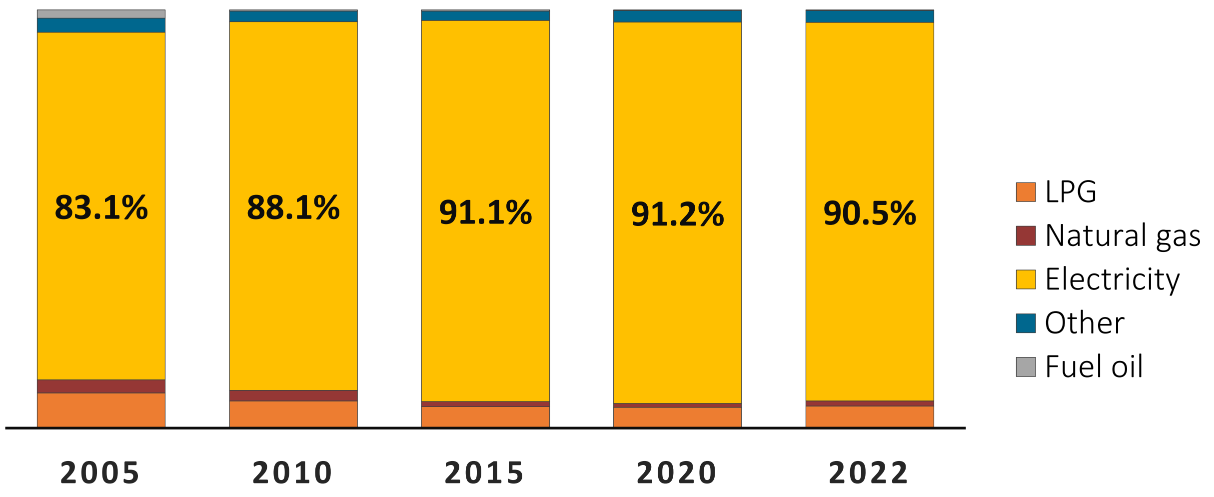
Note. The Residential ODEX methodology has been updated to isolate the ownership effect and specific equipment consumption and, consequently, to highlight energy efficiency gains by equipment. The facilities considered in the calculation of the electrical ODEX are light bulbs, fridges, washing machines, TVs, electric showers, air conditioning and fans. In the energy ODEX, in addition to the electrical equipment energy consumption considered, different energy sources consumption are considered for heating water and cooking food.

Services Sector
(commercial and public services)

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

Electricity remains the final energy consumption main source in the services sector with a 90% share, along with LPG (5.3%) and natural gas (1.2%). It must be noticed that the final consumption data does not include the use of natural gas to generate electricity, according to the National Energy Balance (BEN) methodology.

Figure 24: Final energy consumption by source in services sector
Source: EPE (2023b)



The importance of electricity in the sector's final consumption may be associated with a lot of factors such as electricity availability, the increase in the electrical equipment ownership in facilities, the processes and equipment automation, the replacement of equipment that uses LPG and natural gas by electricity appliances, such as ovens and stoves, among other factors.

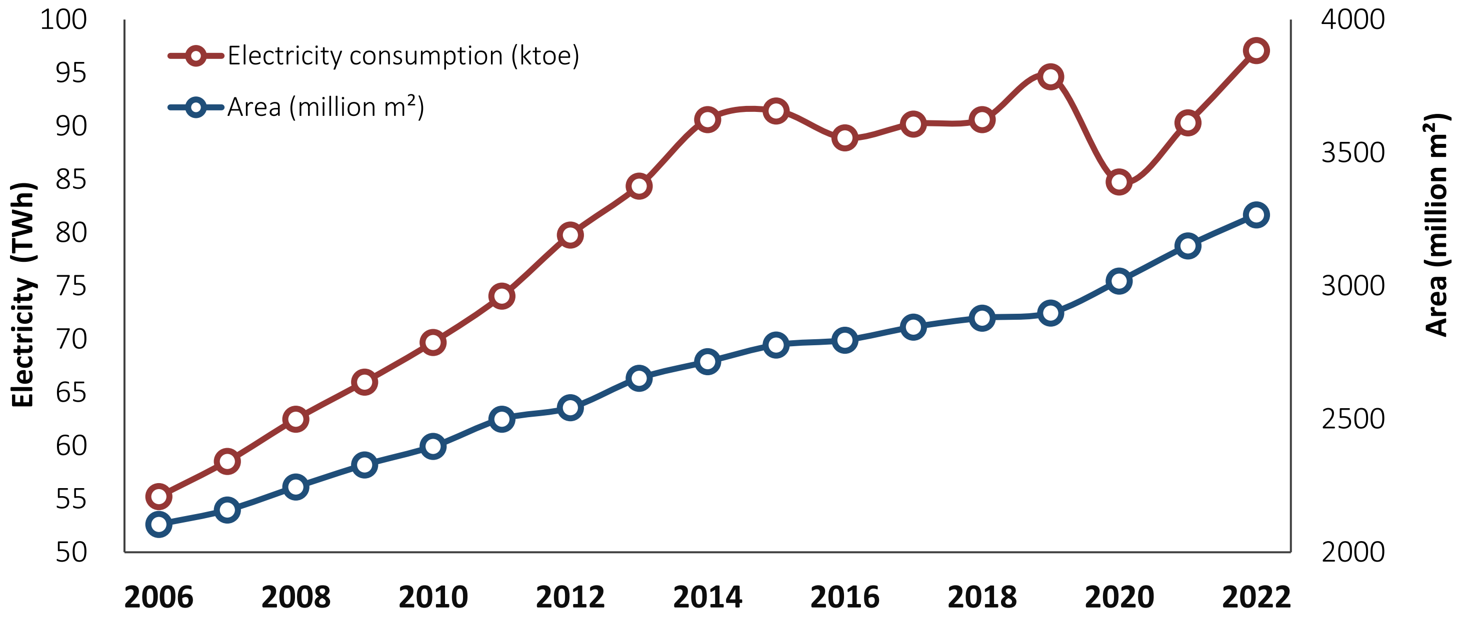
In this sector, electricity is the predominant source and grew up in an annual average rate of 3% during this period. The electricity from solar photovoltaic sources grew by 13.4%.

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

Analysis: Commercial Sector

In 2022, the commercial sector reached its highest level, both in terms of electricity consumption and area. For the period 2006-2022, there was an increase in commercial establishments in an annual average rate of 2.8%, while during the same time the sector's electricity consumption increased by 3.6% per year. ABRAVA's economic bulletin (February 2023) points to a growth in 2022 of 6.9% for central equipment (tons of refrigeration - TR) in comparison to 2021, largely due to the resumption of services.

Figure 25: Electricity consumption evolution and commercial sector area
Source: Compiled by EPE



In 2022, the services volume (incomings) increased by 8.3% in comparison to the previous year, partly due to the resumption of tourist activities, congresses, conventions, hotels and restaurants, etc.

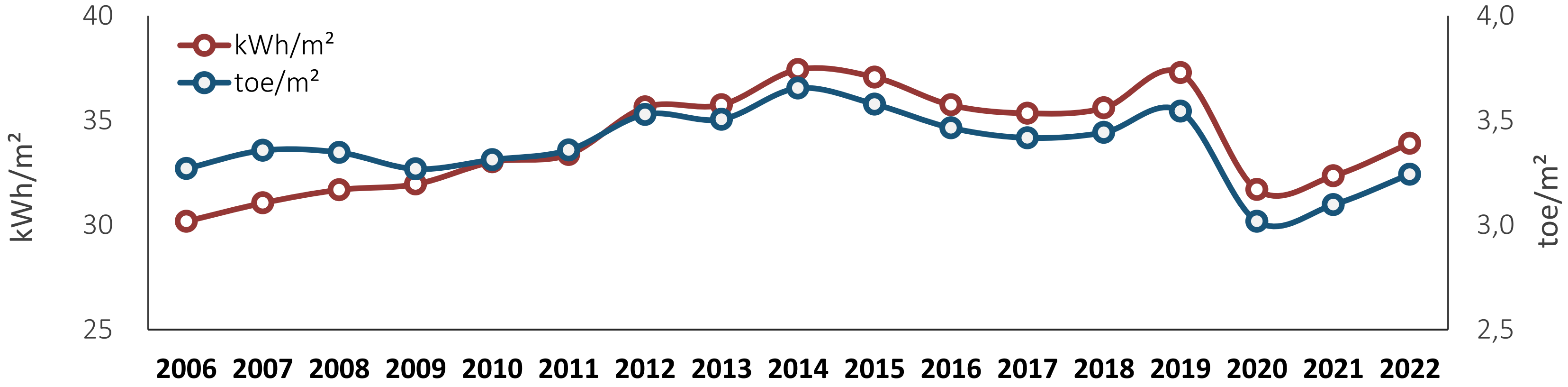
The Civil Construction GDP increased by 7% in 2022 (IBGE), with a positive performance above Brazil's GDP of 2.9%, contributing to the expansion of the built-up area and electricity consumption.

Sectorial Indexes: commercial and public buildings consumption evolution per area

Energy consumption per square meter in commercial and public buildings grew up between 2006 and 2014, mainly due to the electrical equipment ownership and using increase. However, from 2014 onwards, the indicator showed stability until 2019, culminating in a vertiginous drop in Covid-19 pandemic year, with a partial recovery in 2021 and 2022. 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 effects that validate the trajectories illustrated, such as:

- The Aneel Resolution 414/2010 implementation, which reclassified part of the condominium buildings electricity consumption, previously accounted for in the residential sector, to the commercial sector.
- The climatic effect that intensifies/enables the operation of environmental conditioning equipment: air conditioners, fans, among others.
- The recent years water, economic and health crises.

Figure 26: Specific consumption[1] per square meter
Source: Compiled by EPE



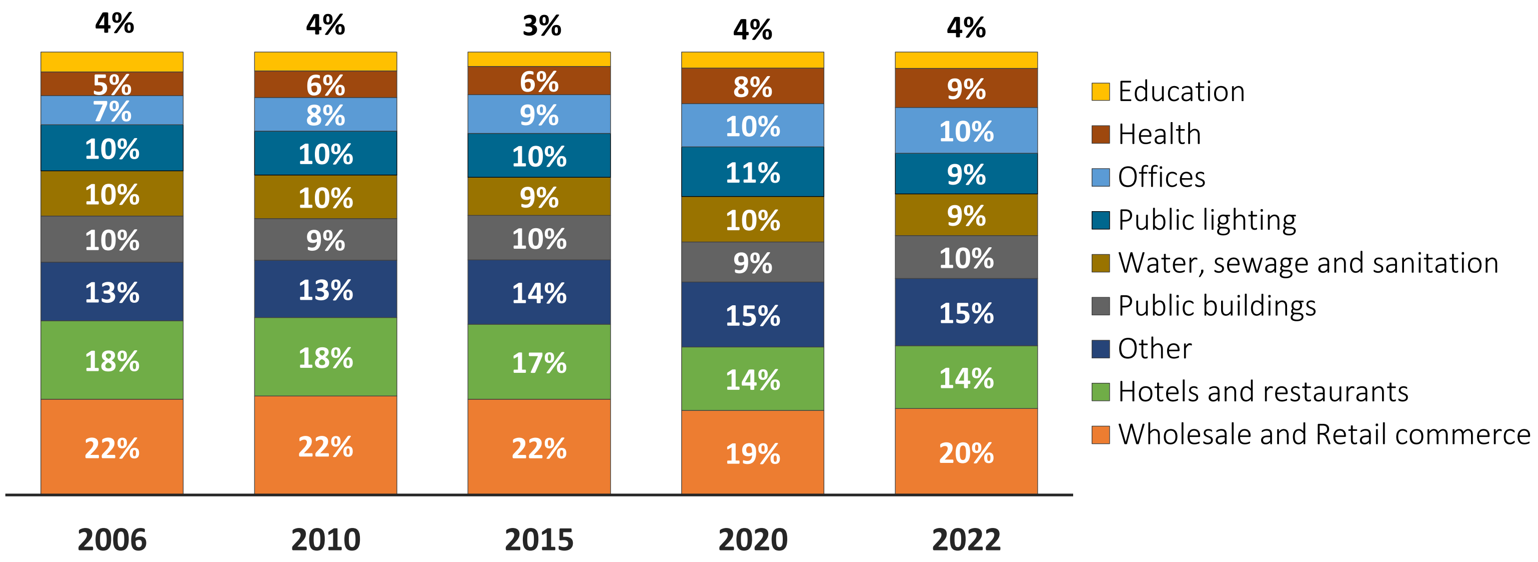
Data	Δ% 22/21
Eletricity Consumption	9%
Energy Consumption	8%
Area (millions m²)	4%

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

Energy Consumption in services segment by sector 2006-2022

The figure shows a decrease in the Wholesale and Retail segment share, from 22% in 2006 to 20% in 2022. This segment holds the largest share of consumption, with 20% of the total. In the Covid-19 pandemic, in 2020, the health segment increased its final energy consumption share in contrast of trade and retail, hotels and restaurants segments.

Figure 27: Final energy consumption in services segment by sector
Source: Compiled by EPE from EPE (2015)



The energy consumption distribution by segment over the period shows a certain homogeneity, although the services sector being heterogeneous in its characteristics and usage profile. There was an increase in energy consumption in 2022 compared to the previous year, with a rate of 6.6%.

[1] Others category includes condominiums, public places (theaters, clubs, museums, churches, galleries, etc.) and information (cinemas, radio, TV, telephony, etc.).

E-commerce share in traditional retail trade sector

Part of the energy consumption decline in the retail trade sector is supported by the increase in internet sales. In 2022, the e-commerce share turnover reached 10.14%.

Figure 28: E-Commerce geographical regions profile
Source: ABComm (2023)

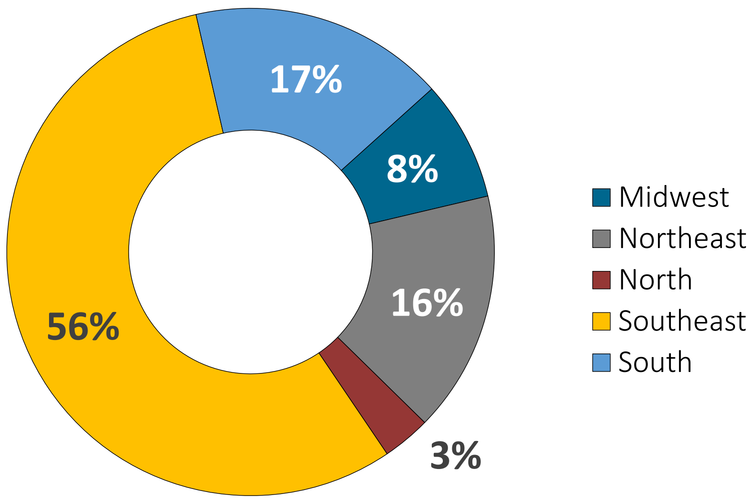
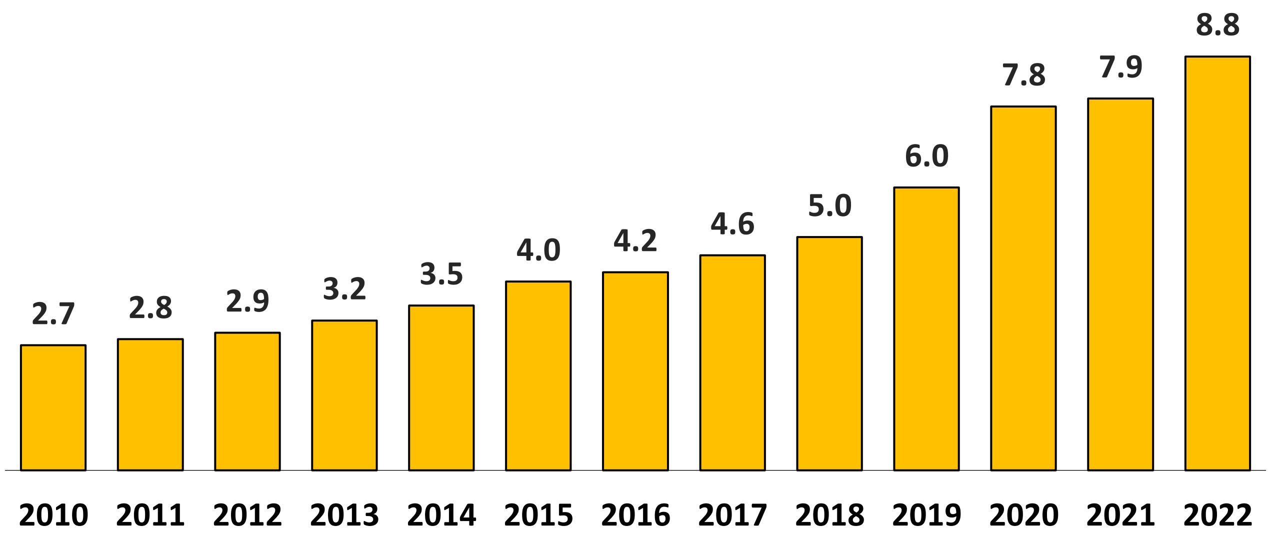


Figure 29: E-commerce in Traditional Retail Share - 2010 - 2022
Source: ABComm (2023)

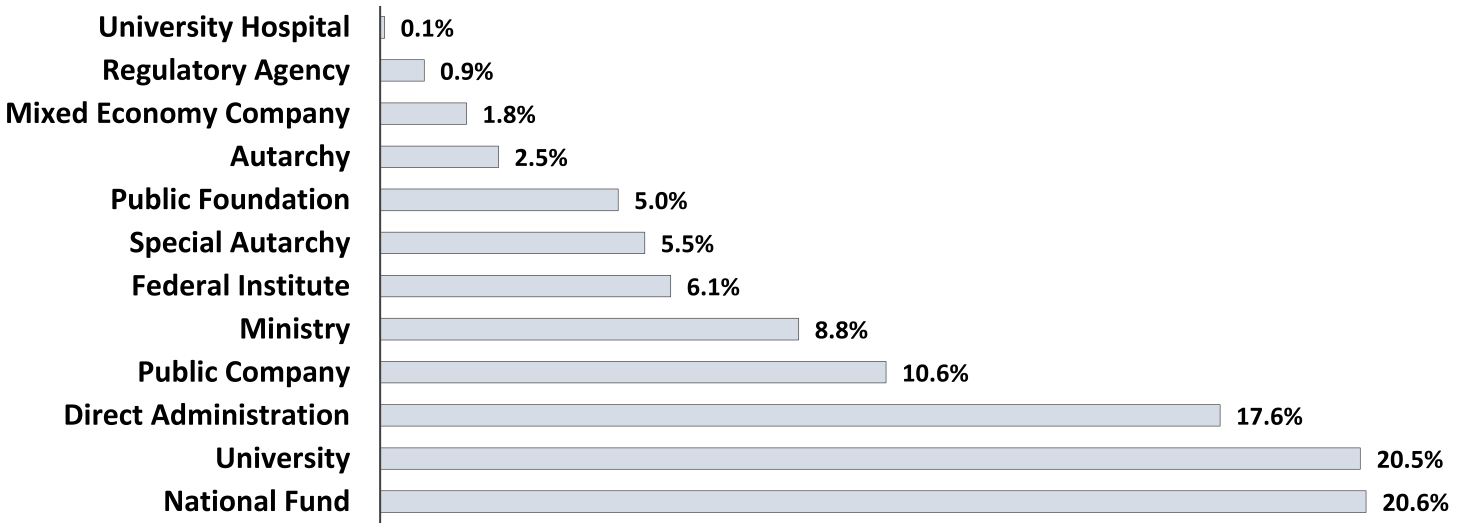


The **Figure 29** shows the growing of e-commerce share.
The Southeast is the main e-commerce market, contributing 56%.

Electricity spends profile in the federal public administration

It is possible to analyze the electricity expenditure profile in the federal public administration through the Administrative Cost Panel. Currently, the panel provides information on expenditure, and Figure X3 shows the distribution by agency. In the absence of electricity consumption data, this information helps to see the biggest expenses to drive policies and prioritize actions for energy efficiency.

