Atlas of Energy Efficiency

Brazil | 2019

Indicators Report

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International Benchmarking chapter by

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This report has an international benchmarking chapter, which is the result of detailed cooperation on data and policies between the International Energy Agency (IEA) and EPE. It represents a milestone in the relationship between the two institutions, and is the result of the first comprehensive exchange of data between the IEA and an associated (non-member) country in Latin America, as well as the continuous exchange of knowledge through the Energy Efficiency Program in Emerging Economies.

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1. INTRODUCTION

1.1 Objectives and contents

This document's main objectives are to develop and deliver a bank of energy efficiency indicators in order to monitor energy efficiency in Brazil. In 2017, a second report, entitled *Consumo de Energia no Brasil – Análises Setoriais* [Energy Consumption in Brazil - Sectorial Analises][1], analysed indicators up to 2016. This document updates and expands upon the first report, with data up to the year 2018[2].

This document consolidates EPE's third work cycle in the development of the database of energy efficiency indicators.

1.2 The importance of energy efficiency

When their cumulative impact is added up, energy efficiency practices are one of the strategies for meeting energy demand. Moreover, avoiding waste and delivering more energy services with the same amount of energy make it possible to deliver competitiveness gains and benefits for the whole of society.

Energy efficiency is also an important means of meeting society's future energy needs, both in Brazil and throughout the world. Noteworthy publications in this context include the *World Energy Outlook* and the *Energy Efficiency Market Report* (both produced by the International Energy Agency - IEA), the *Annual Energy Outlook* (published by the Energy Information Administration/US DOE) and *Energy Efficiency Policies in the European Union* (prepared by ODYSSEE-MURE). In Brazil, the *Plano Decenal de Energia* [Ten-year Energy Plan] *(PDE)*, the *Plano Nacional de Eficiência Energética* [National Energy Efficiency Plan] *(PNEf)*, and the studies of the *Plano Nacional de Energia 2050* [National Energy Plan 2050] *(PNE)* are key documents.

These studies show that society will not be able to get by without an increase in energy efficiency as part of an overall strategy for meeting energy demand and fighting climate

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[1] Available at: http://www.epe.gov.br/mercado/Documents/S%C3%A9rie%20Estudos%20de%20Energia/DEA%2010-14%20Consumo%20de%20Energia%20no%20Brasil.pdf

[2] The indicators in the first report were updated to incorporate revisions of the IBGE's historical series, among others.

change. In addition to its role in this regard, energy efficiency contributes to energy security, moderation in pricing, the postponement of investments in electricity generation, greater competitiveness and productivity, job creation, an increase in the wellbeing of the population, cost savings in public health, and a reduced impact on the environment.

In order to make the most of opportunities for increased energy efficiency, it is necessary to have a joined-up view of energy sources and the actors involved (government, the private sector, financial institutions, and society in general).

However, there are barriers that hinder the spread of energy efficiency, such as: the low prioritisation of efficiency projects on the part of companies and consumers, a lack of knowledge about the potential of energy efficiency and the measures it involves, a lack of information and data, a lack of confidence about the real costs and benefits of efficiency actions, and, among others, barriers when it comes to the right business model for investments in efficiency, and a resistance to change.

In this context, the EPE's work contributes to the planning and dissemination of energy efficiency in Brazil through structured actions such as:

- Developing databases about energy efficiency, which includes identifying the potential for energy efficiency and how much projects will cost;
- The development of strategies and a portfolio of measures to encourage an increase in energy efficiency in Brazil;
- Monitoring the progress of energy efficiency indicators in various sectors, and providing feedback for the impact analysis of energy efficiency policies.

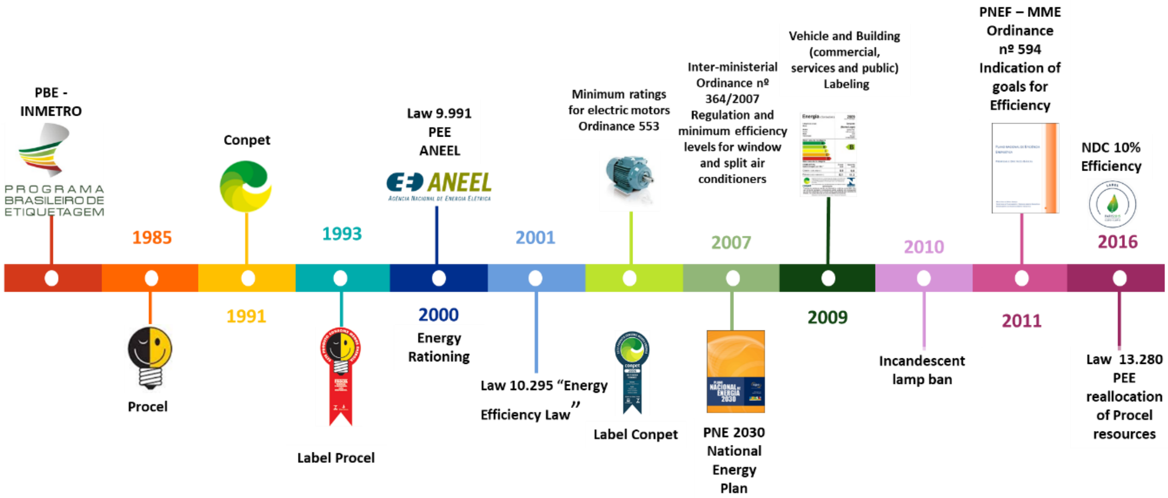
Throughout its history, the EPE has worked on studies and research with the aim of consolidating a statistical database that helps to leverage this process in Brazil. Among other actions, two studies that collected primary data on energy efficiency - under the auspices of the META project and with support from the World Bank - stand out. One of these looked at the service sector, and the other focused on Brazilian industry. At the moment, the EPE is helping Procel to operate its Ten-Year Energy Efficiency Plan.

1.3 Policies to develop energy efficiency - a brief history

Government energy efficiency programmes in Brazil date from 1984, as shown in Image 1. The Programa Brasileiro de Etiquetagem [Brazilian Labelling Programme] (PBE/1984), co-ordinated by INMETRO, was the pioneer programme in this area. Comparative labels indicating the energy performance of equipment provide information on the specific energy consumption of products, guiding consumers' choices. Aside from helping to educate citizens, this programme encourages manufacturers to make products with higher levels of energy efficiency.

The range of equipment that features such labels includes photovoltaic systems, light duty vehicles, and buildings[3].

Image 1 – Timeline of key energy efficiency programmes in Brazil



Source: EPE

In 1985 and 1991, the government rolled out two energy conservation programmes - first Procel, for electricity, and then Conpet, for oil and natural gas products. These programmes are co-ordinated by MME, and carried out by Eletrobras in the case of Procel, and Petrobras in the case of Conpet. In partnership with Inmetro for the PBE, seals of quality have been created to add value to the most efficient products. Procel operates in several areas, such as Procel Seal, industry, buildings, government, and public lighting. Since the enactment of Law 13 280/2016, Procel has been able to count on energy providers to dedicate 20% of their resources earmarked for energy efficiency, through Procel's Plano de Aplicação de Recursos [Resource Application Plan] (PAR).

Procel's actions have resulted in savings of 23 terawatt hours (TWh), which is equivalent to 4.87% of Brazil's total energy consumption (Procel, 2018a).

Law 10 295/2001 ("Lei de Eficiência Energética [Energy Efficiency Law]") established the Comitê Gestor de Indicadores de Eficiência Energética [Energy Efficiency Indicators Management Committee] (CGIEE). One of the committee's responsibilities is to develop programmes promoting energy efficiency targets for equipment.

[3] http://www2.inmetro.gov.br/pbe/pdf/folder_pbe.pdf

ANEEL's Programa de Eficiência Energética [Energy Efficiency Programme] (PEE) was created in 2000, through Law 9 991, and is an important source of financing for energy efficiency projects.

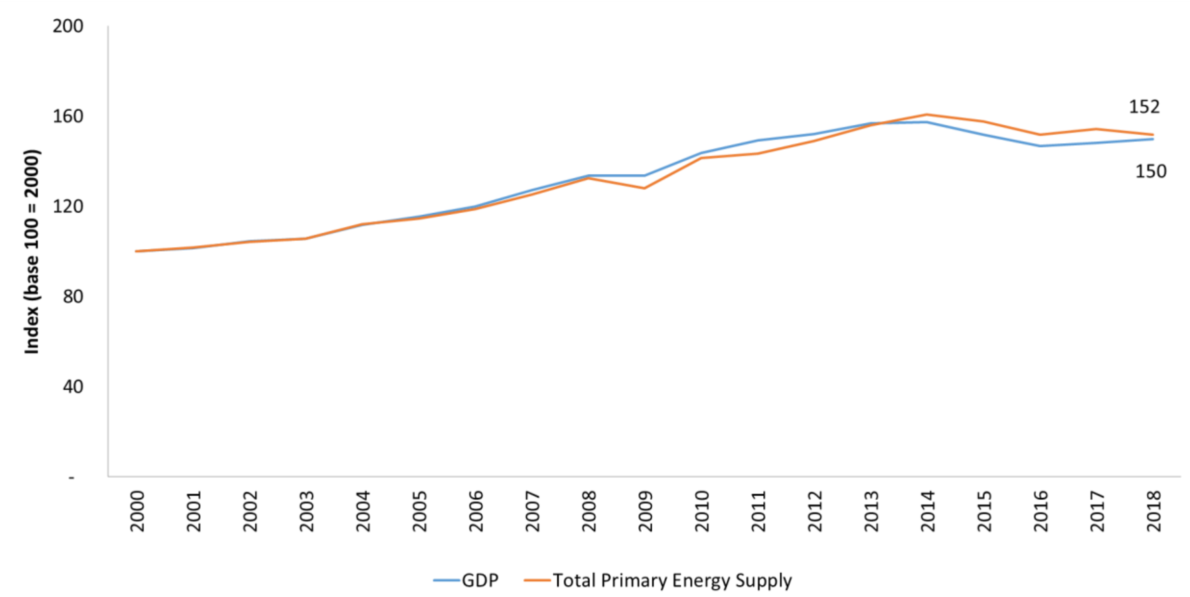
2. Economic and energy overview

2.1 Total primary energy supply and final consumption

Energy consumption is related to the level of economic activity in the country. Therefore, a historical analysis of economic developments is important for understanding changes in consumption.

From 2001 to 2018, Gross Domestic Product (GDP) [4] increased at an average rate of 2.3% per year, amounting to growth of 50% over the period. Domestic energy supply grew at the same pace as the economy (2.3% per year), showing a strong correlation with GDP, as shown in Figure 1.