Figure 30: Distribution of Electricity Spending - 2016-2022
Source: MGISP (2023)



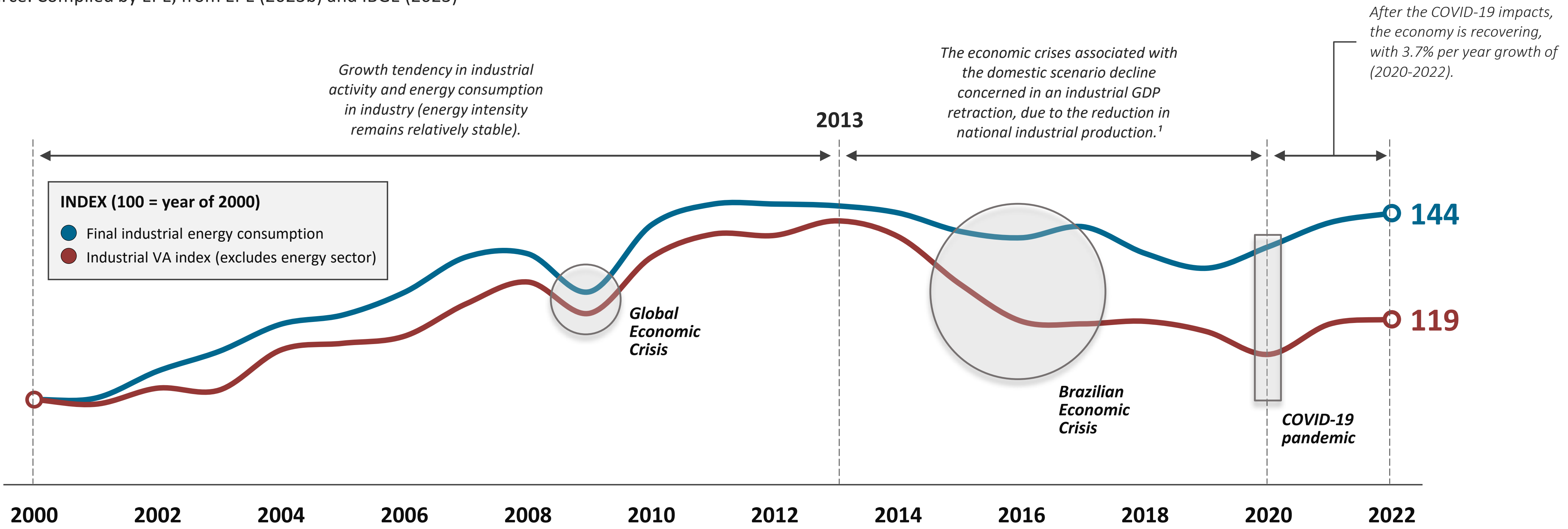
From 2016 to 2022, 60% of expenditure is centered in three segments: Universities and the National Fund with 21% each and Direct Administration with 18%. This information helps us to understand the segments and the electricity use profile.

[1] National funds include, for example: the National Health Fund, the Education Development Fund, the Indian Fund, the Arts Fund, the Anti-Drugs Fund, the Culture Fund, the Civil Aviation Fund, etc.…

Industrial Sector

Energy consumption and aggregated value evolution in Brazilian industry

Figure 31: IOE, Energy Consumption and Aggregated Value by Industries in Brazil (Index 2000 = 100)
Source: Compiled by EPE, from EPE (2023b) and IBGE (2023)

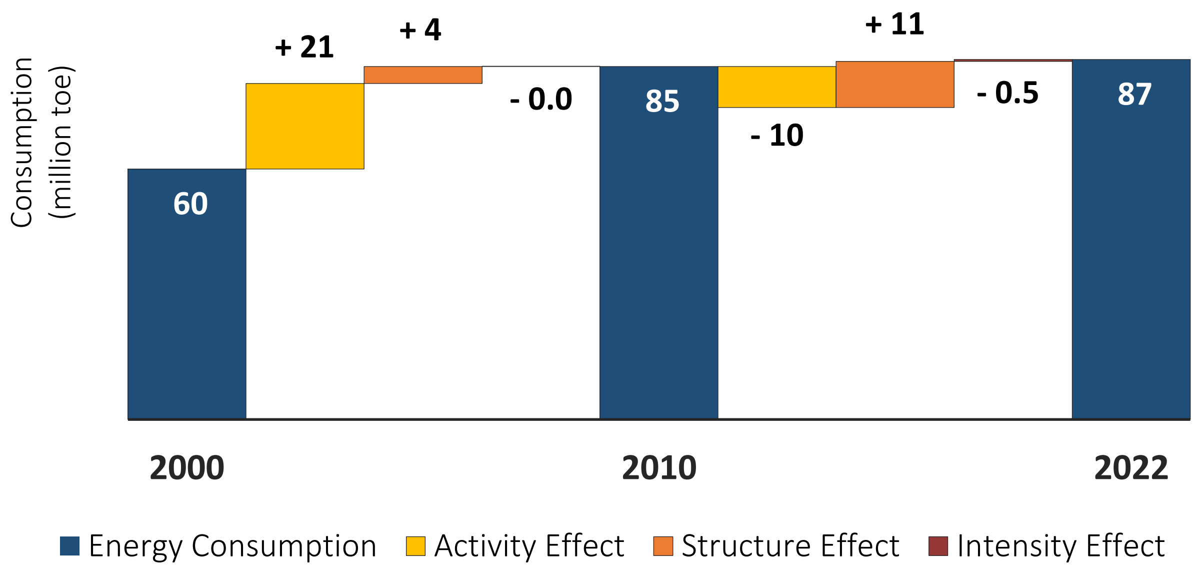


The gap between energy consumption and aggregated value results in energy intensity variations, which increased by 2.1% per year between 2014 and 2020. This intensity increase is **not** related to the industrial factories' energy efficiency, but to other effects such as an energy-intensive segments market share increase.

[1] National industrial production with some exceptions

Energy consumption effects sectioning: from 2000 to 2022 the energy consumption in industry raised up **1.7% per year**

Figure 32: Breakdown of changes in industrial energy consumption
Source: Compiled by EPE, from EPE (2023b) and IBGE (2023)



The three main effects that compose the industrial consumption variation are: added value (changes in the activity level), the industrial segments relative share (i.e. the structure of industry) and each segment intensity (the ratio between energy consumption and added value for each segment).

Between 2000 and 2010 there was a large increase in industrial activity, a moderate change in structure while the intensity effect was low. The industries that most grew up in the period were food and beverages ,mining and pelletizing, and pulp and paper.

In the period between 2010 and 2022, there was a reduction in economic activity, but consumption increased due to changes in structure, an increase in the energy-intensive industries participation, with a consequent increase in the industry energy intensity. Each segment’s energy intensity remains relatively stable.

>> More details about this split in the section Definitions

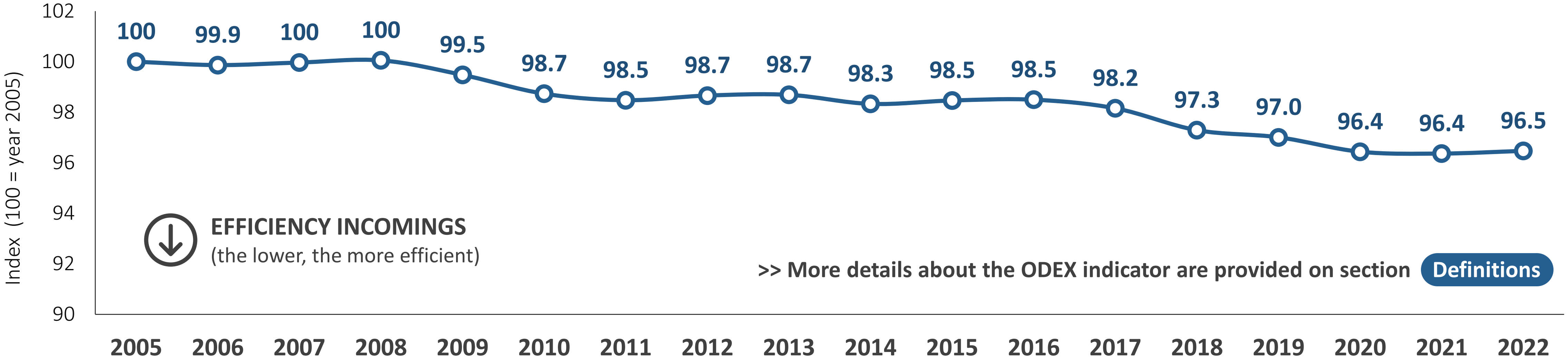
The food and beverage and the pulp and paper industries stand out for their growth over the entire outlook. However, in the first period almost all segments grow, with little structural variation. In the second period, several industries reduce their activity and lose share, especially textiles and other industries, with energy-intensive segments predominating - increasing the national industry intensity.

[1] Decomposition of the variation in industrial energy consumption into activity, structure and intensity effects, according to the LMDI I method ("logarithmic mean Divisia index method I") with additive decomposition (Ang & Liu, 2001).

Energy consumption ODEX in the industrial sector

To accurate the ODEX, the variation in specific consumption based on physical production was considered for the steel, pulp and paper, cement and sugar segments, and the energy intensity for the other food, textiles, chemicals, ceramics, ferroalloys, other metallurgy, mining and other industries segments, and the weight of each segment in consumption.

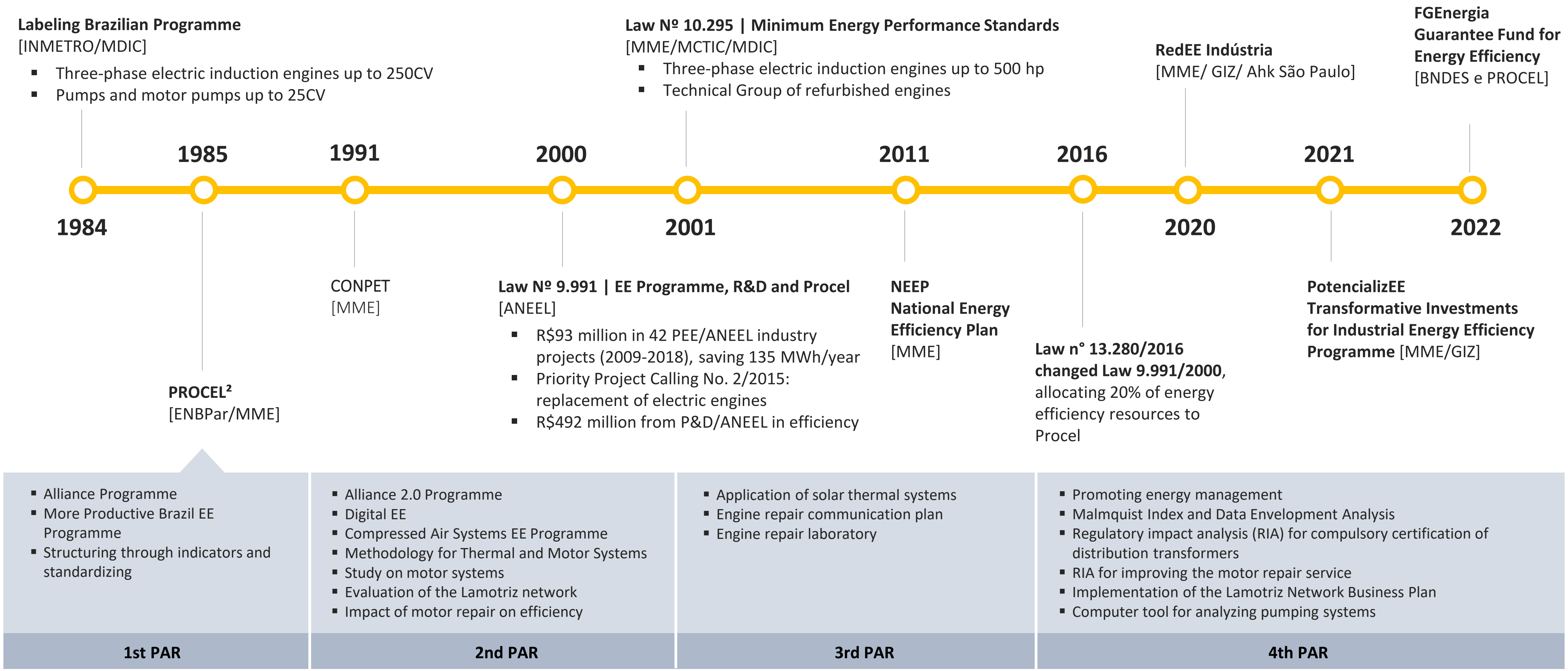
Figure 33: Industrial ODEX
Source: Compiled by EPE



In 2022, the industry's ODEX reached 96.5, which corresponds to an energy efficiency gain of 3.5% in comparison to 2005 (an average reduction of 0.2% per year). Although the industrial ODEX remained relatively stable between 2020 and 2022, the chemicals and pulp and paper segments most contributed to energy efficiency in industry in the last analyzed year.

Timeline: Energy efficiency policies and programs

Figure 34: Main efficiency policies linked to the industrial sector
Source: EPE



[1] Non-exhaustive list
[2] Law No. 13.280/2016 amended Law 9.991/2000, allocating 20% of energy efficiency resources to Procel.

The Industry profile

The oil derivates use is losing share due to the reduction in the fuel oil using in all segments, and the petroleum coke lower share in the cement industry. Coal is also losing share due to the steel sector usage reduction. Even though, it is used more in the ferroalloys sector. Bleach (black liquor) is gaining share, in line with the pulp industry, which uses this co-product in its processes.

Figure 35: Industry share by segment
Fonte: EPE (2023b)

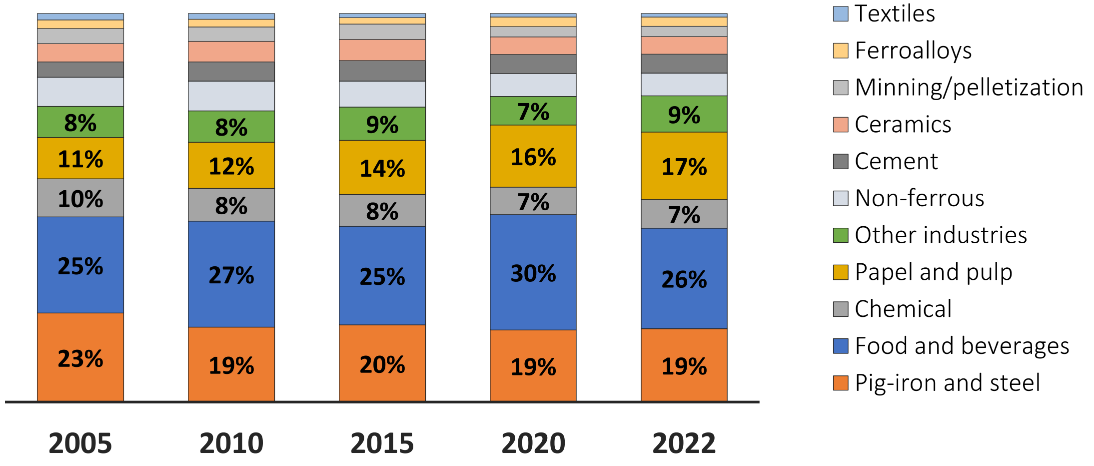
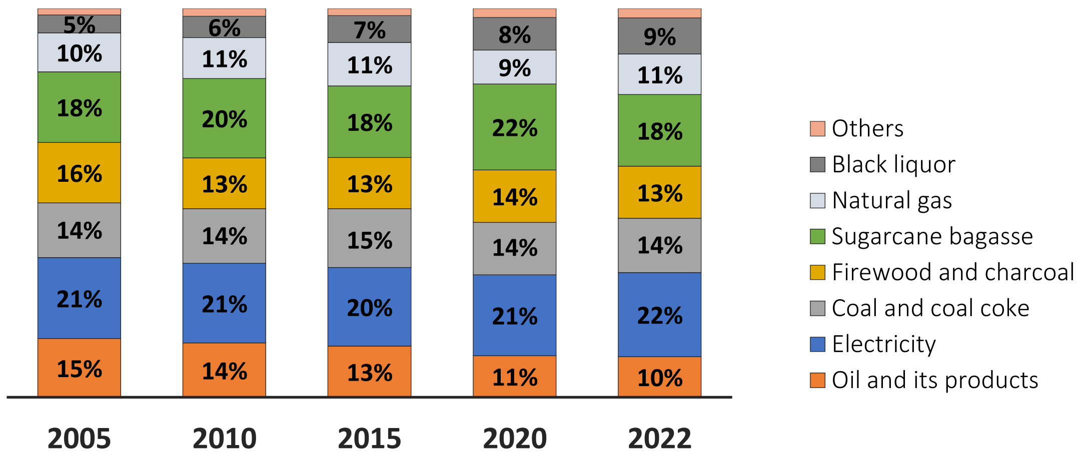


Figure 36: Industrial energy mix
Fonte: EPE (2023b)

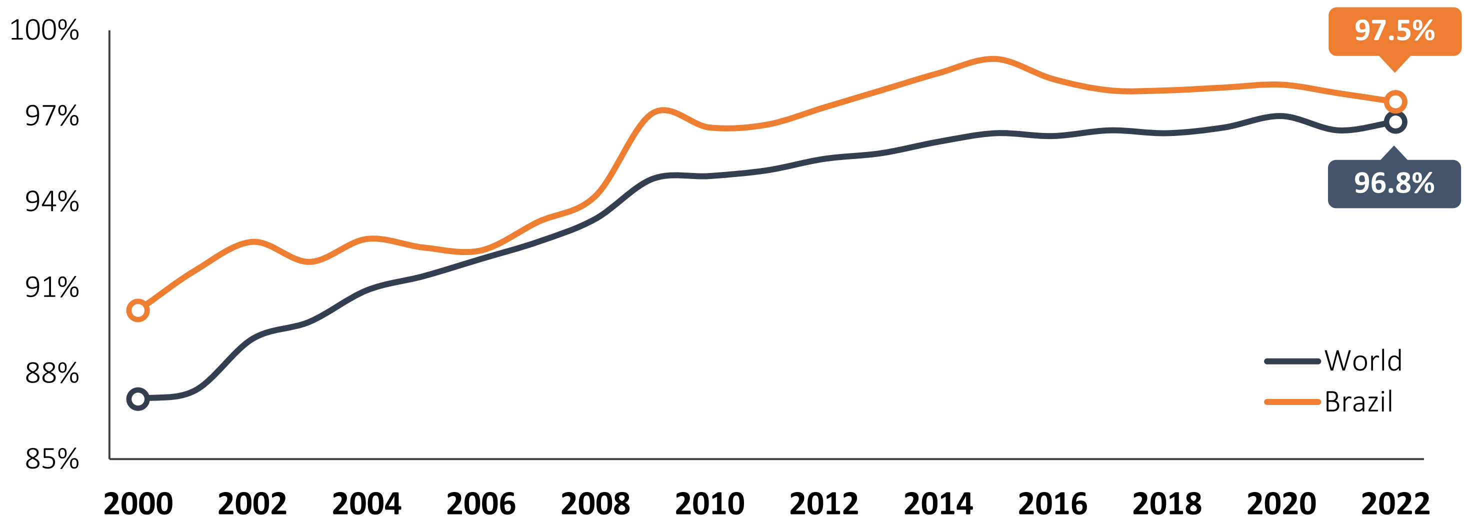


In 2022, the food and beverage, pig iron and steel, and pulp and paper industries were the most representative in terms of energy consumption. Electricity is the most important source and is earning a slight share.

Steel industry: spread of continuous casting

Liquid steel can be solidified by conventional casting[1] or by continuous casting. Continuous casting can be considered one of the radical innovations in the steel industry worldwide, as it now allows a high semi-finished/liquid steel yield (around 98%), is more compact and gives better quality to the final product.

Figure 37: Diffusion rate of continuous casting in the steel industry, Brazil and worldwide (percentage)
Source: Worldsteel (2009, 2019, 2021, 2023)



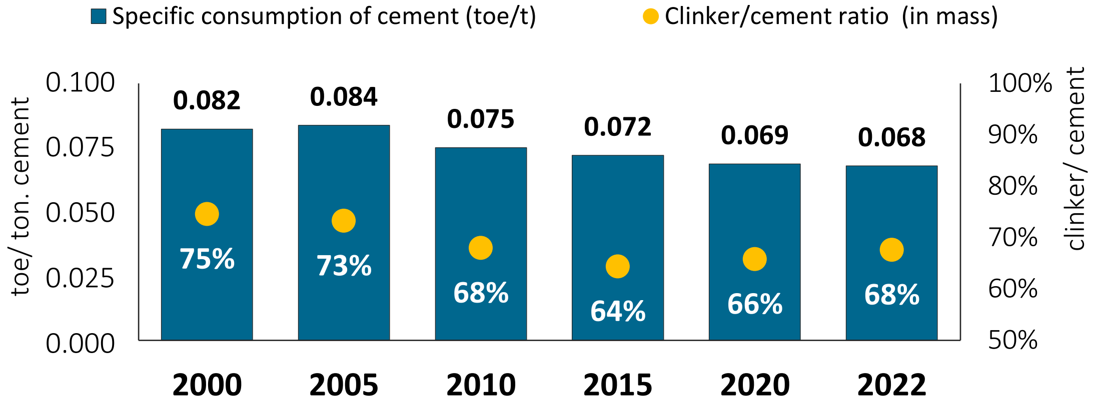
The worldwide diffusion of continuous casting went from 87.1% (in 2000) to 94.9% (in 2010) and 96.8% (in 2022). During this period, the relative importance of continuous casting in Brazil was higher than the world average.

[1] Using ingot moulds, a mould that has the function of receiving metal or metal alloy in a liquid, hot state, to provide a certain piece after the curing time, when the material solidifies

Cement: specific consumption and clinker content

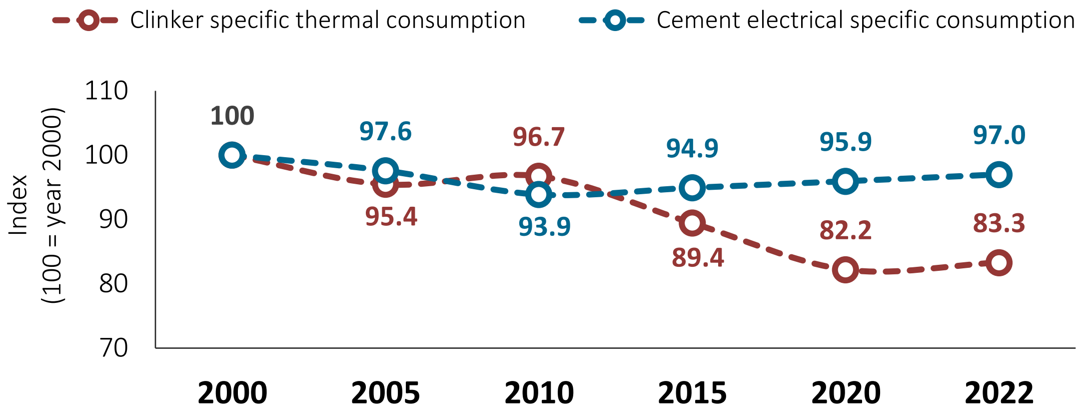
The cement industry in Brazil has a modern and efficient industrial park, which is constantly being updated. More than 99% of production is carried out in dry kilns (the most efficient), around 40% of the industrial park is less than 15 years old and more than 70% of its kilns are equipped with 4 to 6-stage preheater towers and pre-calciners (EPE, 2021). Modern grate coolers equip 80% of Brazilian kilns and approximately 50% of raw material mills are vertical, which are considered to have the lowest electricity consumption.