Figure 1 – GDP and total primary energy supply 2000-18



Source: EPE (2019a)

Looking at shorter time periods, it can be seen that between 2001 and 2009, GDP grew at a higher average rate than that of the domestic energy supply, growing at a rate of 3.3% and 2.8% respectively. In this period, one of the main events that occurred was a sharp reduction in electricity consumption induced by rationing in 2001. That same year, the Lei de Eficiência Energética [Energy Efficiency Law] (No. 10 295/2001) was published, paving the way for the definition of minimum levels of energy efficiency for equipment. The first kind of equipment to be regulated, in 2002, were electric motors, for which a target programme was approved at

[4] All amounts presented in this document are in Reals (BRL), at constant 2010 values.

the end of 2005. This period was further marked by a significant resumption of activity in the sugar-ethanol sector in Brazil, driven by the introduction of flex-fuel cars in 2003.

In 2009, the global financial crisis had only a modest impact on GDP (-0.1%) but significantly affected domestic industry, especially metallurgy (which covers energy-intensive products such as steel, ferroalloys and aluminium) and mining. As a result, total primary energy supply fell by 3.5% that year.

In 2010-13, an increase in the average income of the population and a reduction in inequality due to the social policies implemented in previous years, coupled with improvements in access to credit, contributed to an uptick in the increase in ownership and use of household electrical appliances in Brazil, along with an increase in the population's motorisation rate. As a result, energy consumption grew at an average annual rate of 5.1% over this period, while GDP grew at 4.1% per year. Over the period, various appliances came to be regulated under the Energy Efficiency Law, with efficiency-target programmes approved in 2010 and 2011.

In the past five years (2014-18), there has been a decoupling of the total primary energy supply curve in relation to GDP. This movement indicates an increase in energy intensity resulting from the increased preponderance of energy-intensive activities in the industrial sector, combined with a period of economic slowdown.

Table 1 shows the development of the energy mix between 2000 and 2018. For non-renewable sources of energy, natural gas was the standout category, significantly increasing its share of the energy mix from 5% in 2000 to 12% in 2018.

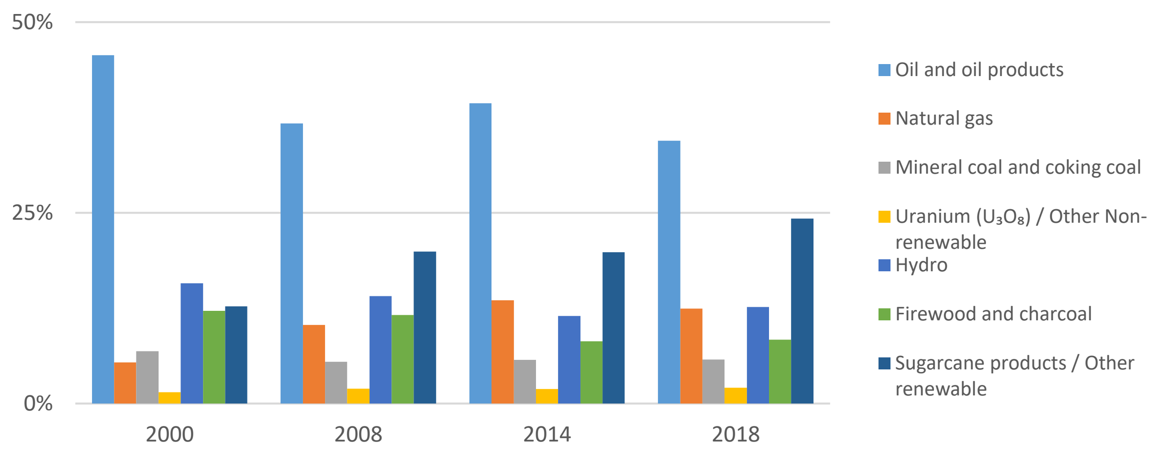
Table 1 – Total Primary Energy Supply

10^3 tonnes of oil equivalent (toe)	2000	2008	2014	2018	Δ% per year. (2018/2000)
NON-RENEWABLE ENERGY	**112 782**	**136 982**	**185 070**	**157 859**	**1.9%**
Oil and oil products	86 743	92 410	120 327	99 320	0.8%
Natural gas	10 256	25 934	41 373	35 905	7.2%
Coal and coke	12 999	13 769	17 521	16 632	1.4%
Uranium (U_3O_8)	1 806	3 709	4 036	4 174	4.8%
Other non-renewables	978	1 159	1 814	1 828	3.5%
RENEWABLE ENERGY	**77 261**	**114 776**	**120 565**	**130 533**	**3.0%**
Hydroelectric	29 980	35 412	35 019	36 460	1.1%
Firewood and charcoal	23 060	29 227	24 936	24 146	0.3%
Sugarcane products	20 761	42 872	48 170	50 090	5.0%
Other renewables	3 460	7 265	12 441	19 837	10.2%
TOTAL	**190 043**	**251 758**	**305 635**	**288 392**	**2.3%**

Source: EPE (2019a)

Renewable sources, on the other hand, developed at a faster pace, due to the expansion of the sugar-ethanol sector, and the strong expansion of other renewable sources, notably wind power and black liquor. From a negligible share in 2000, wind energy grew to the point that it contributed 4.2 million toe to the energy mix in 2018, while black liquor, which is directly associated with the paper and pulp industry, contributed another 9.6 million toe in 2018. Figure 2 illustrates how the mix of energy sources has evolved.