Figure 38: Specific energy consumption in the cement industry
Source: Compiled by EPE, from EPE (2023b).



Regulation advances, cement chemistry researches, new cements development, among other things, would enable progress to make the cement additions incorporation, replacing clinker, which currently stands at 32%, reducing greenhouse gas emissions associated with calcination and energy use.

Figure 39: Specific consumption in the cement industry (clinker and cement)
Source: Compiled by EPE, from EPE (2023b).



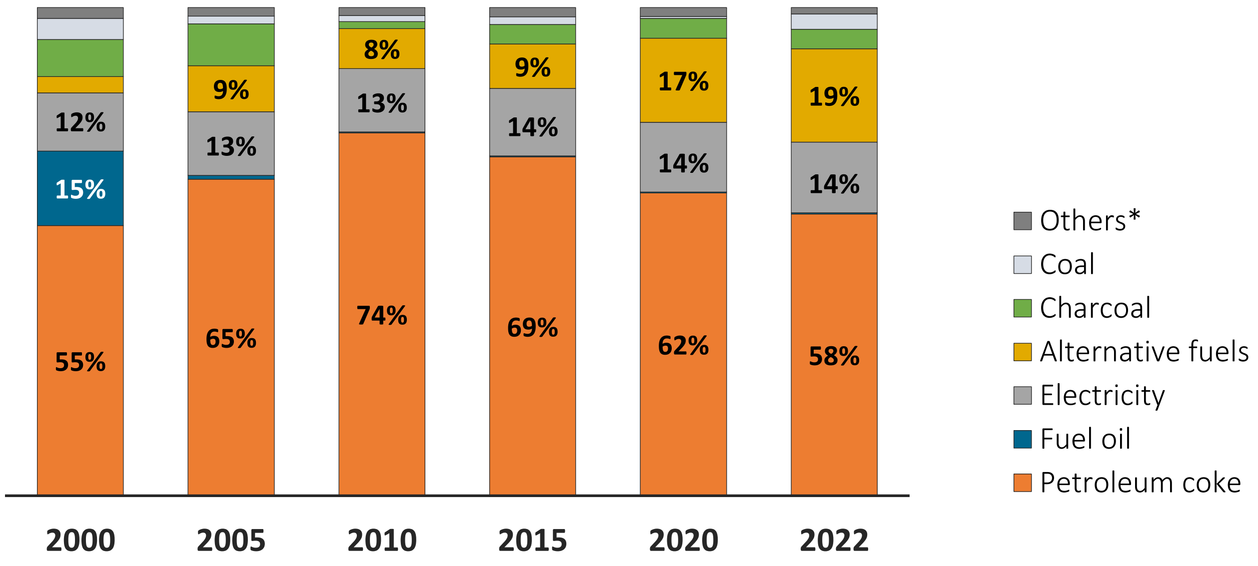
The Figure 39 shows the specific thermal and electrical consumption for clinker and cement production, respectively. Electricity is consumed mainly in cement production (grinding) and fuel in clinker production (kiln).

The specific thermal consumption of clinker fell by 17% over the entire scenario, while the specific electrical consumption of cement fell by 3%.

Cement: energy matrix and co-processing

The cement industry's energy matrix has changed over time. During the oil crises there was a momentary migration from fuel oil to coal (mineral and vegetable). In the 2000s, the sector switched to imported petroleum coke instead of fuel oil. Currently, petroleum coke is the main source, due to its low price and guaranteed supply.

Figure 40: Final energy consumption by source in the cement industry
Source: EPE (2023b).



Since the 2000s, a new energy revolution becomes more important: alternative fuels, characterized by the wasting co-processing and the biomass use.

Co-processing has several environmental benefits, as it provides an appropriate destination for waste and reduces GHG emissions (since most of this waste has a lower emission factor than traditional fossil fuels).

This energy transition has demanded - and will demand even more - investment from the sector in adapting the production process, as well as improvements in monitoring and control (EPE, 2021).

The share of waste co-processing is becoming more important, reaching 19% of consumption in 2022.

Note: "Other" includes natural gas, firewood, diesel oil and LPG

Pulp and paper: profiling and recycling

Pulp production is increasing in a faster pace than paper production, with large pulp-only mills and an increase in exports, because of the great Brazilian product competitiveness. In 2020, domestic pulp production was already double that of paper production. Since pulp production is more energy-intensive than paper production, this affects the evolution of the sector's specific consumption.

Figure 41: Pulp/paper production ratio in Brazil

Source: Compiled by EPE, from Ibá (2023).

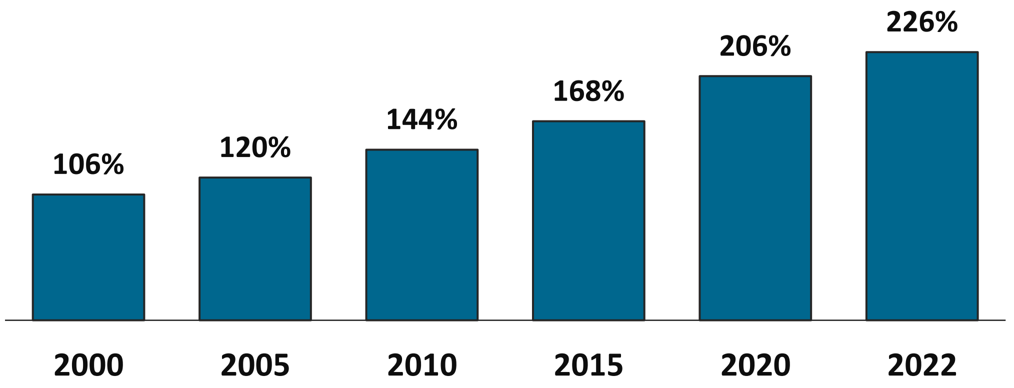
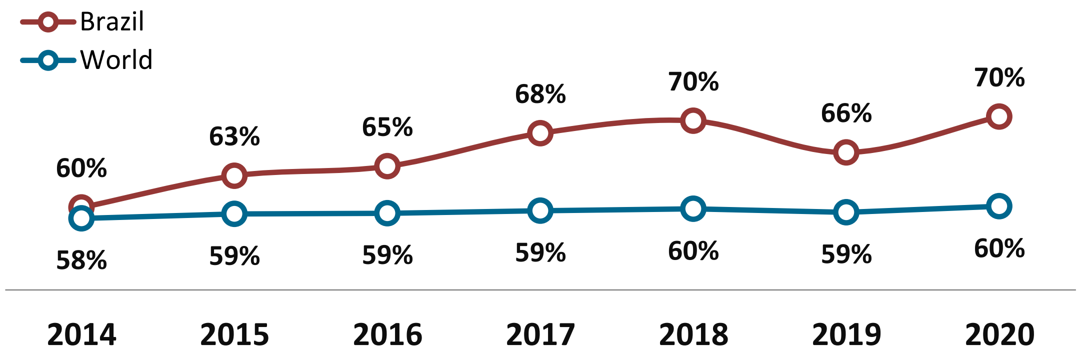


Figure 42: Paper recycling rates in Brazil and worldwide

Source: Compiled by EPE, from ICFPA (2023) e ANAP (2020, 2021)



Paper recycling is an important sustainability measurement. Replacing the paper produced from pulp with paper scraps is a circular economy action that avoids energy consumption and other impacts of pulp production.

The sector has a positive track record in reverse logistics, having reached the 70% recycling rate milestone in 2020, above the global average of 60%. The recycling rate for packaging is even higher, reaching 80%.

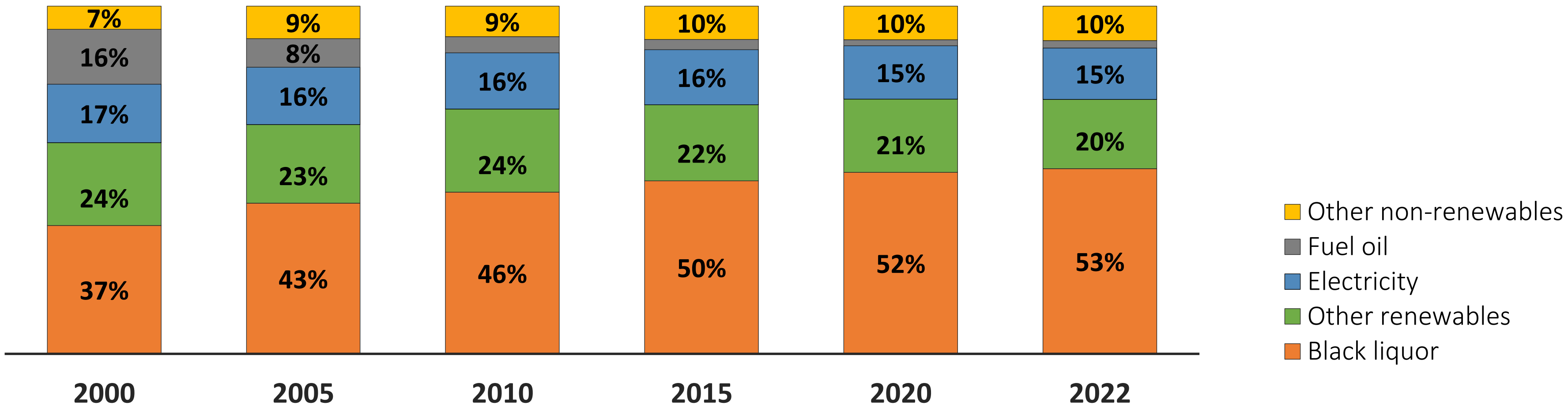
However, it is important to know that recycling paper can switch the product characteristics and quality, and it can't always be used for the same application, and it depends on a logistics grid for collecting paper scraps, which goes beyond the confines of the factory.

Note: Computed on shavings collecting over apparent paper consumption.

Pulp and paper: energy matrix and renewability

The national pulp and paper sector's energy matrix has a high level of renewability, reaching 88%. The sector uses by-products of the pulp production process, bleach (black liquor) and wood waste, for cogeneration. Natural gas began to be used in the 1980s, and its share, since the 2000s, has been relatively stable at 7%, mainly in boilers. Fuel oil, on the other hand, has significantly reduced its share from 16% in 2000 to 2% today, used to start boilers, in lime kilns and in the fuel oil boilers of a few plants (EPE, 2018).

Figure 43: Final energy consumption by source in the pulp and paper industry
Source: EPE (2023b).



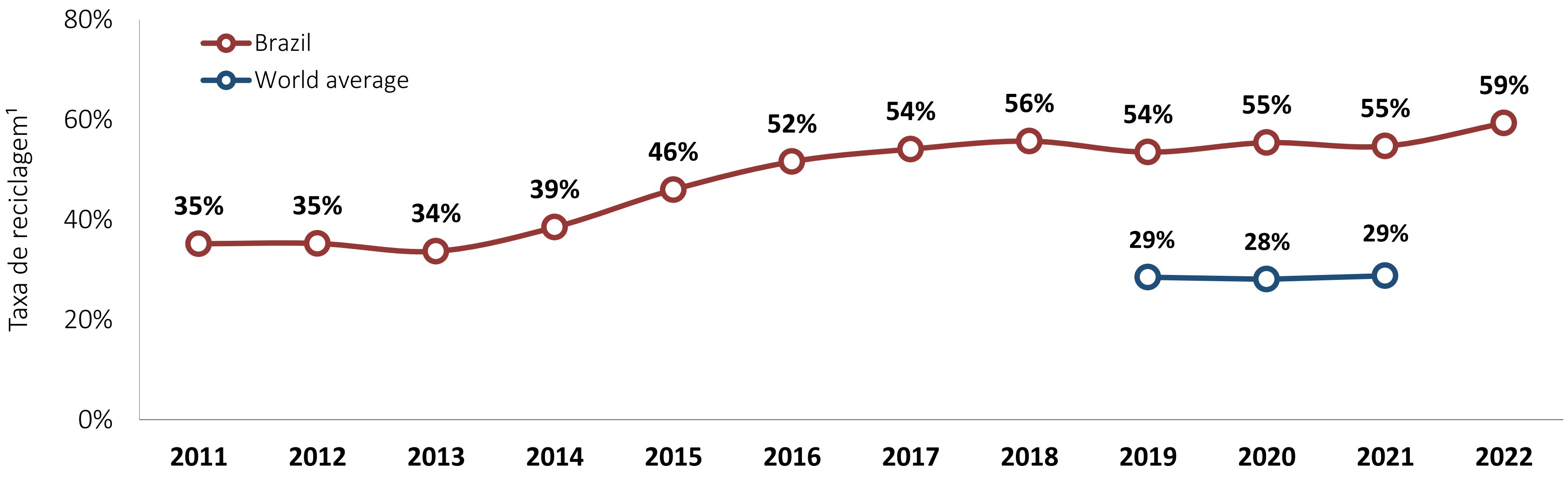
In 2022, the segment produced 75% of its electricity demand, mostly from renewable thermal sources (94%), such as lye.

[1] Assuming that the electricity consumed in the sector is 100% renewable.

Aluminum: scrap recovery rate evolution

The aluminum recycling rate is growing over the world average and reached 59.3% in 2022. That year, Brazil recycled 100% of the aluminum beverage cans sold (ABAL, 2023).

Figure 44: Aluminum scrap recovery rate evolution
Source: Compiled by EPE, from ABAL (2023)



Recycling is a strategy to make the economy run with a lot of socio-environmental benefits. The electricity consumption of secondary (recycled) aluminum is lower than the primary aluminum, which is electro-intensive. According to the World Economic Forum (2021), the consumption of recycled aluminum is in around 5% of the consumption of primary aluminum. This fact is also supported for Brazil, as pointed out by the EPE (2017) study.

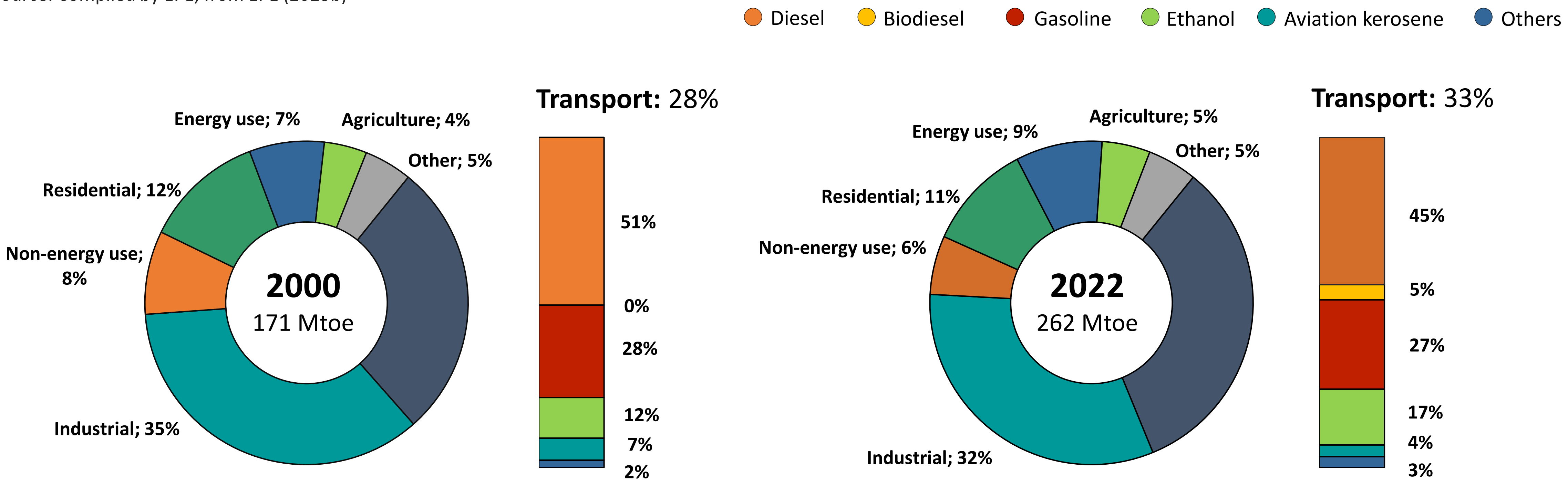
[1] Using ingot molds, a mold that has the function of receiving metal or metal alloy in a hot and liquid form, to build a certain piece after the setting time, when the material solidifies.

Transport Sector

Energy consumption in the transport sector

In 2022, the national energy consumption increased by 2.9% compared to 2021, a slightly lower rate than the 3.0% increase in GDP. Energy demand in the transport sector grew up 5.0% in 2022. Passenger transport activity increased around 17% but it is still 17% below the activity recorded in 2019, before the pandemic. However, this occurred with an increase of only 6,4% in energy expenditure. The increase in freight transport activity also grew significantly, by 6.1%. But this was not due to a recovery from the pandemic, as activity in 2022 was 23% higher than in 2019. And this 6.1% increase in activity was achieved with a 3,8% rise in energy demand.

Figure 45: Transport sector final consumption in Brazil
Source: Compiled by EPE, from EPE (2023b)

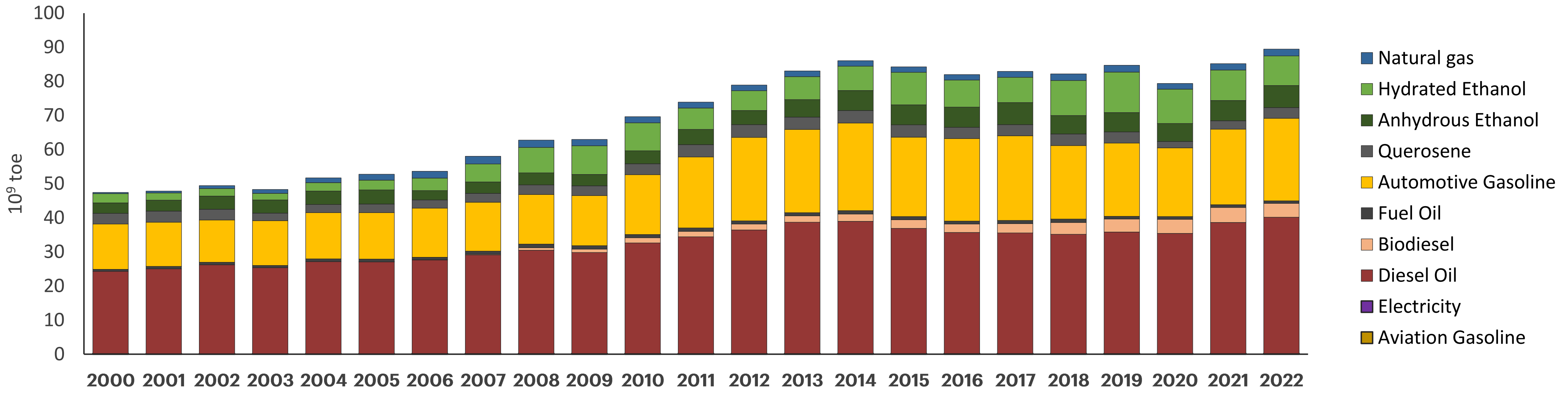


Transport Sector's energy consumption share evolution

The sector's energy demand grew up 5.3% in 2022. This increase was due to the growth in freight transportation, but also passenger transportation. Particularly noteworthy is the increase in demand for diesel oil and gasoline, encouraged by the increase in consumption of goods, greater mobility of the population, and a rise in agricultural and industrial production. The growth rate recorded was higher than the GDP expansion, especially due to the recovery in population mobility following the end of restrictions imposed during the pandemic.

The airline and passenger transport sectors are still below pre-pandemic demand, although they are gradually recovering and with values closer to those of 2019. Freight transportation has shown a greater recovery in the sector, contributing to diesel oil demand.