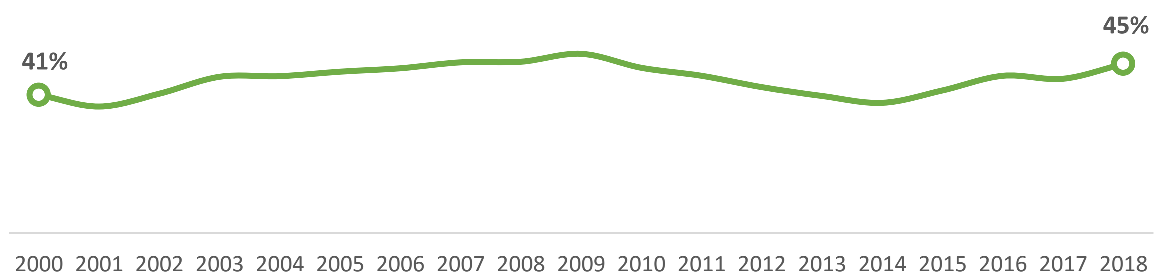
Figure 2 – Energy mix by source



Source: EPE (2019a)

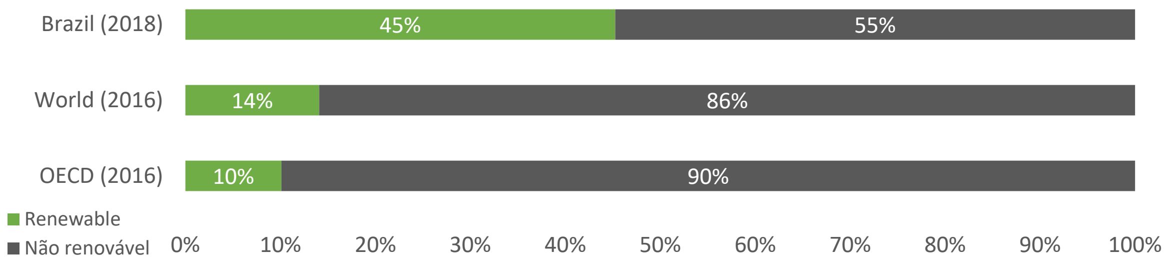
Over the past 18 years, the share of renewables in the Brazilian energy mix has remained stable, with values above 40%, as seen in Figure 3. This in itself presents a major challenge for Brazil, which has one of the highest percentages of renewable energy in the world. Figure 4 compares the renewability of the Brazilian energy mix, both with the world as a whole, and with OECD countries.

Figure 3 – Share of renewable sources



Source: EPE (2019a)

Figure 4 – International comparison of the proportion of renewable resources in the overall energy mix

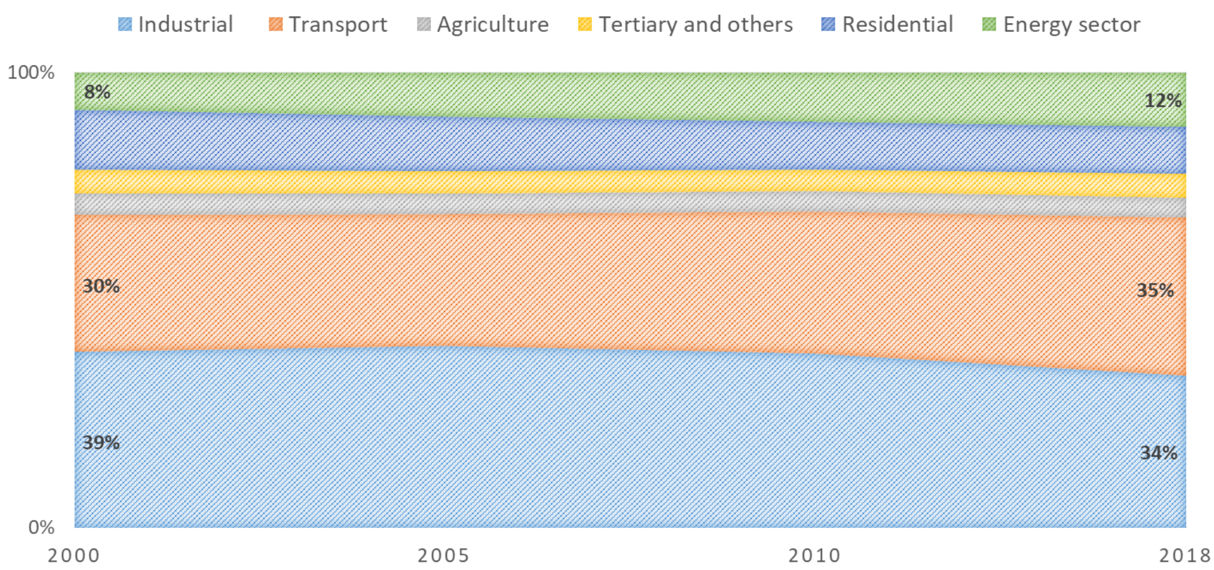


Source: EPE (2019a)

Figure 5 shows the sector-by-sector share of final energy consumption[5]. The main movement observed in this period was the decline of industry's share alongside an increase in that of the transport and energy sectors. In the case of industry, production activities in cement and metallurgy influenced the overall performance of the sector. Aside from a gradual reduction in the clinker/cement ratio from 73% in 2000 to 65% in 2018, the cement industry saw an average annual growth rate of 0.9% in clinker production, which is energy-intensive. As for metallurgy, this sector expanded its physical output at an average annual rate of 1.2%. In other words, the combined cluster of cement and metallurgy, which consumes more than 30% of all the energy used in industry, grew at a slower pace than the transport sector, which saw its value-added (VA) evolve at an average annual rate of 2.0% over the same period.

[5] Non-energy final consumption was excluded from the analysis because it consists of a transformation for non-energy use (e.g. naphtha for production of basic petrochemicals), and is not covered by the scope of the study.

Figure 5 – Final energy consumption by sector



Source: EPE (2019a)

As for the energy sector, energy consumption expanded by 13.2 million toe in 2018 as compared with the year 2000, driven by the production of oil and ethanol, which grew at annual rates of 4.2% and 6.4% respectively over the period. Table 2 shows how the final consumption of energy has developed by sector.

Table 2 – Final energy consumption by sector

10^3 toe	2000	2018	∆% per year. (2018/2000)
Energy Sector	12 847	26 010	4.0%
Residential Sector	20 688	25 012	1.1%
Commercial/Public Sectors	8 210	12 480	2.4%
Agricultural Sector	7 322	10 426	2.0%
Transport Sector	47 385	84 348	3.3%
Industrial Sector	60 646	80 948	1.6%
TOTAL	157 098	239 224	2.4%

Source: EPE (2019a).

2.2 Energy intensity

Energy intensity is the ratio between the final amount of energy supplied and/or consumed, and GDP. A lower level of energy intensity for the overall economy indicates a higher degree of efficiency in the "conversion" of energy into wealth.

This efficiency indicator for the economy can be calculated in two ways: (i) from the perspective of the Total Primary Energy Supply (TPES), identified as Primary Intensity, and (ii) from the perspective of the final consumption of energy (including consumption in the energy sector), which is denoted as Final Intensity. The calculation formulas for each are as follows:

(i) $$\frac{Total\ Primary\ Energy\ Supply\ (thousand\ toe)}{GDP\ (thousand\ USD[2010])}$$

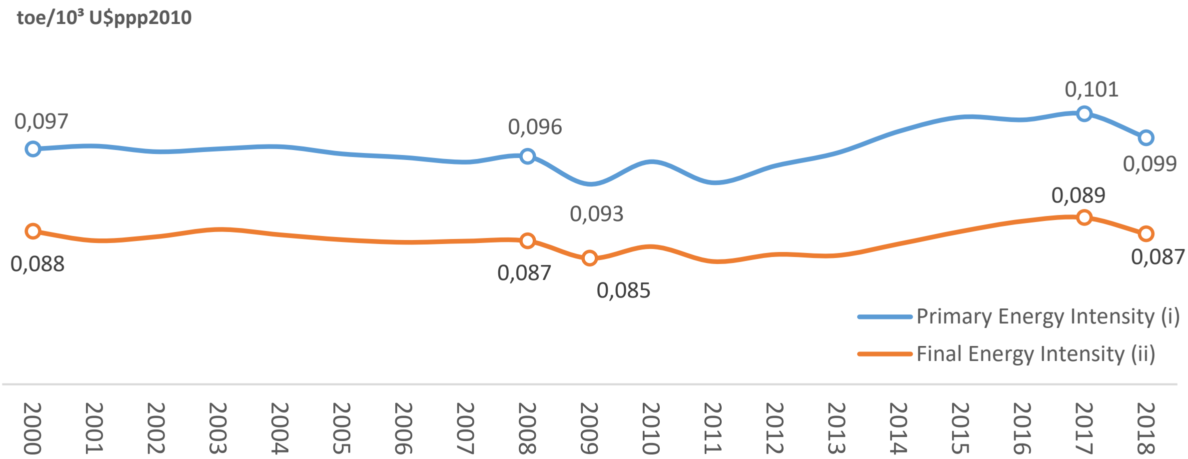
(ii) $$\frac{Final\ Consumption\ of\ Energy\ (thousand\ toe)}{GDP\ (thousand\ USD[2010])}$$

Primary intensity, as calculated using IES methodology, takes into account all of the energy that is available in the country for consumption and transformation, and includes losses in transformation, distribution and storage. For this reason, it in effect incorporates all of Brazil's energy demand. On the other hand, it is important to analyse the performance of transformation centres in order to see how efficiency gains work out over a given period. It is important to note that the reduction of total losses in these centres may occur seasonally, according to the degree to which the hydro supply increases, so this does not necessarily mean there has been a structural gain in efficiency.

Figure 6 illustrates the development of energy intensity based on domestic supply and final consumption in Brazil between 2000 and 2018.

In 2000-08, energy intensity calculated on the basis of the IES remained stable at around 0.097 toe/10^3 US dollars (USD) at purchasing power parity (PPP) [2010]. Similarly, the one calculated on the basis of final consumption stabilised at values close to 0.087 toe/10^3 USD PPP [2010].