Figure 46: Transport sector consumption by energy source (million toe)
Source: EPE (2023b)

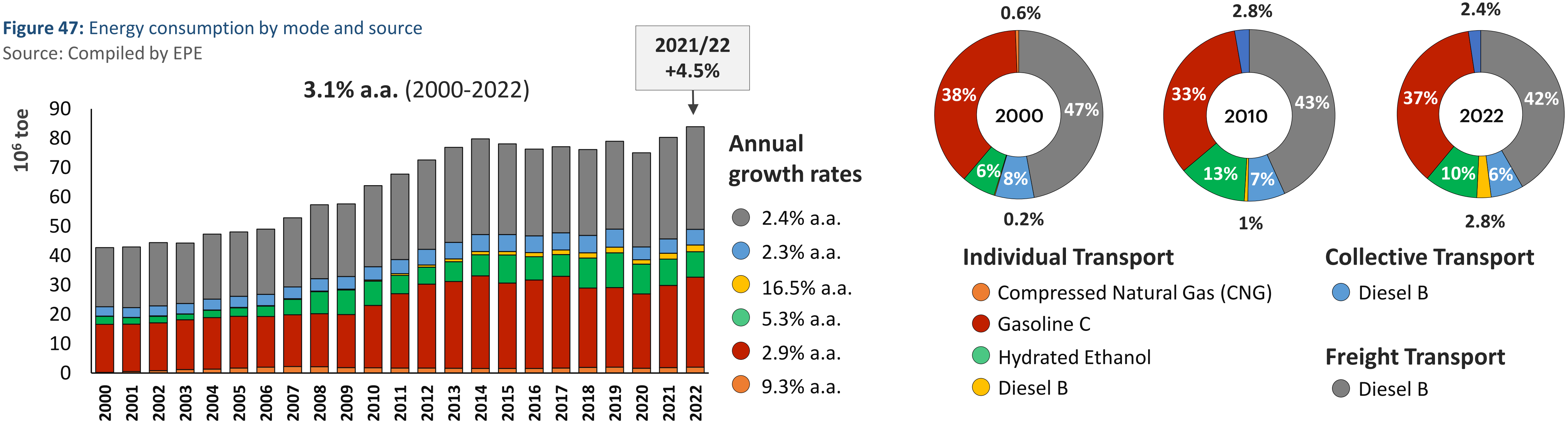


Road transport energy consumption evolution

Between 2000 and 2022, the passenger demand for transport increased by 2.2% per year, and freight transport grew by 4.8% per year. In 2022 the road transport had recovery up. One highlight was the Otto Cycle demand increase of 6.4%, foremost because of the people individual transport. Another spotlight was the increase in freight transport, particularly because of grain harvests records, but also due to a reduction in unemployment and a consumption increase. The demand fall in hydrous ethanol, due to a lower supply from sugar cane mills, was more than offset by an increase in demand for petrol.

Figure 47: Energy consumption by mode and source

Source: Compiled by EPE



It's important to emphasis the C petrol growth in the road transport matrix, while the price of ethanol and diesel decreased in comparison to 2021. In 2022, CNG showed a demand increase of 9.3 %, with a continuous gain share since 2021, while hydrated ethanol is in decline. In this situation, hydrous ethanol loses share in the energy matrix compared to C petrol, whose demand increased by 2.9%.

Passenger transport

In 2020, the pandemic had a strong impact on energy demand for passengers in Brazil, especially due to the number of passengers in public transport decrease, but also due to less sharing of private vehicles, reducing the number of passengers per car. The passenger transport supply strongly recovered in 2021 and 2022, with an increase in the number of trains, cars and buses in circulation.

Figure 48: Energy Intensity by mode [toe/(10^6 p.km*)]
Source: Compiled by EPE

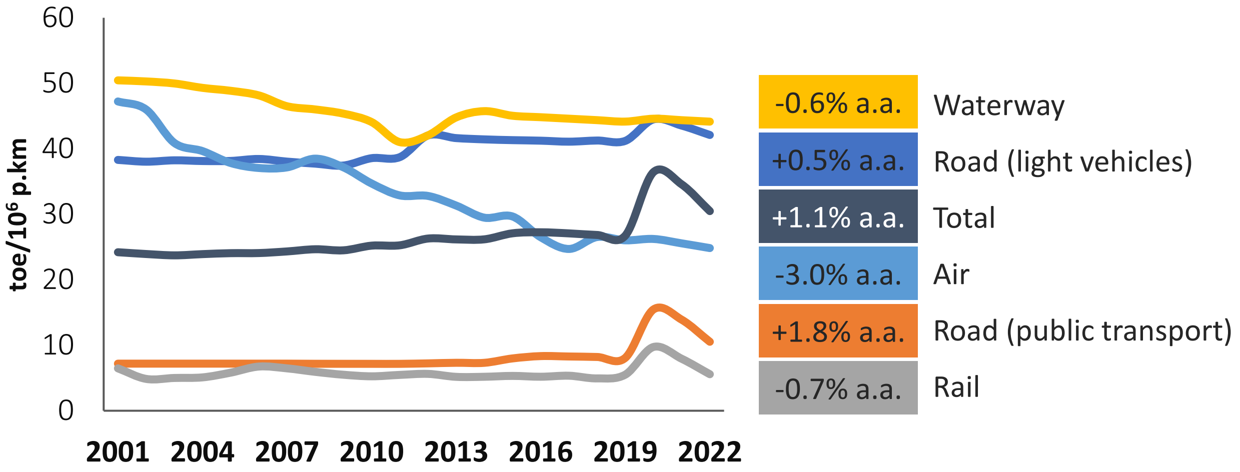
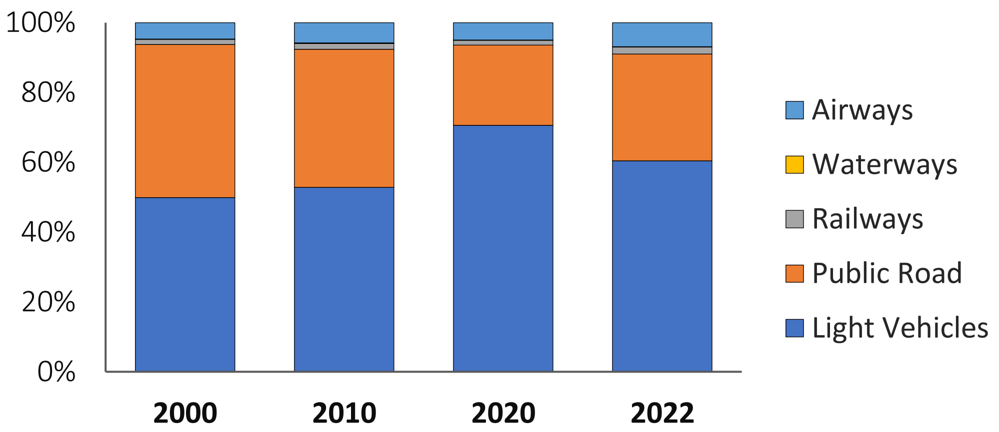


Figure 49: Activity by mode[p.km*]
Source: Compiled by EPE



However, this increase was not entirely followed by a growth in the transported people number, since not everyone returned fully to face-to-face work. In addition, the unemployment level, combined with the increase in public transport fares had an impact in transports demand. In this context, a lot of buses, trains, subways and airplanes continued to be less busy than in pre-pandemic times. In the airline sector, international flights are recovering even more slowly, especially due to the increase in ticket prices and the exchange rate.

***Note:** the unit "p.km" refers to passenger-kilometers.

Individual passenger transport

Figure 50: Cars fleet and specific consumption from 2000 to 2022
Source: Compiled by EPE

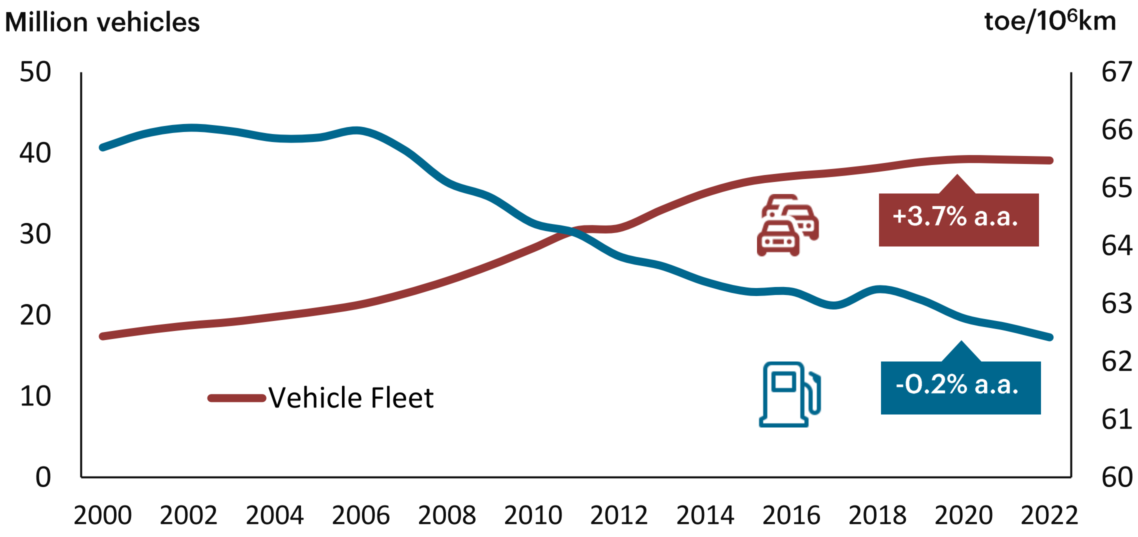
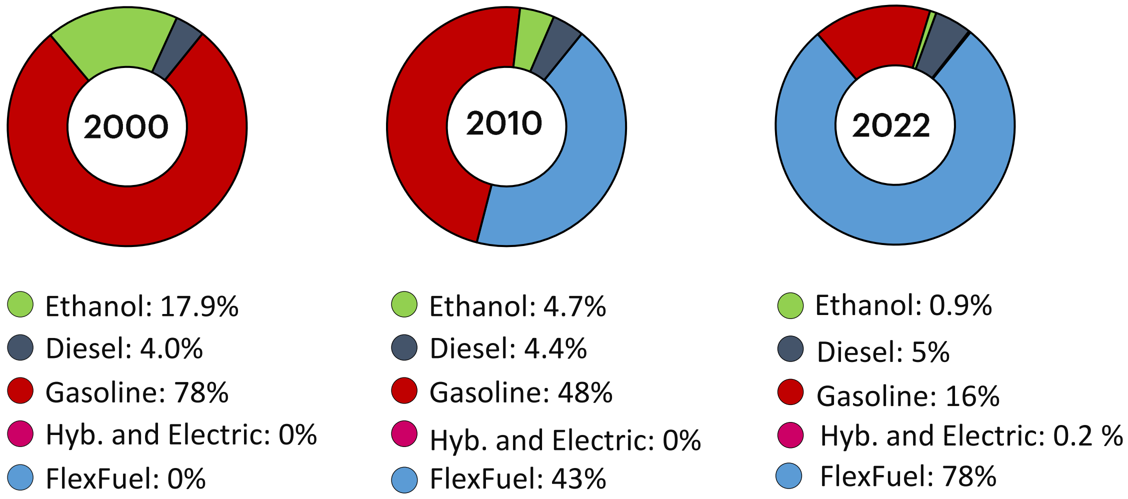


Figure 51: Light vehicle fleet by type of motorization in selected years
Source: Compiled by EPE



Car sales followed the growth in Brazilian per capita income throughout the 2000s. In the last three years, light car sales have stabilized at around 2 million units.

The Brazilian Vehicle Labelling Programme (PBVE), Inovar Auto and Rota 2030 promoted improvements in the energy efficiency of new vehicles.

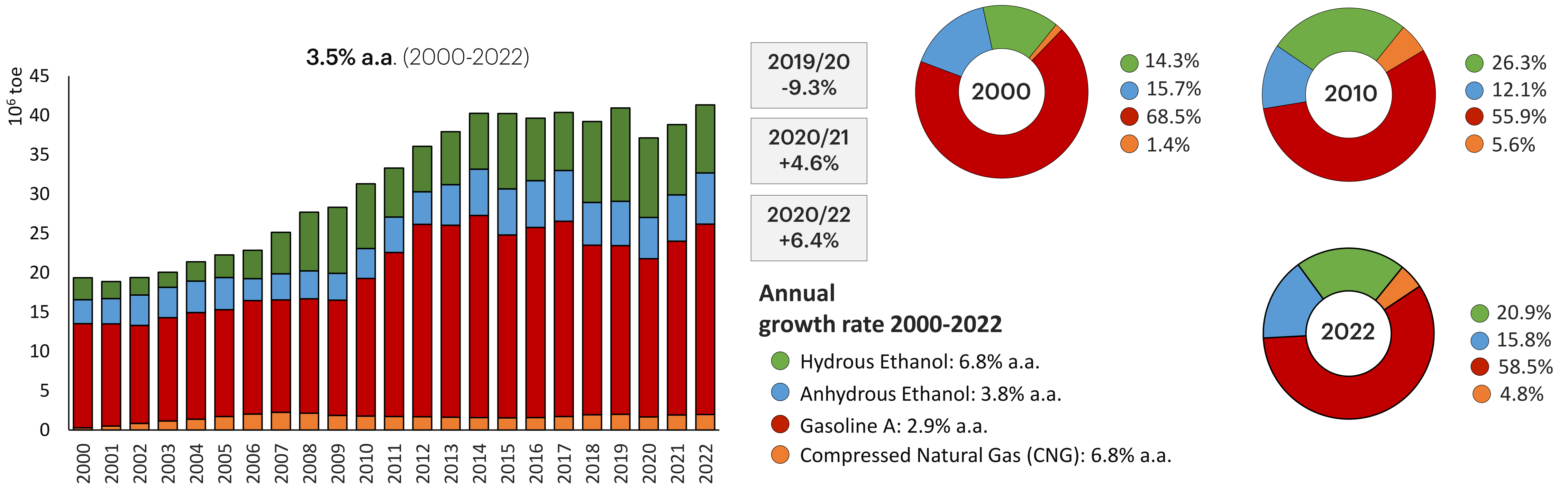
The increase in the of the flexfuel vehicles in the fleet has rapidly grown, reducing the fleet's average efficiency gains, as they are slightly less efficient than dedicated fuel types.

The increase of the sport utility vehicles (SUVs) has also increased the fleet's specific consumption, since they are less efficient vehicles.

It is important to note the growth of the light commercial electric vehicles, which increased by 68% in 2022, reaching around to 90,000 units. This amount represents 0.2% of the total cars fleet in Brazil.

Otto cycle and individual road transport

Figure 52: Energy consumption by source
Source: Compiled by EPE



There was a recovery in fuel demand and urban mobility in 2022, reaching pre-pandemic levels. The vaccination spread and the return to face-to-face work allowed the country to recover. However, much of this recovery was concentrated in individual transport, which explains the increase in Otto Cycle demand. In turn, high international sugar prices reduced the sugarcane ethanol supply, and even with greater production of corn ethanol, there was a significant increase in demand for petrol.

Freight Transport

At the beginning of the Covid-19 pandemic, throughout the first few months of 2020, freight transport, especially by trucks, was impacted. Despite this fact, it quickly recovered, and at the ending the year, it grew 5.8%. Since then, it has been growing substantially. This good performance happened again in 2021, with one of the reasons for it being the demand for consumption goods increasing, driven by restrictions on mobility, and the reduction in money spending on services. In 2022, freight transport again contributed to the diesel oil demand increase, the growth of e-commerce, the transport of goods between factories and distribution centers and between distribution centers and final consumers, as well as the grains transport to ports.

Trains demand has also recovered, with new connections increasing the transport of agribusiness products by rail. Bigger investments in infrastructure and the high harvest in 2022 contributed to the percentage increase in activity in this area, which was the highest among the others. Meanwhile, although air transport is recovering to pre-pandemic values, aviation fuel (kerosene) prices increased, affecting the use of this transport way.

Figure 53: Energy intensity by mode [toe/(10^6 t.km)]
Source: Compiled by EPE

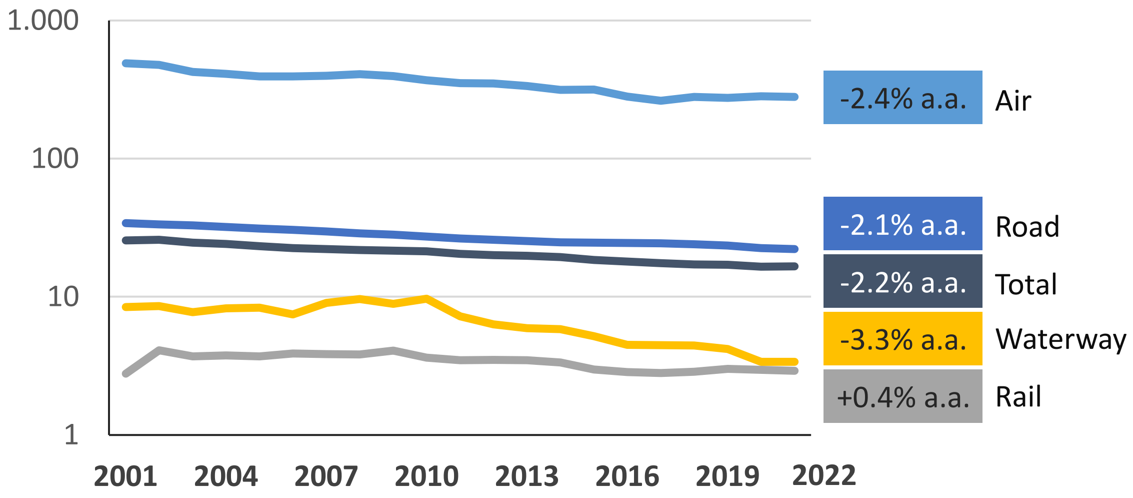
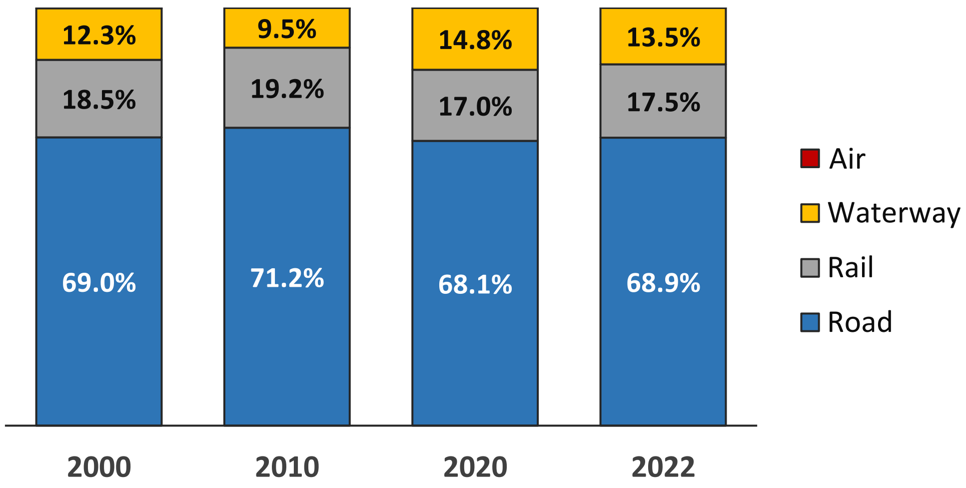


Figure 54: Activity by mode [t.km]
Source: Compiled by EPE



Road freight transport

Figure 55: Trucks fleet by category (million units)
Source: Compiled by EPE

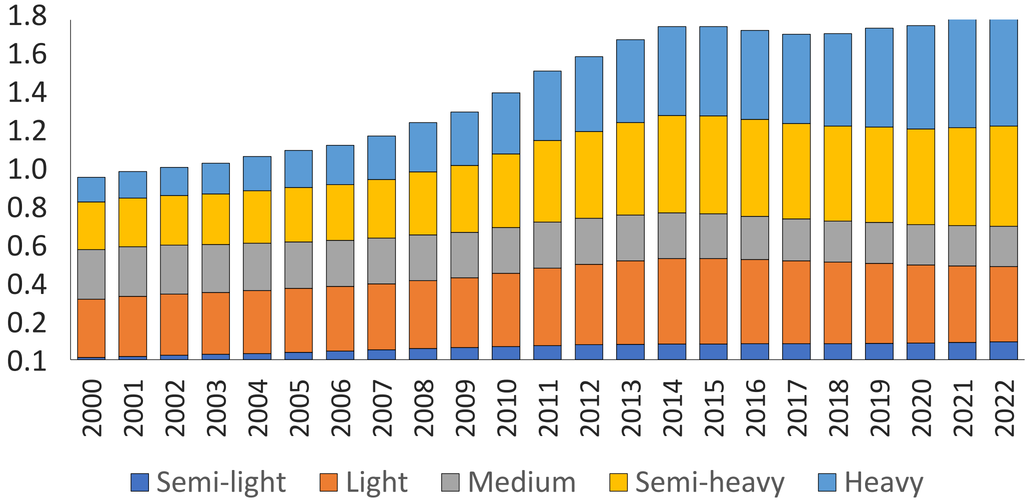
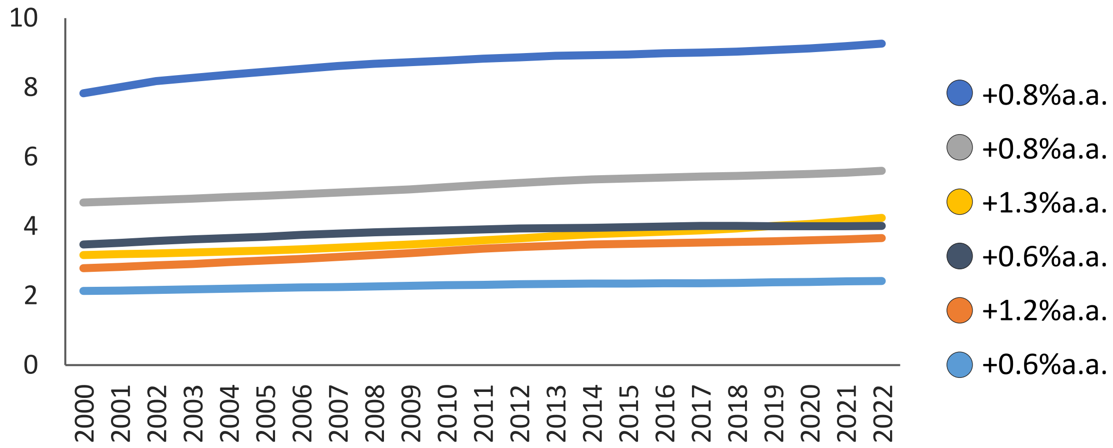


Figure 56: Average energy efficiency of new vehicles sold (with load) [km/l]
Source: Compiled by EPE



In 2021, the Brazilian truck market had a strongly recovery, mainly by the economic activity recovering, especially the agricultural, mining, construction and e-commerce sectors good performance. In 2022, the demand for trucks remained high, especially due to the advance of new trucks purchase, because of the requirement for engines to comply with the new Proconve P8 regulations from 2023. However, problems with semiconductors made factories to shut down for several months, impairing truck manufacturing.