Figure 6 – Development of energy intensity in Brazil



Source: EPE (2019a)

In 2009, the aforementioned effects of the international crisis on industry contributed to a reduction in primary energy intensity to 0.093 toe/10^3 USD PPP [2010]. In that year in particular, it was possible to observe the shutdown of more inefficient (less competitive) units with higher energy intensities. Between 2010 and 2013, the primary and final intensities grew at rates of 1.0% and 0.1% per year respectively, reflecting growth in IES that outpaced growth in GDP.

Between 2014 and 2018, primary energy intensity grew by 0.4% per year, even with the economy in recession (an average contraction of -0.9% per year). In the same period, final energy intensity grew by 0.6% per year. This upward trend in energy intensity may be associated with the growth in production of low value-added, energy-intensive items aggregated together in the production schedule, as compared to other manufactured products.

2.3 Overall energy efficiency in Brazil

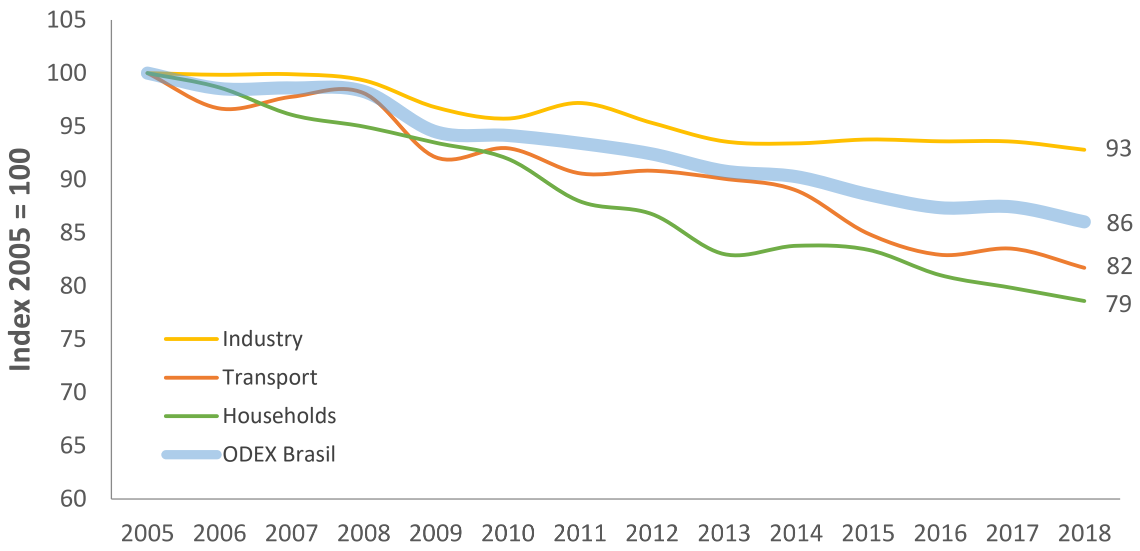
The ODEX indicator is an energy conservation index that looks at changes in consumption indicators, weighted against the share of a given element in overall consumption.

The use of ODEX decreases the influence of the structure effect, that is, a greater share of a more energy-intensive sector does not influence the indicator.

In this Technical Note, 2005 was set as the base year (100), encompassing the industrial, residential, transport, energy, services and agriculture sectors.

Figure 7 shows ODEX results for the Brazilian economy. In the period, all sectors that were analysed showed efficiency gains, with the largest gains occurring in the residential and transport sectors.

Figure 7 – ODEX Brazil



Source: compiled by EPE.

The ODEX calculated in 2018 shows that the country became 14% more energy efficient between 2005 and 2018.

3. INDUSTRY

This chapter will look at the industrial sector, dividing it in line with the Balanço Energético Nacional [National Energy Balance] (BEN) concept into industrial and energy sectors.

3.1 Industrial sector

3.1.1 Overview

The industrial sector[6] consumes approximately a third of total final energy consumption to meeting the needs of its productive processes. Until 2017 it was the sector with the highest level of consumption. However, as industrial economic activity declined between 2014 and 2017, and as sugar production fell in 2018, it was surpassed by the transport sector.

Table 3 shows that industry's share began to decline following 2010, the moment at which the impact of the global economic recession made itself felt. In final energy consumption, the sector grew by 33% between 2000 and 2018.

Table 3 – Final energy consumption in the industrial sector

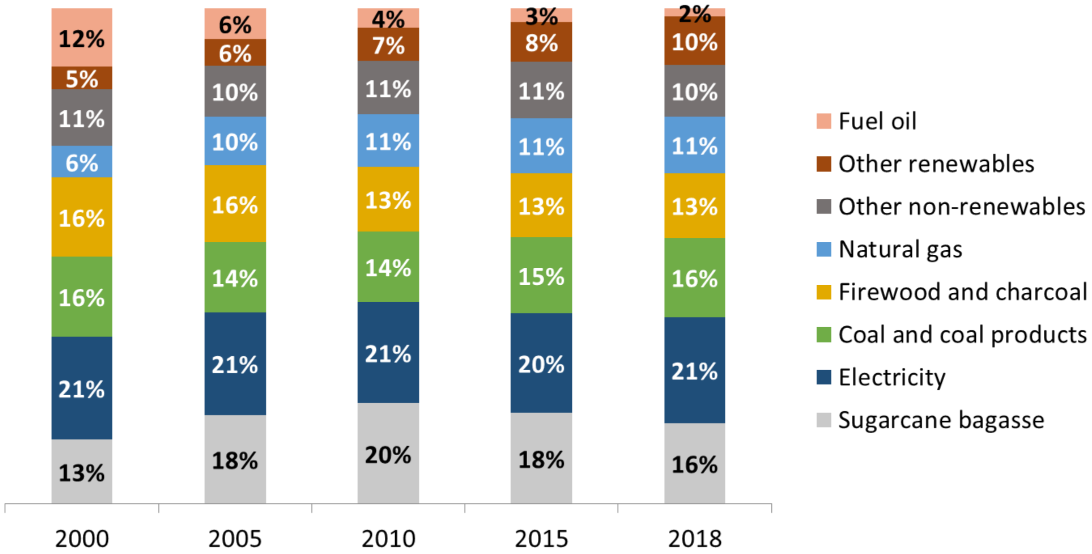
Industrial Sector	2000	2005	2010	2015	2018
Final consumption of the sector [10^3 toe]	60 646	72 806	85 564	84 559	80 948
Share of final energy consumption	35.4%	37.2%	35.5%	32.5%	31.7%