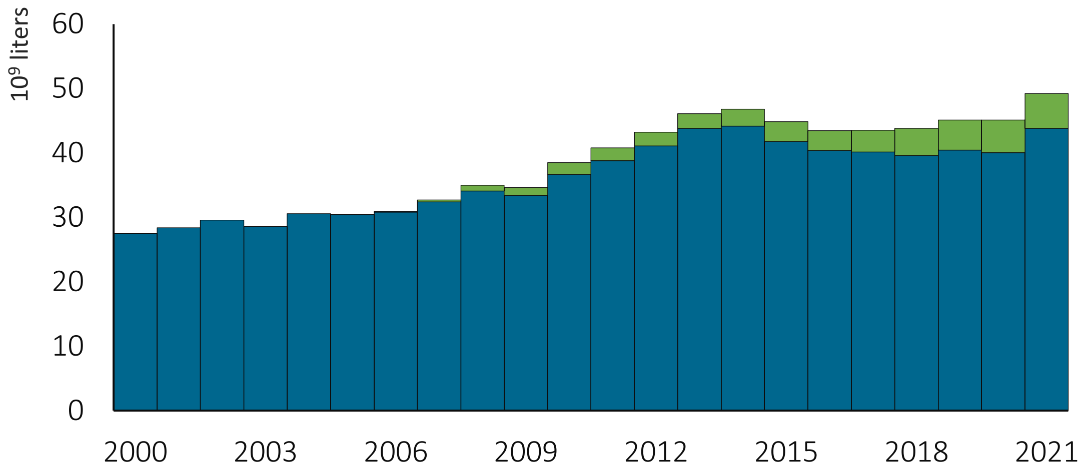
The inclusion of new phases in the Vehicle Emissions Control Programme (Proconve) encouraged the adoption of more efficient engines to fit the new emission limits. In 2022, the energy efficiency of new vehicles evolved, especially semi-light vehicles, which had a greater increase in the fleet share, as well as the medium-sized vehicles. The medium-sized vehicles efficiency was affected by the electric cars models sales, which, although at the beginning, started to expand. Efficiency in the sector increased by 0.7%, showing progress in all categories.

Note: The Vehicle Emissions Control Programme (Proconve) was set up to reduce the levels of pollutant emissions from motor vehicles. Phase P8 applies to new heavy-duty vehicles sold from 1 January 2023, and stipulates new maximum emission limits for exhaust gases, particulates and noise, equivalent to the European Euro VI standard.

Diesel and biodiesel consumption

Figure 57: Road diesel and biodiesel consumption (billion litres)

Source: Compiled by EPE



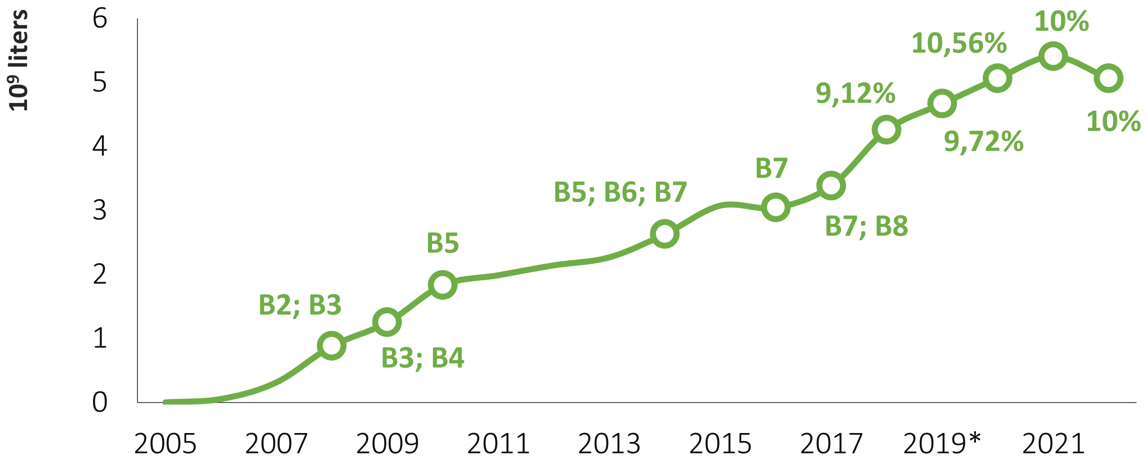
The demand for diesel fuel by trucks grew by 2.8% per year between 2000 and 2019. And despite the pandemic, which reduced industrial production and consumption, and, at the beginning of the pandemic, restricted truck drivers' free movement, the demand for road diesel oil fell by 1.0% in 2020, with a growth of 9.3% in 2021. In 2022, it kept recovering, although slower, with an increase of 2.8 %.

Since January 2022, the system for marketing biodiesel between producers and distributors began to happen via direct negotiation, ending up the auctions.

The biodiesel mandatory percentage blend into diesel oil was 10 % during whole 2022, with a 6.4% falling in biofuel consumption in the previous year.

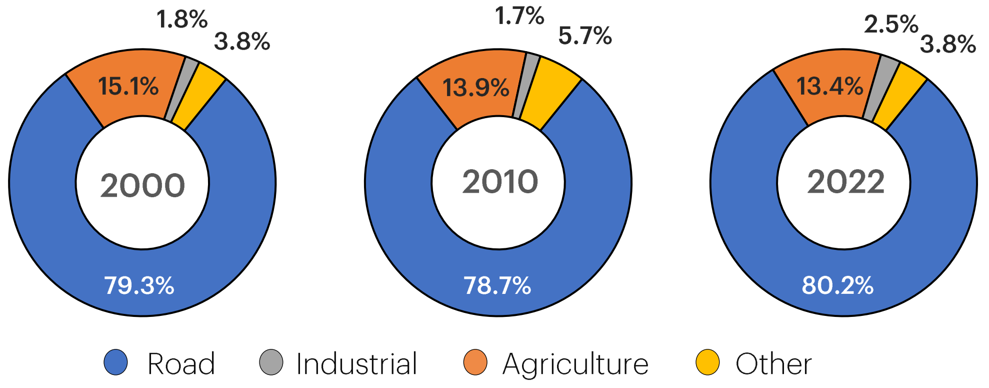
Figure 58: Evolution of road biodiesel consumption and average addition percentages

Source: Compiled by EPE



* As a preventative action to guarantee supply to the domestic market, the ANP carried out three temporary mandatory percentage reductions throughout 2019 and 2020. These actions also took place in 2021.

Diesel oil use sector division



Additional remarks on the Transport Sector

The transport sector is the country's biggest energy consumer, closely followed by the industrial sector. The main reason for the transport high energy intensity is the transport matrix setting, which is extremely dependent on road transport. Freight transport has increased, with demand for diesel fuel increasing due to the increased use of trucks. Coupled with a post-pandemic growth in individual road transportation by car, there is a transport sector with growing demand, despite of each type advances in the energy efficiency.

The individual car transport has increased even more the energy demand of passenger transport. After the end of post-pandemic restrictions, the mobility increasing impacted mainly on individual transport, as the public transport activity is still in a lower level as it was in 2019. The total mobility has also not fully recovered yet, and it can be a reflect of hybrid work, which remains in big cities, as the relatively high unemployment and underemployment rate. Car sales have also become restricted, especially due to logistical issues, which have hampered the production and raised the prices of these assets.

The main component responsible for the Otto’s cycle fuels demand increasing was Gasoline A. In 2022, there was less availability of hydrous ethanol from sugarcane mills, implying in a drop of this biofuel share from 24% to 21%. This reduction is justified mainly by the increased attractiveness of sugar on the international market and the Brent spot price variation which, among other factors, implied in an increase in the ratio between hydrated ethanol prices and the price of C gasoline (PE/PG).

Road freight transport remained dominant in 2022 and had a significant growth. In 2022, rail transport also grew, specially because of flow of the agricultural harvest. However, most of the record harvest was still delivered to consuming centers by truck, as well as other types of cargo, such as liquid bulks, which still mainly use road transport. It's worth noting that more energy-intensive trucks sales were, since heavy trucks accounted for a high proportion of these sales.

In 2022, the recovery in diesel oil demand kept working, with an increase of 2.8%. The mandatory blended biodiesel percentage was 10% throughout all the period, and consumption of the biofuel fell in comparison to the previous year. A new marketing system began in January of the same year, via directly deal between producers and distributors. However, the increased efficiency of the truck fleet limited the increase in demand for diesel oil, despite the growth in cargo handling.

Special Chapter on the Residential Sector

Revealing inequalities in residential energy consumption patterns

The brazilian case in an international comparison

This analysis intends to discuss the Brazilian residential sector's energy consumption patterns through an international comparison using different perspectives to identify energy poverty issues and energy efficiency potentials.

In addition, we aim to…

- propose a methodology to measure the inequality in the access to energy services
- bring some examples of energy efficiency policies focused on mitigating energy poverty in Brazil

The motivation for this analysis is…

To propose analysis that can support the design of public policies focused on eradicating energy poverty, mitigating Greenhouse Gases (GHG), promoting Energy Efficiency and achieving Sustainable Development Goals (SDG).

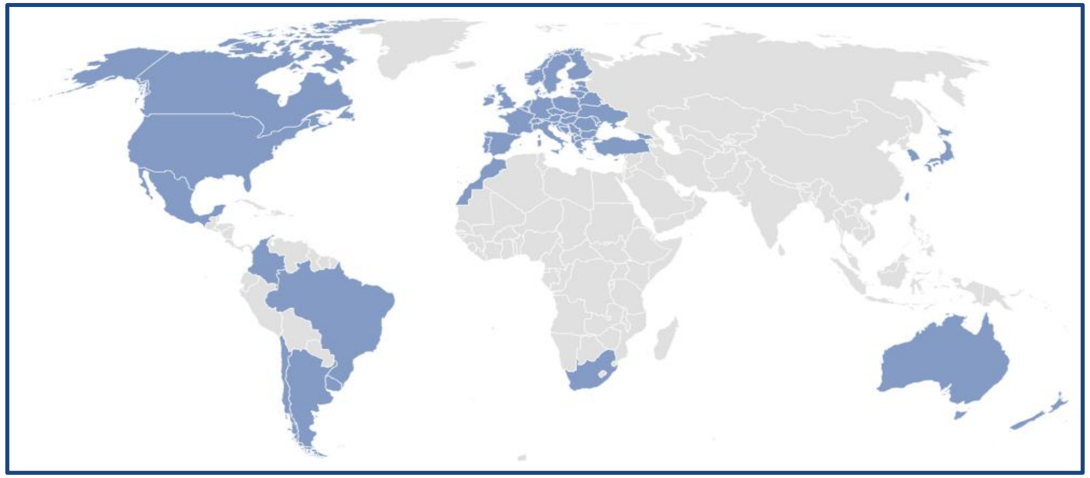
Brazilian Residential Sectors’ energy demand in an international comparison

International Data

This analysis was based on the following data from the Energy Efficiency Indicators Database IEA (December 2022) on Residential Sector’ Energy Demand from 2000 to 2019.

Data from 57 countries:

- 21 developing countries, according to the IMF (2023)[1]
- 6 Latin American countries
- 2 African countries
- 3 BRICS countries



Most countries with a mostly Temperate or Subtropical, or Mediterranean climate

Brazilian data

On the Brazilian side, additional databases were considered:

- Electricity - Survey of Ownership and Usage Habits of Electrical Equipment in the Residential Class (PPH/PROCEL)
- Firewood and Charcoal – Annual Continuous National Household Sample Survey (PNADCA/IBGE)
- LPG and Natural Gas – Household Budget Survey (POF/IBGE)

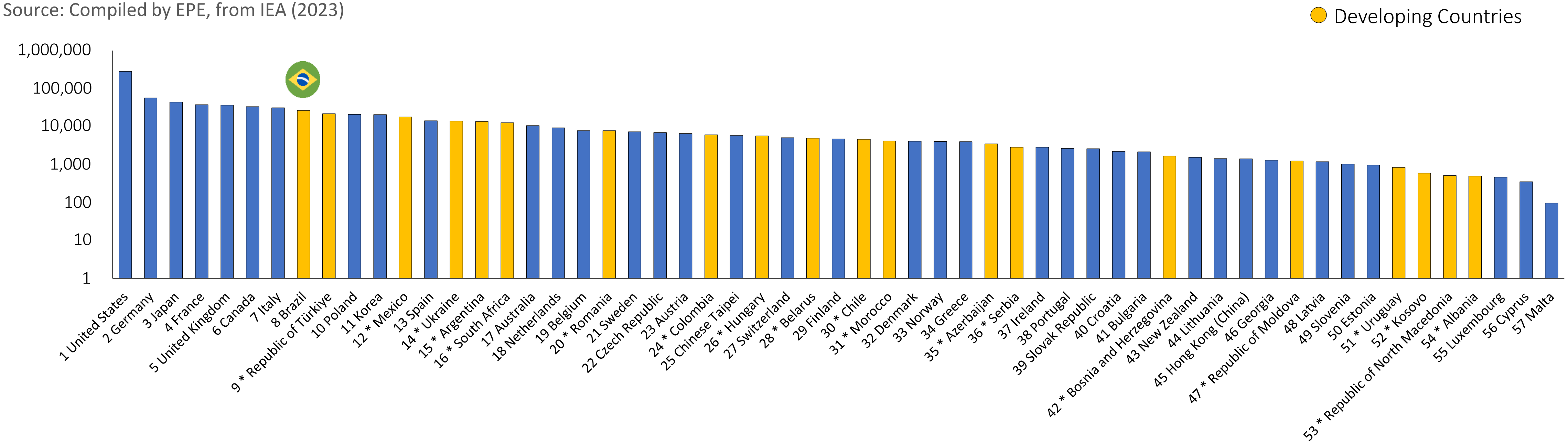
[1] IMF’s World Economic Outlook Database (April 2023);

International comparison of Residential Sector's Total Energy Consumption

Comparing the Total Energy Consumption of households among countries, Brazil was the 8th highest consumer and the developing country with the highest residential energy consumption.

Figure S1: Residential Sector's Total Energy Consumption (in thousand toe) in 2019

Source: Compiled by EPE, from IEA (2023)

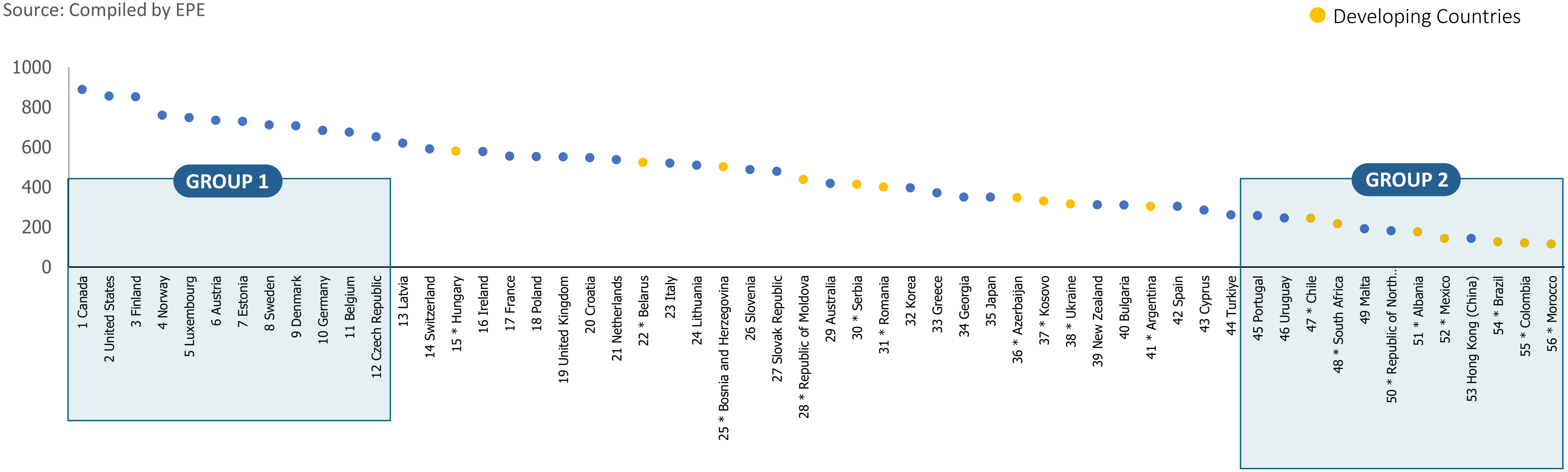


However, Residential Sector's total energy consumption doesn't seem to be a very conclusive indicator, because it does not isolate the size of the population (the populational effect), which is one of the main drivers of energy consumption in the residential sector. Considering the case of Canada and USA as an example, it is worth noting that Canada has a much lower residential sector's energy demand than its neighbor, despite of having a territorial area equivalent to the USA. That can be explained by the fact that USA has a much larger population than Canada.

International comparison of Energy Per Capita Consumption (EPCC)

On the other hand, the Energy Per Capita Consumption (EPCC) can be an interesting indicator. When observing the same group of selected countries ordered by the EPCC indicator, we see that Canada and the USA have the highest per capita consumption.

Figure S2: Residential Sector's Energy Per Capita Consumption (10^{-3} toe per capita) in 2019.
Source: Compiled by EPE

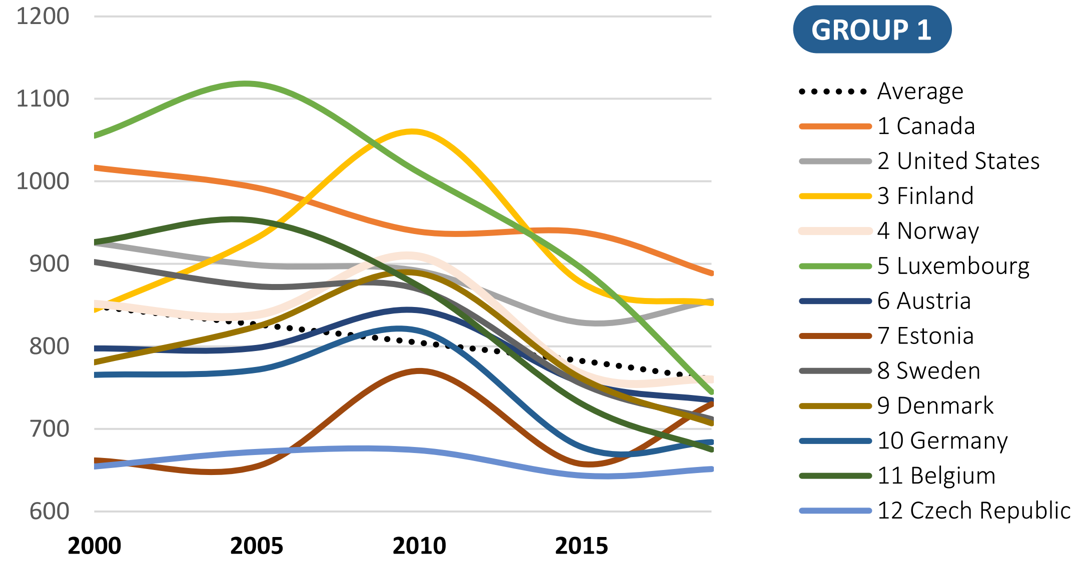


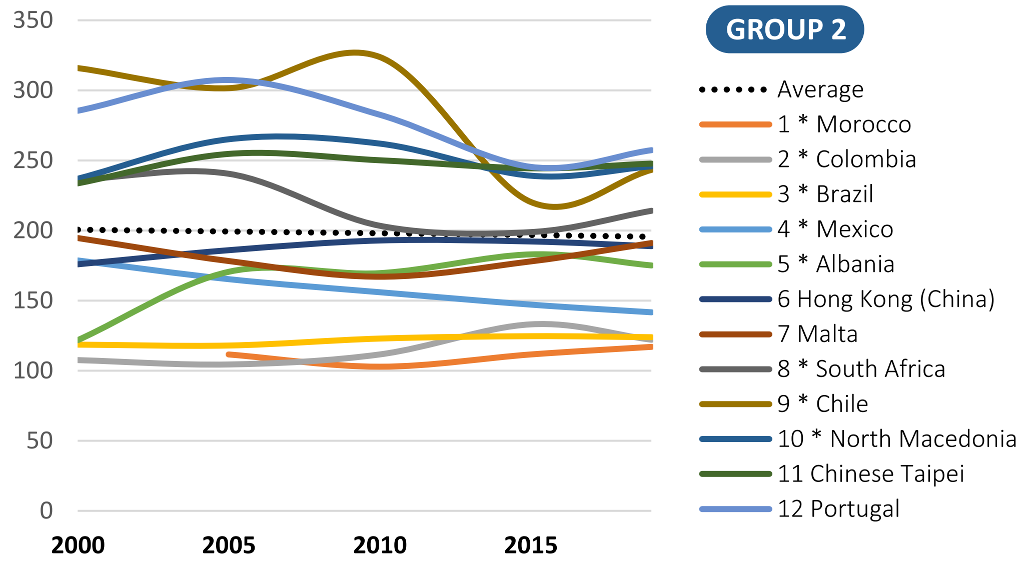
Considering the EPCC indicator Brazil is at the bottom of the list along with other developing countries, demonstrating a possible correlation between per capita energy consumption and the level of development. Observing the ranking we notice that the 12 highest EPCC (Group 1) are related to developed countries while the 12 lowest EPCC (Group 2) are related mostly to developing countries.