Source: EPE (2019a)

In the year 2000, industry's main energy sources were, in order of importance, electricity, coal and its products, firewood and charcoal, sugarcane bagasse, and fuel oil. By 2018, sugarcane bagasse stood in joint second place in the table of most-consumed energy sources, along with coal and its products, and second only to electricity (Figure 8).

[6] In order to ensure compatibility with the National Energy Balance, this document considers as "Industrial Sector" the sectors of industry (as defined by IBGE in the National Accounts) without including the energy sector. Namely, this means excluding the oil and natural gas extraction and coal-mining industries, the oil and gas refining and biofuels manufacturing industry, and the electricity and gas production and distribution industry. In 2016, this corresponded to 79.3% of total industrial added value.

Figure 8 – Industrial sector: final energy consumption by source (%)



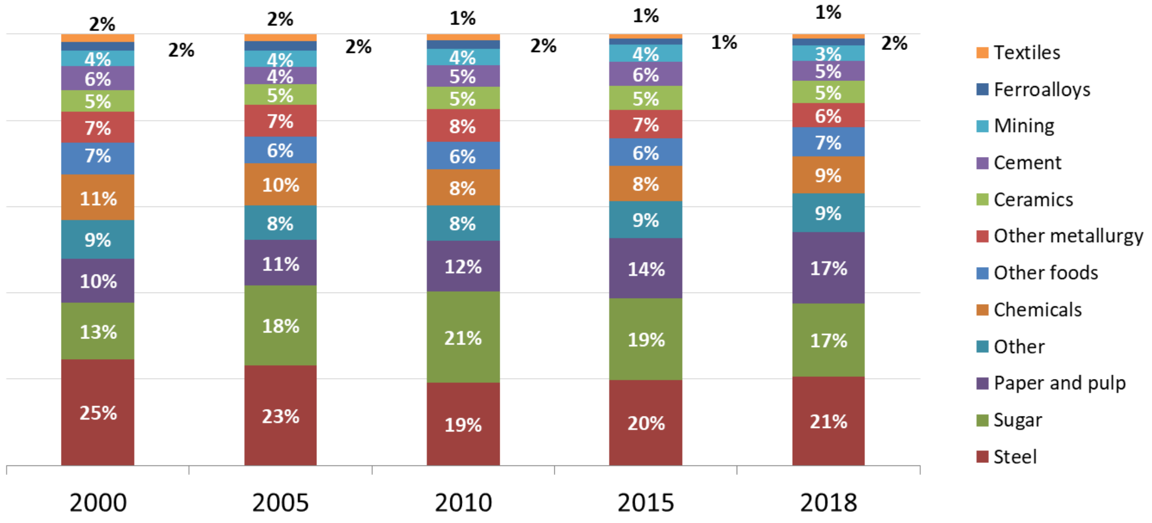
Note: other renewables are composed mainly of black liquor.

Source: EPE (2019a)

The increase in the share of sugarcane bagasse and other renewables in industrial consumption is related to the increase in the shares of the sugar and pulp sectors. A reduction can be observed in the shares of fuel oil, which has gradually been displaced by petroleum coke (notably in cement production), and in natural gas and other renewables (in paper and pulp production).

Industry's largest consumers of energy (Figure 9) are the steel, sugar, and paper and pulp sectors, which together accounted for 48% of the total in 2000 and 55% 2018. Over this period, there was a reduction in the steel industry's share (-4%) and in that of chemicals (-2%), while the share of the paper and pulp (+7%), and sugar (+4%) sectors increased.

Figure 9 – Sectorial shares of final energy consumption in industry



Source: EPE (2019a)

Note: The food and drink sector was broken down into sugar and other foodstuffs, while the base metals sector was broken down into steel, ferroalloys and other metallurgy (which includes aluminium).

3.1.2 Current policies

The main policies and mechanisms adopted to harness the potential of energy efficiency in industry have been: (i) minimum efficiency levels for motors and distribution transformers; (ii) the labelling of motors, pumps and distribution transformers; (iii) ANEEL's Programa de Eficiência Energética [Energy Efficiency Programme] (PEE/ANEEL); and (iv) Procel Indústria [Procel Industry].