Energy Per Capita Consumption (EPCC) evolution

Analyzing the 12 countries with the highest residential sector's Energy Per Capita Consumption (EPCC) (Group 1), it is worth noting that this group tended to reduce its consumption, possibly demonstrating gains in energy efficiency.

Figure S3: Evolution of Energy Per Capita Consumption (EPCC) in the Residential Sector (10^{-3} toe per capita).
Source: Compiled by EPE, from IEA (2023)

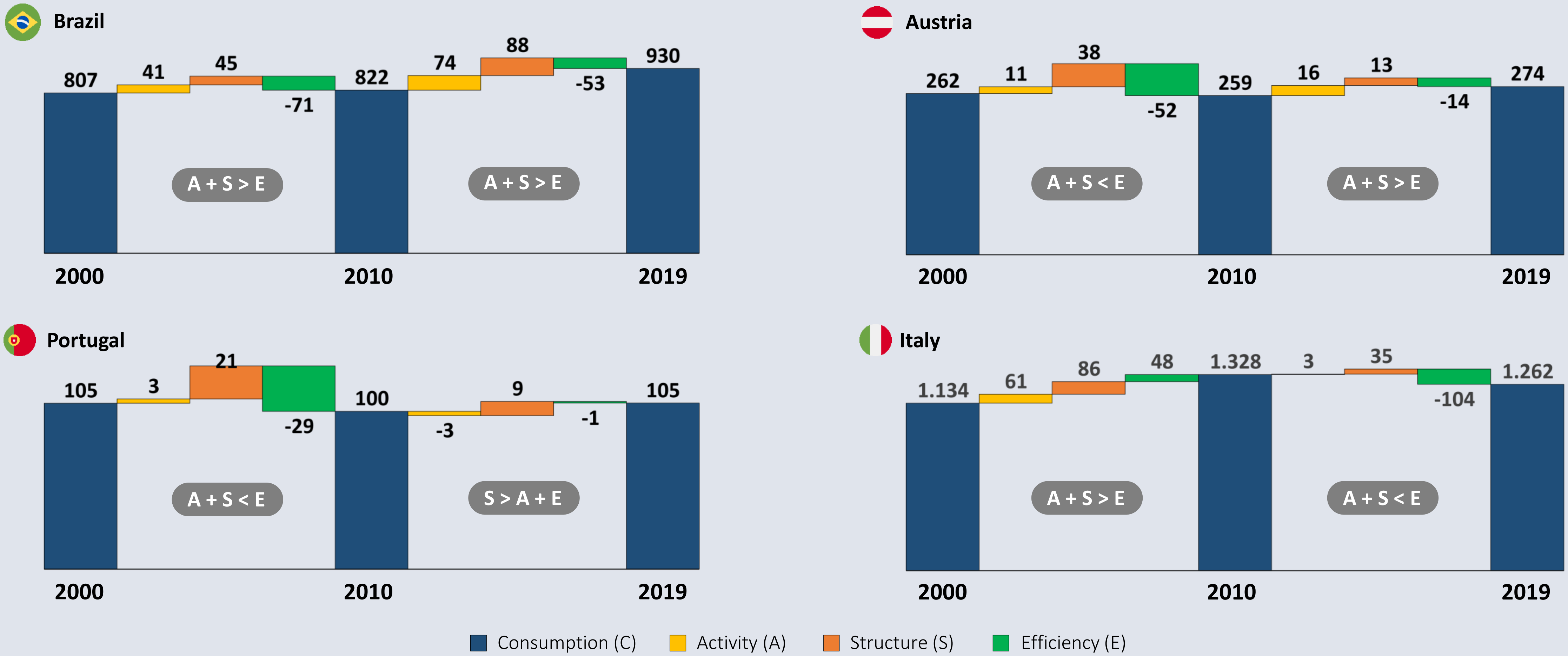




On the other hand, the 12 countries with the lowest residential sector's EPCC (Group 2) showed a static trend. **This may indicate that families are not showing changes in consumption patterns on average or that possible efficiency gains were mitigated by possible increased consumption to meet a repressed demand for energy services (boomerang effect).**

Box 1. Decomposition analysis of residential sector's energy consumption variation in selected countries

The structural decomposition analysis for those 4 selected counties (IEA, 2023) shows how in the 3 developed countries there were periods in which efficiency gains exceeded the possible increase in consumption related to activity and/or structural effects. But, in the case of Brazil, a developing country, the activity and structure effect overcome the energy efficiency effect, demonstrating an increase in consumption to possibly meet a repressed energy demand.



Note: A, S and E refers to the absolute values of each effect.

Residential sector's consumption patterns of energy services

The analysis of aggregated indicators provides an interesting overview of energy consumption in the residential sector. However, it is important to analyze energy consumption in more granular ways in order to understand:

- which energy services are consumed
- using which sources and
- by which consumer socioeconomical profile

Those pieces of information can help to improve the design and implementation of public policies compromised to energy efficiency promotion and energy poverty reduction.

Main energy services demanded by households

Lighting
Electricity, kerosene

Space Heating
Electricity, natural gas, process heat, firewood, coal derivatives, charcoal

Space Cooling
Electricity

Cooking
Electricity, natural gas, LPG, ethanol, firewood, charcoal

Food Conservation
Electricity

Water heating
Electricity, natural gas, LPG, ethanol, firewood, charcoal

Other uses[1]
Electricity

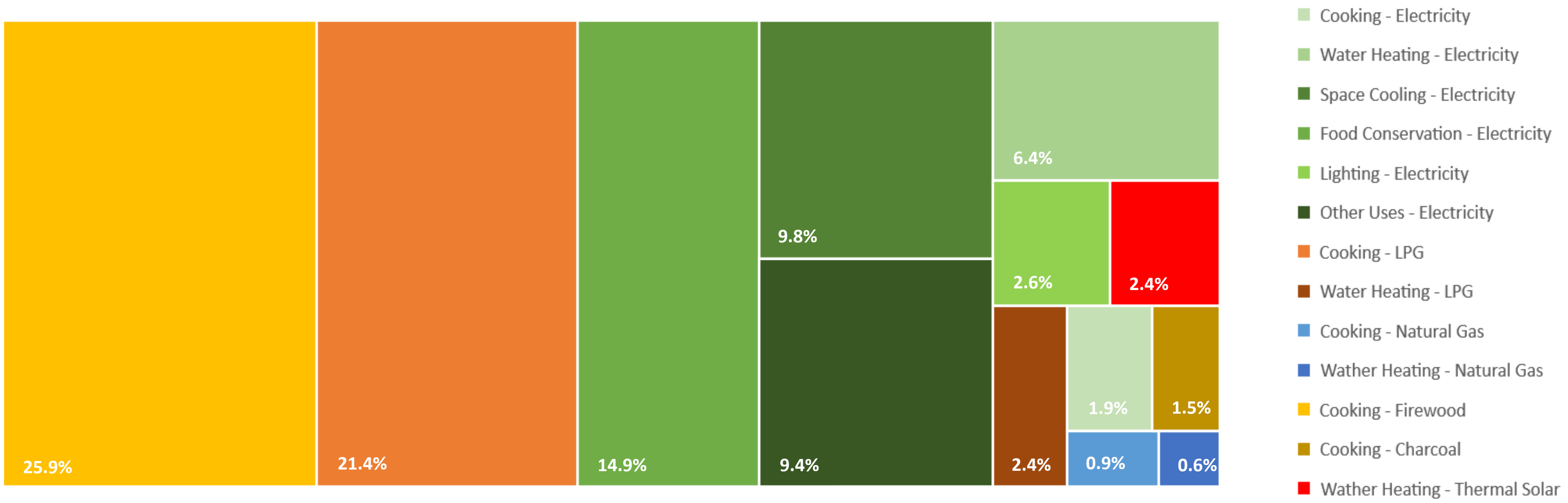
Households demand Energy Services, but what about the energy sources?
They will depend on secondary factors, such as availability, technology, efficiency, costs, cultural, political and environmental issues.

[1] **Other uses** such as leisure, communication, cleaning etc.

Contextualizing Energy Services in Brazilian Residential Sector

Considering the residential sector's energy mix, electricity is the energy source most consumed, specially for food conservation, space cooling, water heating, lighting, cooking and other uses (appliances). In 2019, 99,8% of Brazilian population had access to electricity.

Figure S4: Allocation of Energy Sources by Energy Services in the Brazilian Residential Sector, 2019.
Source: EPE (2023)



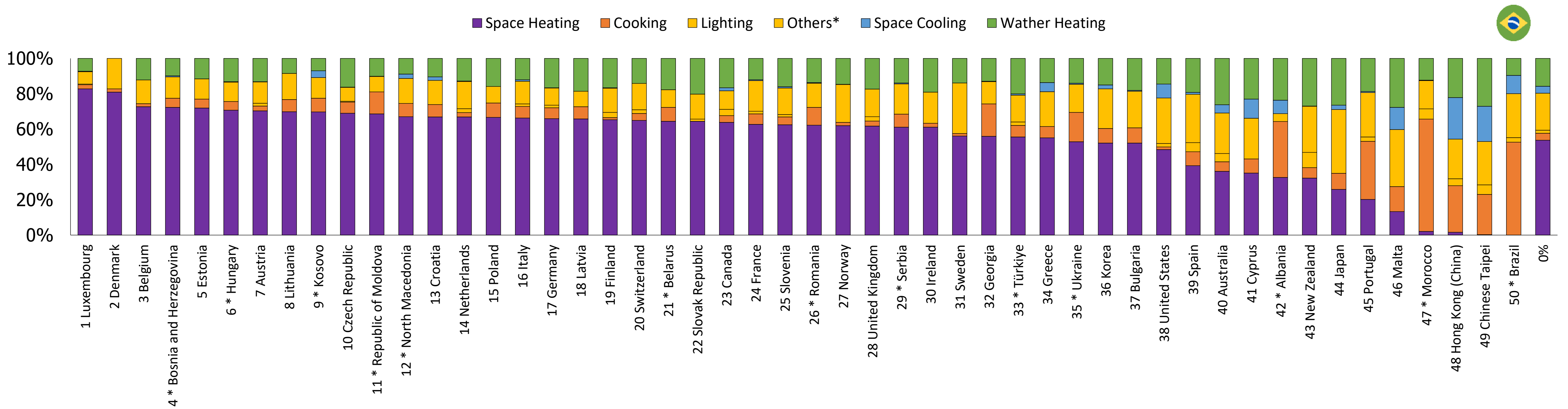
On the other hand, considering energy uses, cooking represents almost half of the energy demand and is mainly attended by firewood and LPG

International comparison of energy services' consumption patterns

Most of the selected countries have space heating as their main energy service. This can be explained by the fact that most countries are located in regions with a temperate, subtropical or Mediterranean climate. Morocco, Hong Kong, Taiwan and Brazil were the only countries with low demand for this use, given that they are also the only countries with available data that are in regions with a tropical or equatorial climate.

Figure S5: Energy Consumption distribution by Energy Services in the Residential Sector in 2019.

Source: Compiled by EPE, from IEA (2023)



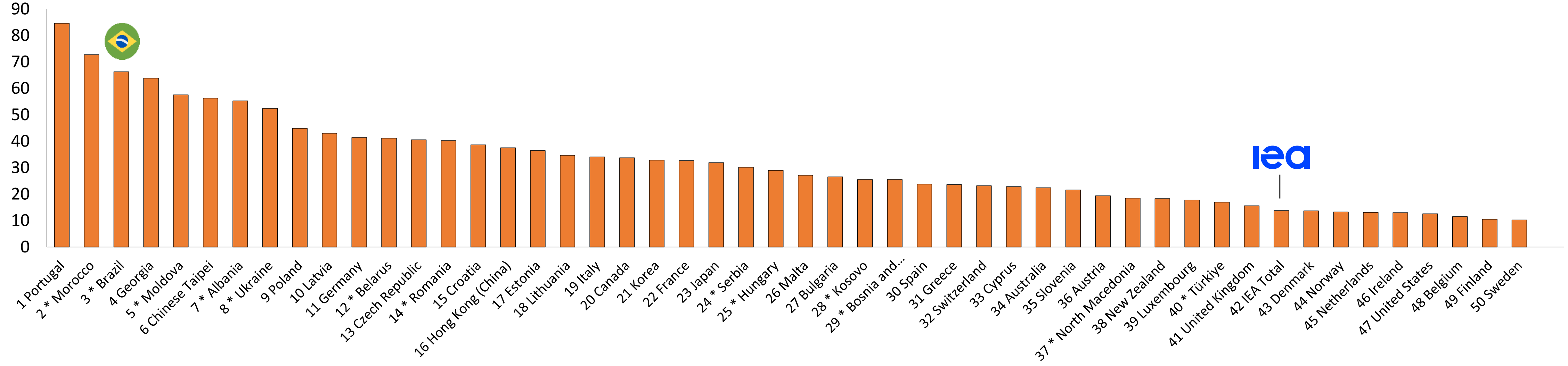
In order to compare the energy efficiency status of each country it is important to analyze the energy per capita consumption (EPCC) for each energy service. Energy demand for space heating is not considered in the EPCC analysis, since it is not a relevant energy service in Brazil.

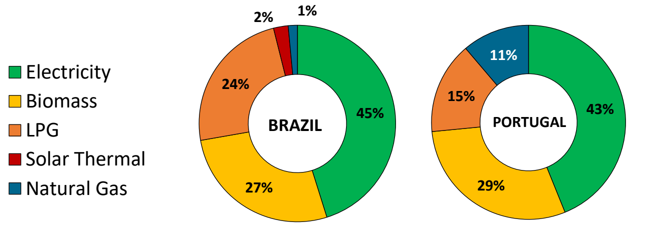
Note: Developing countries are identified with (*) in front of their names

International comparison | EPCC for cooking

Ordering the countries according to Energy per capita consumption (EPCC) for cooking, it is possible to observe that, among the 10 countries with the highest CEPC for cooking, 5 are developing countries. Portugal presents itself as the country with the largest EPCC, followed by Morocco and Brazil.

Figure S6: Energy Per Capita Consumption (EPCC) for Cooking in the Residential Sector in different countries in 2019 (10^{-3} toe per capita).
Source: Compiled by EPE, from IEA (2023)





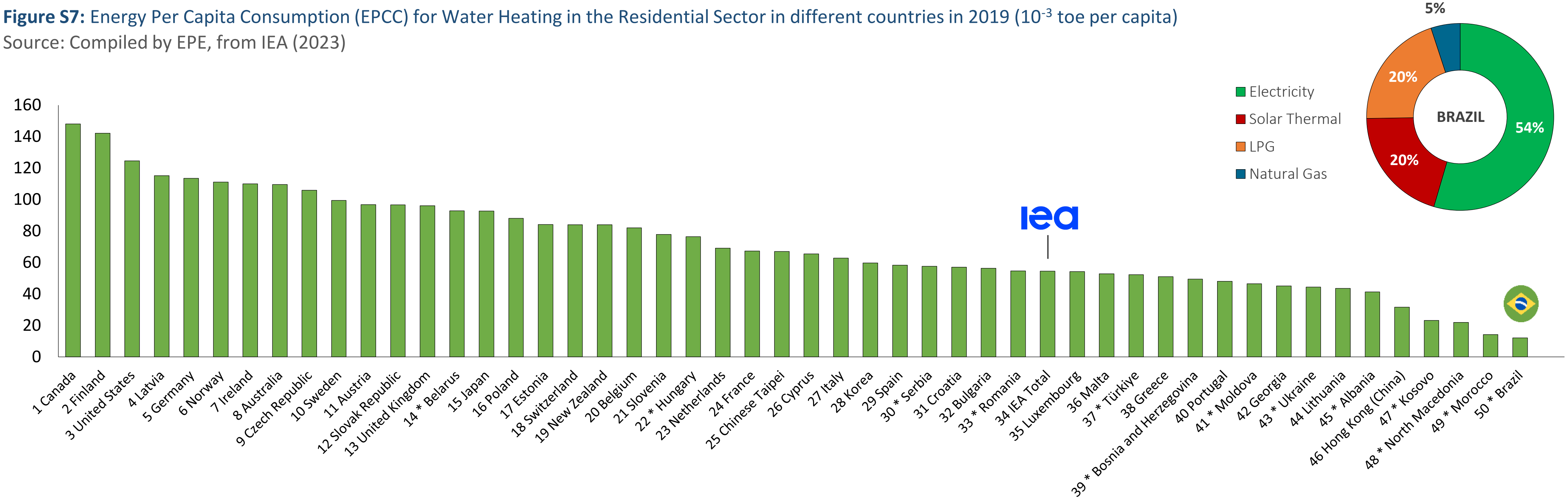
Additionally, when analyzing the energy mixes of the residential sector in both countries, it can be seen that both Portugal and Brazil have a high share of firewood. This may be related to the high ECC for Cooking.

Note: Developing countries are identified with (*) in front of their names

International comparison | EPCC for water heating

Analyzing the energy per capita consumption (EPCC) for water heating, we see that Brazil and Morocco are the countries with the lowest EPCC for this energy service. This can be explained by cultural and climatic aspects. For example, as in general both countries have a tropical climate, water heating is probably exclusive to bathing.

Figure S7: Energy Per Capita Consumption (EPCC) for Water Heating in the Residential Sector in different countries in 2019 (10^{-3} toe per capita)
Source: Compiled by EPE, from IEA (2023)



In the case of Brazil, another particularity is that water heating is mainly attended by electric showers and thermal solar system – both clean and efficient technologies.

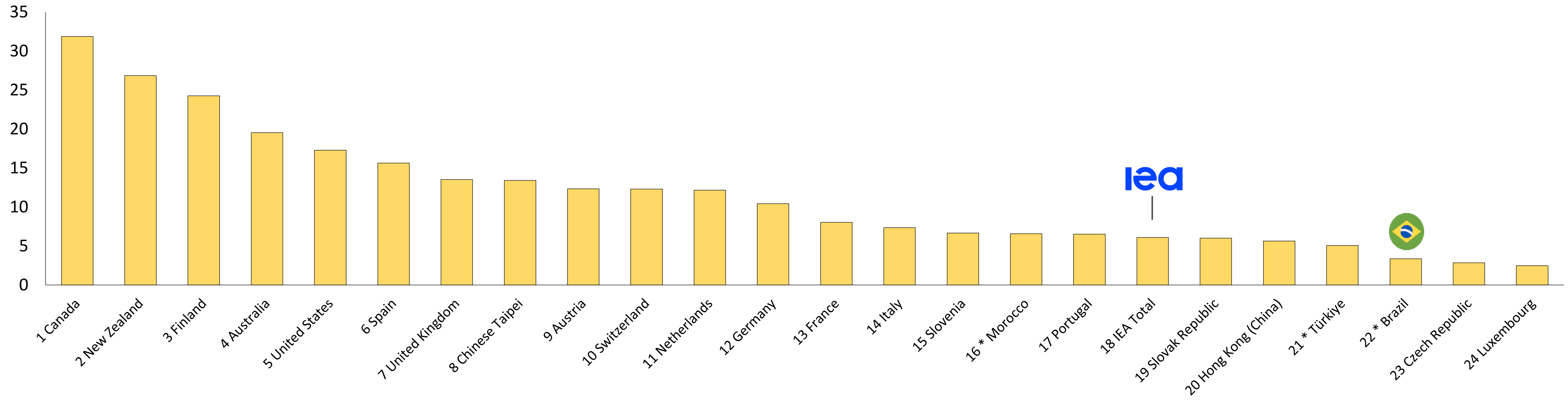
Note: Developing countries are identified with (*) in front of their names

International comparison | EPCC for lighting

Analyzing per capita energy consumption (EPCC) for lighting, it is possible to note that developed countries tend to have higher EPCC than developing countries. In the case of Brazil, EPCC for lighting is even lower than the IEA sample average, indicating the likely effectiveness of energy efficiency policies focusing on lamps in Brazil.

Figure S8: Energy Per Capita Consumption (EPCC) for Lighting the Residential Sector in different countries in 2019

Source: Compiled by EPE, from IEA (2023)



In Brazil, there are two main policies to promote energy efficiency in lighting in the residential sector: (i) minimum energy performance standards for compact fluorescent lamps (regulated in 2006 and 2010) and incandescent lamps (regulated in 2010), and (ii) replacement of lamps by electricity distribution companies through the Energy Efficiency Programme/ANEEL.

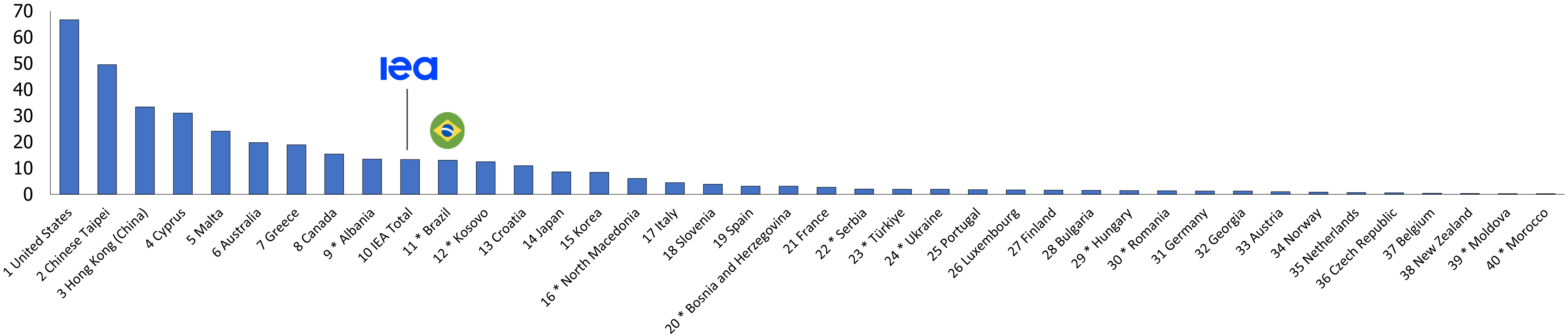
Note: Developing countries are identified with (*) in front of their names

International comparison | EPCC for space cooling

Although space cooling is one of the highest energy-consuming services in residential sector, it is not necessarily a popular energy service due to income constrains, structural, climate, or cultural aspects. For example, many countries does not depend on energy consumption for thermal comfort since not facing high temperatures. That explains the reason for many countries in IEA's sample have low EPCC for space cooling.

Figure S9: Energy Per Capita Consumption (EPCC) for Space Cooling in the Residential Sector in different countries in 2019 (10^{-3} toe per capita)

Source: Compiled by EPE, from IEA (2023)



Among developing countries in IEA sample, Brazil is the country with the highest EPCC for space cooling, presenting a EPCC equivalent to the IEA sample's average EPCC. It is interesting to highlight that Brazil has a lower EPCC for space cooling than Canada and Albania, both countries with lower average temperatures than those found in Brazil. **This may be an indication of energy poverty in Brazil. However, more accurate studies should be developed in order to assess the real potential demand for space cooling based on regional climate data (such as temperatures and number of days with extreme heat and the need for space cooling - *cooling degree-days.***

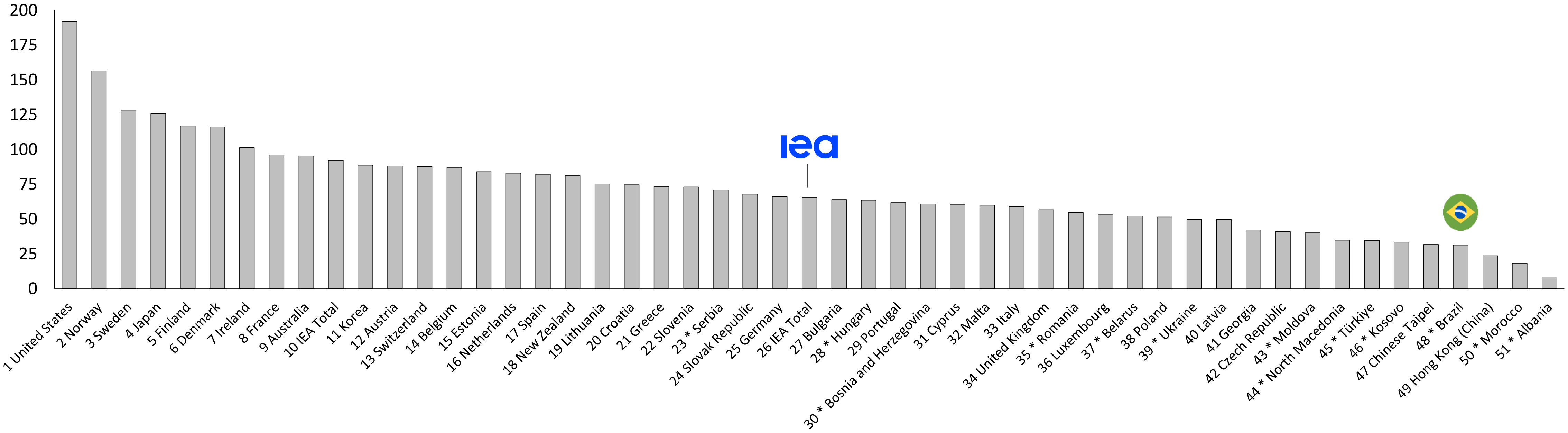
Note: Developing countries are identified with (*) in front of their names

International comparison | EPCC for electrical appliances

Analyzing energy per capita consumption (EPCC) for other uses, it is possible to note that developing countries tend to have a lower EPCC for electrical appliances. For example, Brazil has the 4th lowest PCC for electrical appliances (including refrigerators).

Figure S10: Energy Per Capita Consumption (EPCC) for Electrical Appliances (including refrigerators) in the Residential Sector in different countries in 2019 (10^{-3} toe per capita).

Source: Compiled by EPE, from IEA (2023)



The lower EPCC for electrical appliances in developing countries may be related to the existence of a suppressed demand for other energy services, especially in lower income classes. **Therefore, especially in developing countries, it is important to analyze inequality in energy consumption, especially by income classes.**

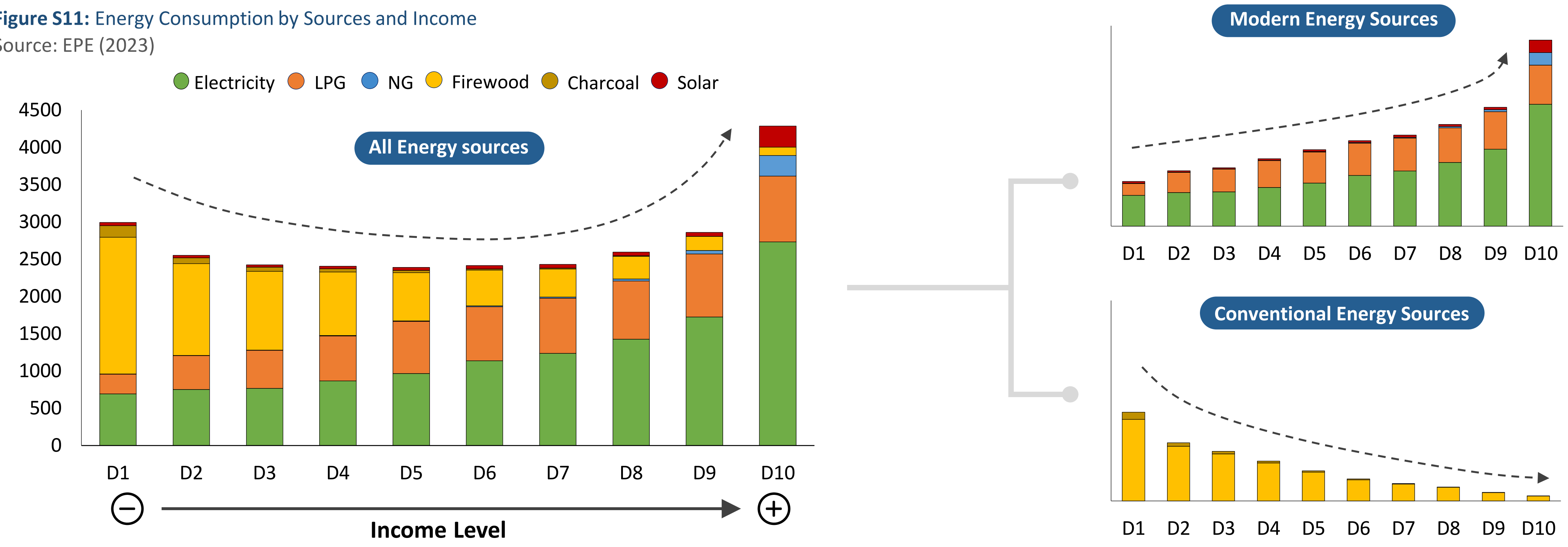
Note: Developing countries are identified with (*) in front of their names

Energy Consumption by income classes in Brazil

In Brazil, there is a significant concentration of electricity consumption in the higher income classes and biomass (firewood and charcoal) consumption in the lower income classes. As a result, lower income classes tend to have greater potential for energy efficiency due to the use of conventional energy sources (firewood and charcoal), and a greater suppressed demand for energy services provided by modern energy sources (electricity, solar thermal, LPG and natural gas). This analysis then separates the energy consumption into two groups of energy sources, in order to contribute in a more appropriate way to the design of public policies.

Figure S11: Energy Consumption by Sources and Income

Source: EPE (2023)



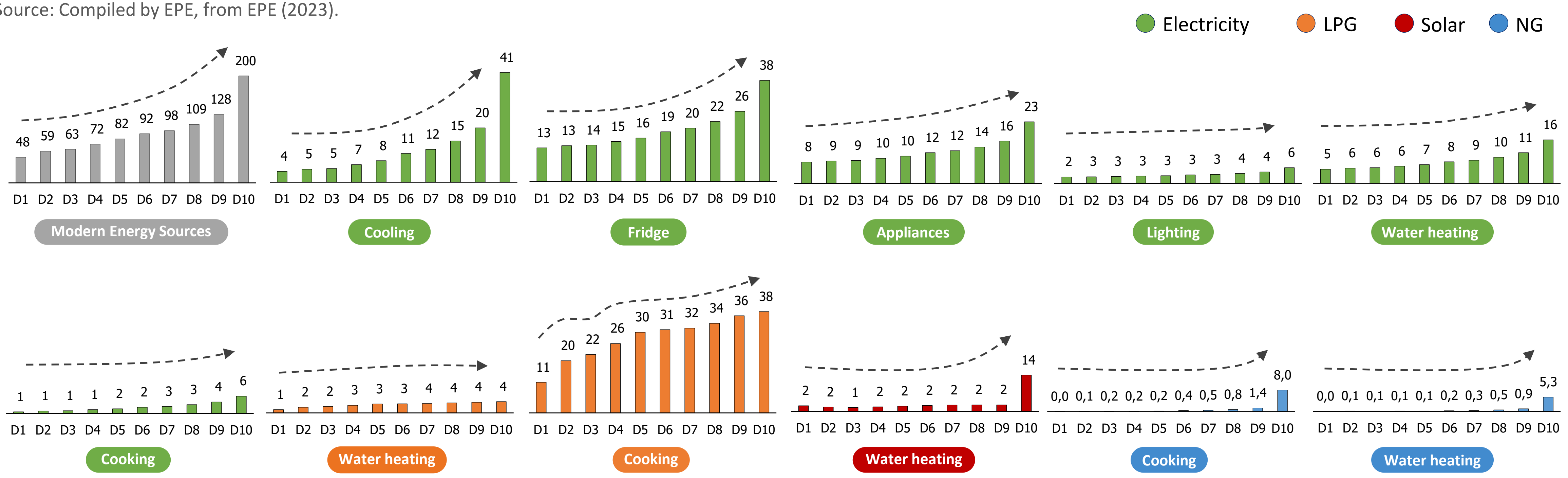
Note: All classes from D1 to D10 have the same amount of people, so each one has 10% of the Population, that means 20,9 Million people. D1 stands for the lower income class and D10 stands for the higher income class.

Demand of Modern Sources by energy services and income classes in Brazil

Analyzing by energy sources and energy services, it is possible to note that energy per capita consumption (EPCC) tends to increase while income increases. However, the elasticity depends on the energy source and services.

Figure S12 Energy Per capita energy consumption by uses and income classes (10^{-3} toe).

Source: Compiled by EPE, from EPE (2023).

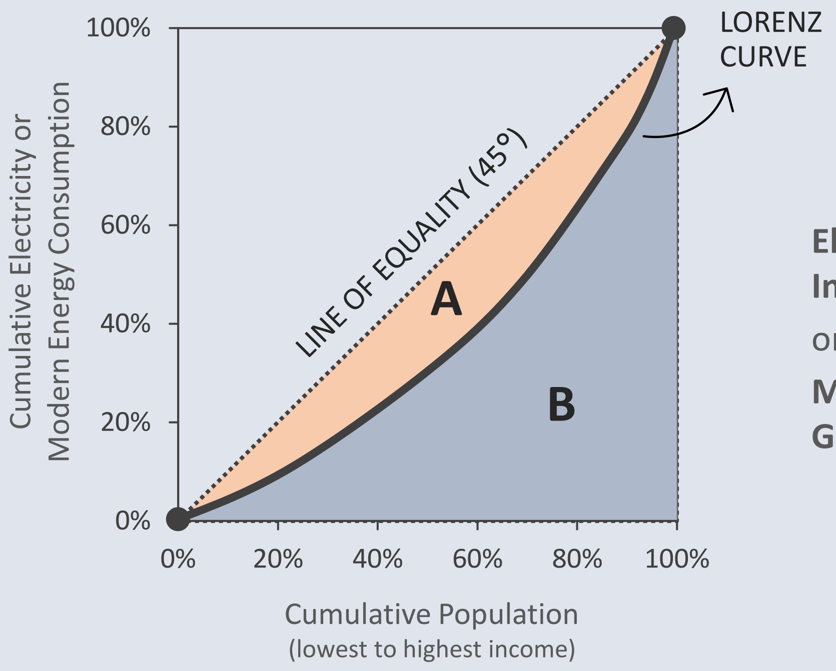


LPG is the source that presents the most different elasticity (inverse U), especially for cooking. That can be explicated by the fact that the majority of Brazilian household use LPG for cooking purposes. The only exceptions are the lowest income classes, where there is a high penetration of firewood and charcoal for cooking, and the highest income class, where there is a significative access to natural gas and electric stoves.

Note: All classes from D1 to D10 have the same amount of people, so each one has 10% of the Population, that means 20,9 Million people. D1 stands for the lower income class and D10 stands for the higher income class.

Box 2. Proposal of a new indicators: Electricity Gini Index and Modern Energy Gini Index

The Gini Index shows the relation between the share of a specific group of people or households on the whole population (horizontal axis), and the share of the demand of this very same group (vertical axis). This demand may be related to Electricity consumption (in the case of the Electricity Gini Index) or related to Modern Energy Sources consumption (in the case of Modern Gini Index). This relation is represented by the Lorenz curve, displayed below on the picture:



Electricity Gini Index or **Modern Energy Gini Index**

$$= \frac{A}{A + B}$$

The Electrical Gini Index is calculated based on the area between the Lorenz curve and a 45º curve (area A), that represents the perfect inequality absence in the electricity consumption distribution. The larger the area between those two curves, the larger is the inequality and the Gini Index.

The index can vary between 0 and 1. When it equals zero, there is no inequality; what means that all families would present the same electricity consumption. On the other hand, if the index is equal to one, that means the maximum concentration and, one single family would be responsible for consuming all the country's electricity demand.

The electricity and modern energy gini indices measure inequality in access to energy services provided respectively by electricity and modern energy sources. These indicators can be used together with the odex and energy per capita consumption (EPCC) to design, monitor and evaluate energy efficiency policies with focus on reduction energy poverty.

[1] Decile means an interval that contains 10% of a sample or a class containing 10% of the data.

Electricity Gini Index and Modern Energy Gini Index for Brazil

The Residential Sector's Electricity Gini Index and Modern Energy Gini were calculated for Brazil. From 2005 to 2014, both indicators decreased, indicating a reduced inequality. However, in 2015, the Gini Indexes changed their courses and started to show upward trends, indicating a slightly increased demand concentration in the higher-income classes. In 2019, the consumption of modern energy sources was less concentrated than the electricity consumption in the Brazilian residential sector.

Figure S13: Lorenz Curves for Electricity and Modern Energy Sources, 2019.
Source: EPE (2023)

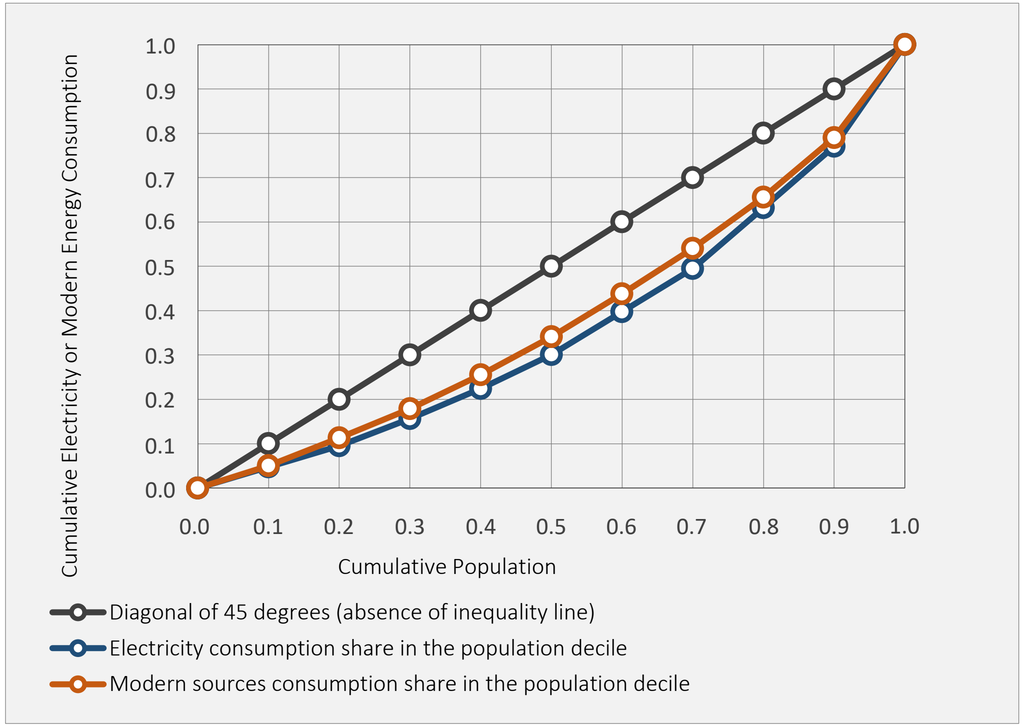
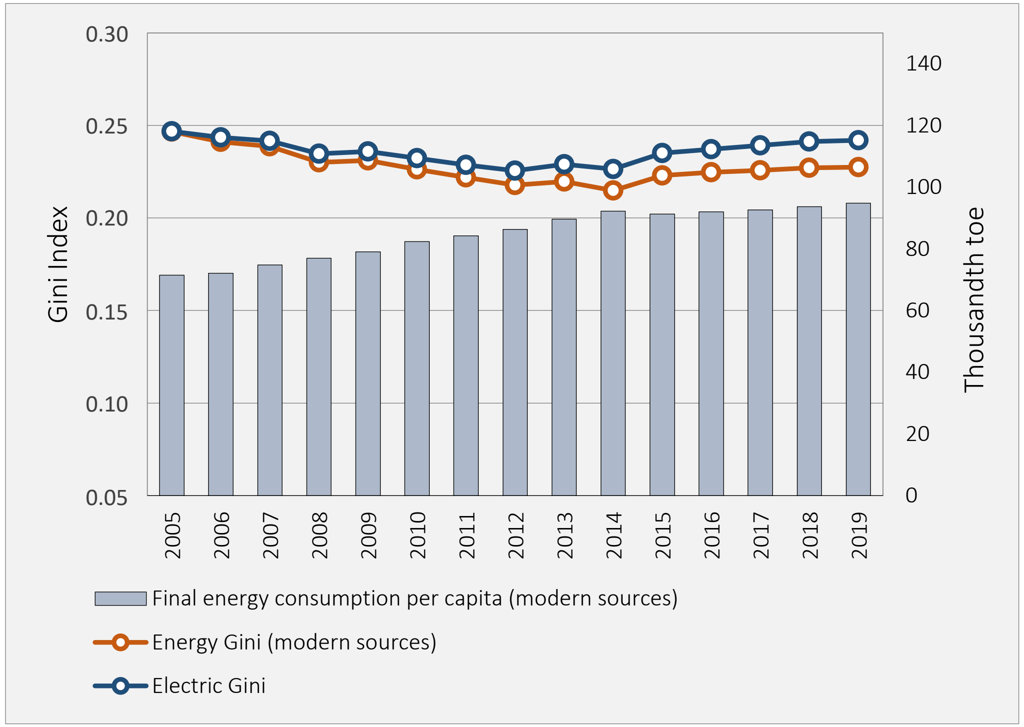


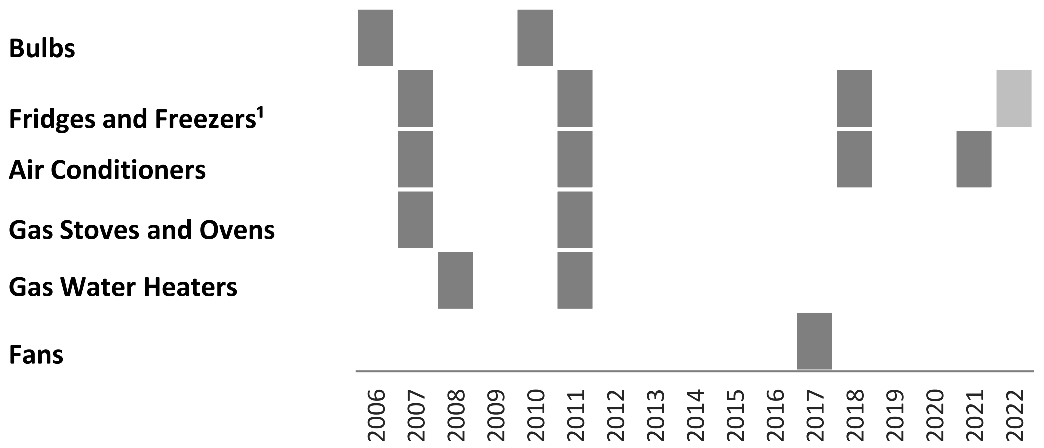
Figure S14: Electricity Gini Index and Modern Energy Gini Index, 2005-2019.
Source: EPE (2023).



Policies for boosting access to energy efficiency in the use of Modern Sources in Brazil

The Brazilian residential sector embraces several pivotal energy efficiency policies. These encompass the Minimum Energy Performance Standards (MEPS), the Brazilian Labeling Programme (PBE), and endorsement seals. The MEPS criteria is applied for equipment listed on Figure S16. Appliances meeting MEPS guidelines are also integrated into the PBE and carry endorsement seals. Those two last initiatives also include other appliances such as microwave ovens, washing machines, televisions, solar water heaters, photovoltaic systems. Moreover, the residential sector benefits from energy efficiency seals specifically designed for buildings.

Figure S15: Minimum Energy Performance Standards (MEPS) for home appliances in Brazil.
Source: EPE (2023)



Distribution Energy Efficiency Programme

Furthermore, Brazil has implemented the Energy Efficiency Programme (PEE) compelling electricity distributors to annually allocate a portion of their net revenue to energy efficiency projects. One key initiative of the programme involves replacing outdated and inefficient electrical appliances in low-income households with new, energy-efficient alternatives.

According to ANEEL's 2023 report, the PEE has remarkably invested over R$ 1.9 billion (55%) in 274 energy efficiency projects dedicated to lower-income households between 2009 and 2022. Analyzing a subset of 62 PEE projects aimed at 8,256 lower-income households from 2018 to 2022 (ANEEL, 2023), the outcomes how that energy efficiency investments have contributed to a 6.9% reduction in the monthly electricity consumption of these households. The energy efficiency gains can be translated into significant benefits for these households, such as alleviating the burden of electricity bills within household budgets or granting access to additional energy services.

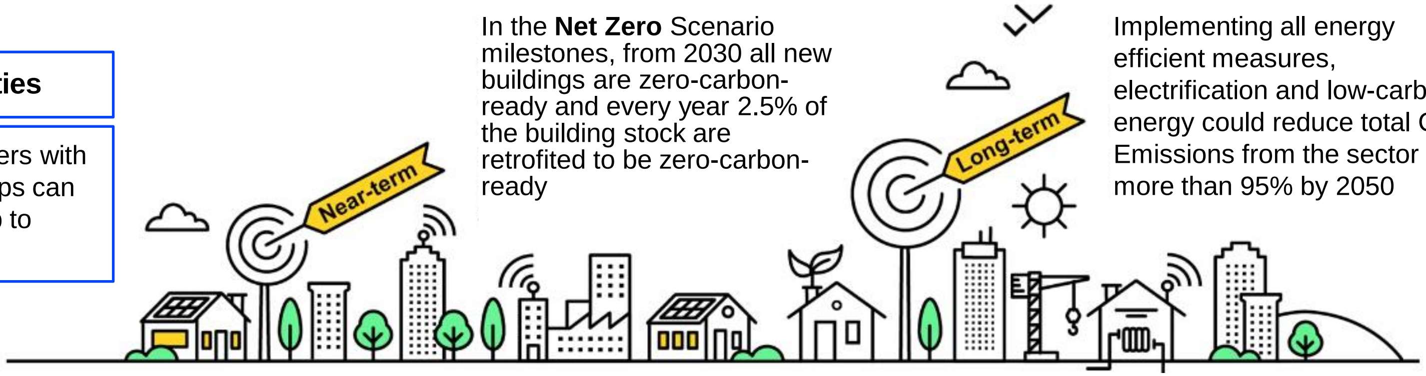
Brazil has other programmes focused on alleviating inequality in the use of modern energy sources. For example, the Social Electricity Tariff Programme provides discounts on the electricity bill for low-income and other vulnerable families, aiming to reduce the electricity bill burden. Another example is the Minha Casa Minha Vida Programme which subsidizes the acquisition of affordable housing incorporating energy efficiency criteria, such as solar thermal water heating, to help reducing household electricity expenses.

Note: The minimum efficiency standards for fridges and freezers were under revision in 2022.

Buildings Energy Efficiency Policy Package

Immediate opportunities

Replacing fossil fuel boilers with high efficiency heat pumps can reduce energy use by up to 75%



In the **Net Zero** Scenario milestones, from 2030 all new buildings are zero-carbon-ready and every year 2.5% of the building stock are retrofitted to be zero-carbon-ready

Implementing all energy efficient measures, electrification and low-carbon energy could reduce total CO_2 Emissions from the sector by more than 95% by 2050

REGULATION

- **Targets for energy efficiency** in buildings, including for renovation rates, fosters market growrth and facilitates long-term investment decisions.
- Building energy codes for new buildings and retrofits are essential to accelerate the transition to zero-carbon-ready buildings.
- **Minimum energy efficiency requirements** for renovation help guarantee performance and accelerate the process of renovation through instruments such as the standardisation of services.
- **Regulations** ensure that buildings can become “demand response ready” to enable future flexibility.

INFORMATION

- **Information on building performance** allows consumers to identify the most efficient options when buying or renovating buildings. Examples include energy performance certificates, Disclosure programmes, one-stop shops for upgrades and renovation passports.
- **Smart interactive technologies** can show real-time energy performance and help adjust occupants’ behaviour.
- **Trainning and education programmes** for building sector workers are important to ensure a suitable skilled work force.
- **Public awareness campaigns** designed to include behavioural insights encourage low-cost actions, such as thermostat adjustment.

INCENTIVES

- **Financial incentives** such as green mortgages, energy performance-based preferential loans and tax rebates and grants can motivate consumers and developers to increase investment in energy efficient solutions.
- **Expedited administrative procedures**, including accelerated permiting, targeted at high performing new build or retrofit projects, encourage the implementation of energy efficient measures.
- **Award and recognition programmes** encourage the development of highly energy efficient buildings.

Key policy recommendations to improve energy efficiency in the building sector

Regulation

- Improve building energy performance by implementing Codes and MEPS. Adopting a holistic approach to building energy codes and MEPS should be considered, covering building envelopes, appliances and equipment. Initially, these could be implemented on a voluntary basis to allow enough time for market adaptation before transitioning to mandatory regimes.
- Develop regulations and legislation for standards and labelling of lighting, appliances and equipment and ensure these are enforced and regularly updated. The standards and labelling should focus on products that will deliver the greatest energy savings and provide the greatest economic and environmental benefits to users and the country.
- In the case of existing buildings, a combination of policies that improve the minimum codes and the efficiency of buildings through renovation, operation and maintenance best practices is recommended.

Information

- For existing and new buildings, these policies could be combined with demonstration projects, financial mechanisms, technical capacity building, consumer education, and introducing energy tariff structures that promote efficient energy use.
- As the first measure to reduce the amount of energy needed for space cooling, proper building design can improve natural ventilation and thermal insulation, reduce air leakage, and improve internal and external shading by incorporating advanced envelope components such as reflective roofs, as well as passive-building design elements, integrated storage and renewables.
- Greater effort is needed to expand and strengthen MEPS, with targets and requirements that progressively advance air-conditioning energy performance towards the level of best available technology and set a course for continuous improvement.

Incentives

- Regulation and financing to provide access to collective cooling spaces for people without household AC is also critical to protect the most vulnerable.
- While efficient air conditioners will reduce the impact of cooling on electricity systems, more flexibility is needed to distribute electricity demand intelligently.
- Governments can promote innovative business models and demand response incentives to encourage the use of digital technologies such as smart thermostats and other improved controls that optimise the load distribution of energy demand for cooling.

International Energy Efficiency Initiatives for Lower-Income Households

The IEA policies database lists various energy efficiency, electrification, renewable energy sources, greenhouse gas mitigation, eradication of energy poverty, research, development, and innovation policies, among others. There are several labeling programs, MEPS, and electricity bill subsidies, whether targeted to lower-income households or not. Below, the listed initiatives reconcile the promotion of energy efficiency and the eradication of energy poverty for lower-income families or the construction of energy efficient social interest housing.

Energy Efficiency Policies for Lower Income Households	Country	Year	Status	Tecnology
Recovery and resilience plan / CTD / Energy efficiency in buildings	Portugal	2021	Ended	Appliances
National recovery and sustainability plan / Green transition / Renovate	Greece	2021	In force	Lighting
Cost of living package [Amendment to Energy Act]	Czechia	2022	In Force	Appliances and others
Subsidies for renovation and boiler upgrade for low income households	Austria	2021	In Force	Heating
"Update your heating" programme	Chile	2021	In Force	Heating
Municipal-level Measures to Lower Energy Bills for Households	Netherlands	2021	In Force	Appliances and others
Social Climate Fund	European Union	2021	In Force	Appliances and others
National Cooling Strategy	Rwanda	2019	In Force	Air conditioning

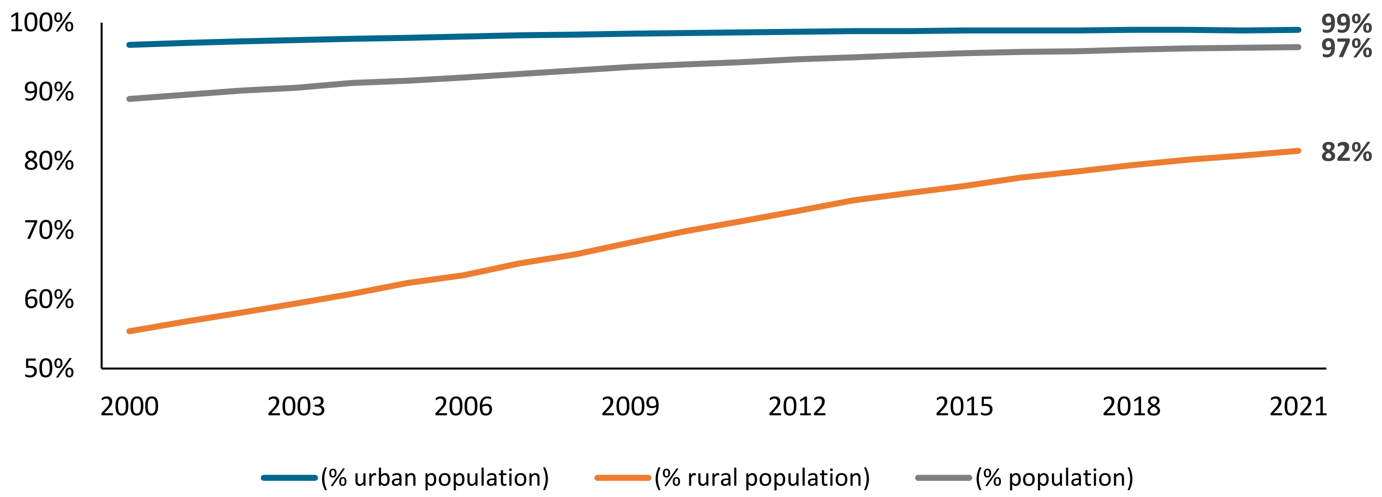
Energy Efficient Social Interest Housing	Country	Year	Status	Tecnology
New Housing NAMA	Mexico	2012	In force	Buildings
Improving access to affordable housing project	Mexico	2022	In force	Buildings
Technical support for self-construction “Decide y Construye”	Mexico	2022	In force	Buildings
Energy Efficiency and Renewable Energies in Existing Housing	Mexico	2018-2023	Ended	Buildings
New South Wales	Australia	2009	In force	Buildings
Weatherization Assistance Program	USA	2021	In force	Buildings

Source: IEA (2023).

Access to clean fuels and technologies for cooking in Brazil

According to the United Nations, the use of open fires and collected biomass for cooking can cause several health and environmental problems, being associated to nearly 4 million premature deaths every year in the world. Women and children are disproportionally affected, suffering from toxic smoke, time poverty, and consequences of deteriorating environments. Therefore, universal access to clean cooking is part of the Sustainable Development Goals (SDGs) of the Agenda 2030.

Figure S16: Share of population with access to clean fuels and technologies for cooking in Brazil.
Source: Compiled by EPE, from IBGE (2023).



Access to clean fuels and technologies for cooking
Like other countries, Brazil is making efforts to improve the access to clean fuels and technologies for cooking.
According to IBGE, 96.1% of Brazilian population had access to clean fuels and technologies for cooking in 2015 (IBGE, 2023). According to the World Bank, this value rose to 97% in 2021 (WB, 2023), being 81.5% in rural areas and 99% in urban areas. The improvement in the access to cleaning cooking fuels and technologies was mainly concentrated in rural areas.

However, it is important to highlight that access to clean cooking technologies does not mean necessarily consumption of only clean fuels for cooking.

Demand of Conventional Sources for cooking by income classes in Brazil

In 2022, according to IBGE(2023), 17.1% of Brazilian households declared to still use firewood or charcoal for cooking. Those households can be divided into two subgroups: the ones that consume only firewood for cooking and the ones who consume firewood and other fuels for cooking, mainly LPG. This last group is the most common in Brazil (16.3%). It means that households have access to LPG stoves, but they often find in the collected firewood a solution for cooking towards alleviating LPG cost burden on household budget.

Figure S17: Percentual of Households who declared to consume biomass in Brazil.
Source: Compiled by EPE, from IBGE(2023).

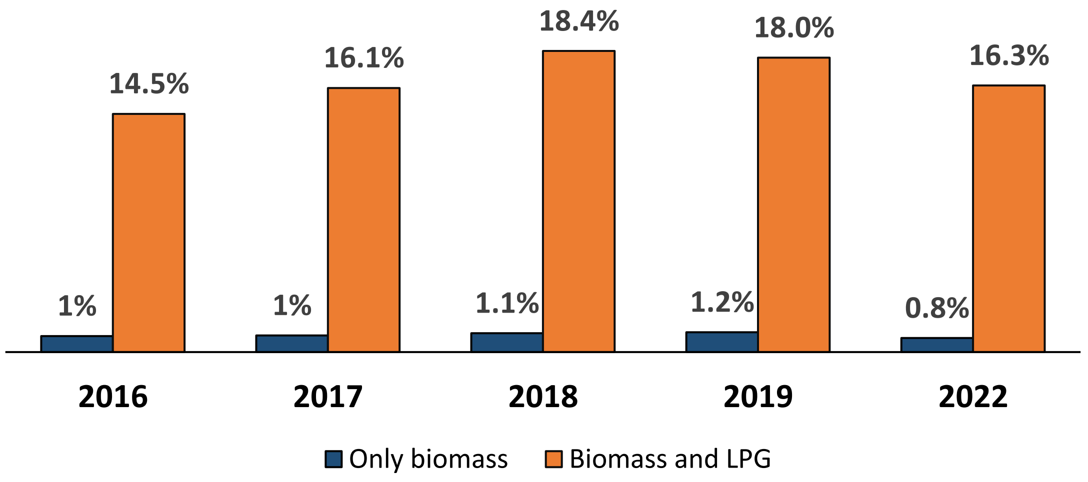
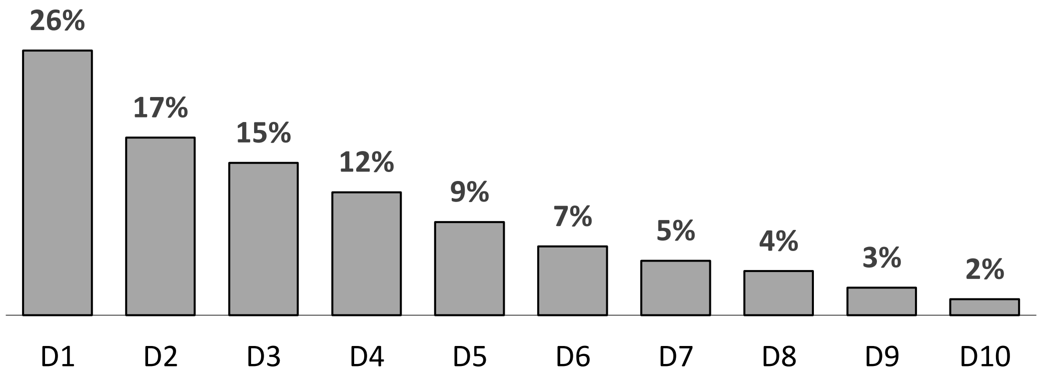


Figure S18: Distribution (by income class) of Households declaring to use firewood in Brazil (2019)
Source: Compiled by EPE, from IBGE (2023).



Biomass consumption is concentrated in the lowest income classes in Brazil, according to IBGE (2023). The half of the population with the lowest income accounts for approximately 80% of the firewood consumption for cooking in the residential sector. Most of the firewood consumed by families is collected in nature and used in improvised stoves with very low efficiency.

Note: All classes from D1 to D10 have the same amount of people, so each one has 10% of the Population, that means 20,0 Million people. D1 stands for the lower income class and D10 stands for the higher income class.

Policies for boosting clean cooking in Brazil

The use of open fires and collected biomass for cooking can be strongly related to other socioeconomical vulnerabilities. Therefore, it is important to discuss other public policies focused on eradicating poverty and its consequent challenges.

Some Brazilian government programs are designed to alleviate vulnerabilities and facilitate the consumption of clean sources for cooking by low-income households, such as:

Brazilian Gas Aid Programme

The Gas Aid is a Brazilian Federal Government program whose goal is to reduce the burden on the budget of low-income households. Created in 2001, the programme was incorporated to Bolsa Família in 2003 and relaunched separately in 2021 during COVID-19 pandemic crisis. In 2023, the Gas Aid was boosted and, since then, the selected households has received every two months the amount equivalent to one LPG cylinder. The Gas Aid can be combined with other social programs, such as the Bolsa Família Programme. In August 2023, more than 5.5 million families received the Gas Aid, whose value was R$108 per family in the respective month.

Bolsa Família Programme

Bolsa Família is an income transfer programme created by the Brazilian Federal Government in 2003 and internationally recognized for having saved millions of families from hunger. Its benefit is designed to be proportional to family size and characteristics to guarantee basic income for families in vulnerability. From 2020 to 2022, because of COVID-19 pandemic, the Emergency Aid was granted to the families. In 2023, the programme is expected to benefit 21.2 million families. In June, the average value of the Bolsa Família benefit was R$ 705.40.

Note: Through the CadÚnico (government's Single Registry), Brazilian government seeks to integrate public policies, strengthening access to health, education and social assistance. To be entitled to Bolsa Família Programme, families must be registered in CadÚnico and have a monthly per capita income of up to R$218. To be entitled to Gas Aid Program, families, in addition to being registered in CadÚnico, must have a per capita income of up to half the minimum wage and be selected by the prioritization criteria defined by the Ministry of Development and Social Assistance, Family and Fight Against Hunger. In 2023, the minimum wage was R$1302.

Key policy recommendations to improve clean cooking in households

Regulation

- Design a high-level political vision, ideally with cross-ministry support, with clear targets, a determined implementation plan, effective subsidies, and international funds distribution.
- Establishing clear regulatory oversight through agencies can help track the domestic stove market, ensure minimum standard requirements and provide support only to approved ones.

Information

- Design training programmes and educational strategies that account for local traditions while addressing barriers to adoption rooted in traditional cooking practices.
- Programmes should include training salespeople and safety technicians, which can make the difference between lasting adoption or stoves going unused.
- Deliver strategic guidance and support for reskilling those individuals employed in the inefficient cooking sector to access long-term employment opportunities (including redeployment in the clean cooking industry).
- Programmes must consider societal perceptions of gender, customs, land rights and wildlife protection, as well as different ethnic communities within the same country.
- Integrate clean cooking with electricity access efforts and make sure these programmes define outcomes for gender equality, health standards, forestry/agricultural practices, including metrics to track progress against these outcomes.
- Track the progress on clean cooking deployment and evolving technology costs and make this publicly available. This will support a more dynamic and successful private sector participation.

Incentives

- Design and implement incentives, promote appropriate business models and cover a cookstove's upfront costs to encourage uptake, and create a competitive ecosystem for private sector actors.
- Reducing or scrapping tariffs and duties on imported cookstove components to encourage further market participation.
- Design well-designed cross-subsidisation between low-income and high-income consumers, combined with end-user financing schemes.

International initiatives on Clean Cooking

Ecuador

- Promoting Induction Cooking Program (PEC).

Peru[1]

- Campaign "Half a million Improved Kitchens for a Smokeless Peru"
- Haku Wiñay/Noa Jayatai Project
- Social Energy Inclusion Fund (FISE)
- Peru National Kitchen Program
- Energizing Development Program (EnDev)

Kenya

- Women's Engagement in the Improved Cookstove Value Chain in Kenya.
- Kenya's clean cooking champions (Story of Change).
- Increasing biodigester functionality for clean cooking in Kenya.

India

- Cleaner cooking technologies for forest-dependent women in India
- PAHAL Programme on Direct Benefit Transfer for LPG (DBTL)
- PMUY Programme on free LPG connections to poor households.

Asia and Africa

- "Women in Clean Cooking" Mentorship Program

Indonesia

- Electric Cooking in Indonesia

Malawi and Nigeria

- Integrated Energy Plans (IEPs) that set clear goals for both electrification and clean-cooking access.

Note: [1]Details about the programs are available at Box 2 and Box 3 on the report *Clearing Up the Smoke: Untapping the Potential of Tailored Clean Cooking Programs in Latin America (BID, 2020)*.

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