Three-phase electric motors have been subject to regulations setting out minimum indices since 2002 (decree 4508/2002). In 2017, the review of the premium category (level IE3) was approved, and the scope of regulation was widened for motors up to 500 horsepower (Portaria Interministerial [Inter-ministerial Ordinance] No. 1/2017). These new indices are expected to generate an accumulated saving of 11.2 TWh between 2019 and 2030 (Procel, 2018a).

As for PEE/ANEEL, 7.6 million reals (BRL) have been invested in six industrial projects since 2015, with estimated efficiency gains of around 133 gigawatt hours (GWh) a year (ANEEL, 2019a).

Within the Procel Indústria framework, and via the new regime of governance instituted by Law No. 13 280 in 2016, the programme has expanded its activities alongside the industrial sector and micro and small enterprises, through the Plano de Aplicação de Recursos [Resource Application Plan] (PAR), which has made it possible to support important programmes. Examples include the Programa Aliança [Alliance Programme], a partnership with the CNI and SENAI/DN, which already managed to achieve savings of 42 GWh in 2018. It has done this thanks to energy efficiency measures implemented in four energy-intensive industries, as well as the expansion of the Programa Brasil Mais Produtivo [More Productive Brazil Programme], co-ordinated by the Ministry of the Economy, to create a new energy efficiency component. This should make it possible to provide services to 300 small and medium-sized industrial enterprises, helping them to adopt energy efficiency practices in their production processes. As for new measures, there are plans to invest in projects and programmes to encourage the industrial sector to adopt Energy Management Systems (EMS). Table 4 presents the EMS projects foreseen in the Plano de Aplicação de Recursos [Resource Application Plan] (PAR) 2018:

Table 4 – Projects related to EMS contained within Procel's Resource Application Plan 2018

Energy Efficiency (EE) Projects	Budget [million BRL]	Companies targetted	Business size
More Productive Brazil EE	6.3	300	micro and small
Aliança 2.0 [Alliance 2.0]	10.0	24	large
EE Digital	2.5	8	large
EE in compressed air systems	6.5	170	small/medium-sized/large
Development of methodology and performance of energy diagnostics in associated thermal and drive systems	1.5	10	small/medium-sized/large
Total	***26.8***	***512***	

Source: Compiled by EPE, using Procel (2018b)

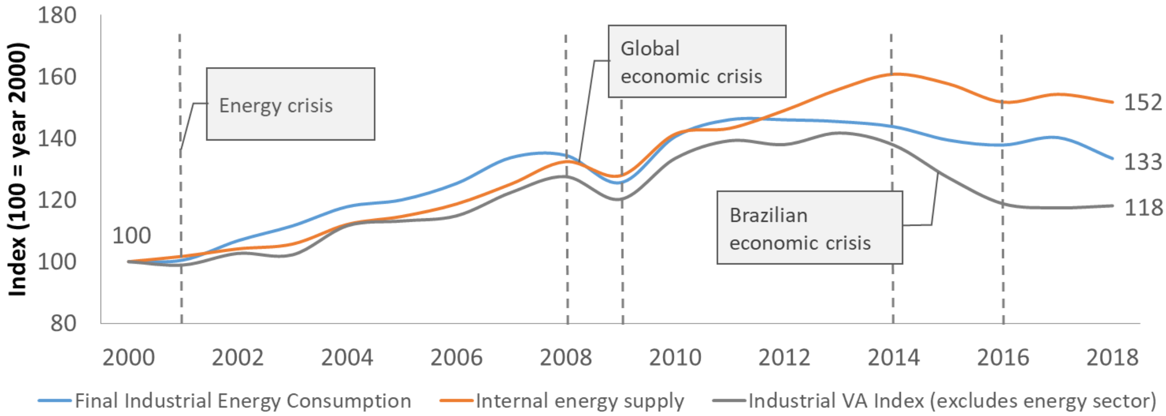
The implementation of systems of this kind is seen as one of the key measures for encouraging the spread of energy efficiency in industry. Many of the measures identified in energy reviews require little or no investment, and result in reductions in business operating costs and energy consumption and greenhouse gas (GHG) emissions, and also in productivity gains.

3.1.3 Analysis of sectorial indicators

Figure 10 shows the development of energy consumption both at the industrial level and in total, and also of industrial[7] value-added (VA) over the time horizon mentioned. Variations in energy intensity are due to changes in the relationship between energy consumption and the value-added of the sector.

A trend of growth can be observed over the period, interrupted only occasionally in the years of the rationing crisis (2001) and the international financial crisis (2008-09). From 2014, however, the outbreak of a national crisis began to reverse this trend.

Figure 10 – Energy consumption and value-added for industry and Brazil as a whole



Source: compiled by EPE, using EPE (2019a) and IBGE (2019a)

Between 2001 and 2005, industrial energy intensity grew at a rate of 1.2% per year, due to increasing consumption in more energy-intensive sectors such as sugar, chemicals, ferroalloys and steel. This was driven, in the case of the first of these sectors, by the increase in external demand, and in the other three by the expansion of the construction and automotive sectors.

The period that ran from 2006 to 2010 was marked by strong economic growth, with industrial GDP and industry's final energy consumption both growing at a rate of 3.3% a year. As a result, the energy-intensity indicator remained stable (-0.1% per year). The global financial crisis of 2008-09 caused recession in the major world economies, with a climate of generalised instability and a reduction in external demand for Brazilian products. As a result, there was a negative impact on the basic metallurgy sector, and the paralysis and even the decommissioning of less efficient industrial units, which in turn reduced energy consumption.

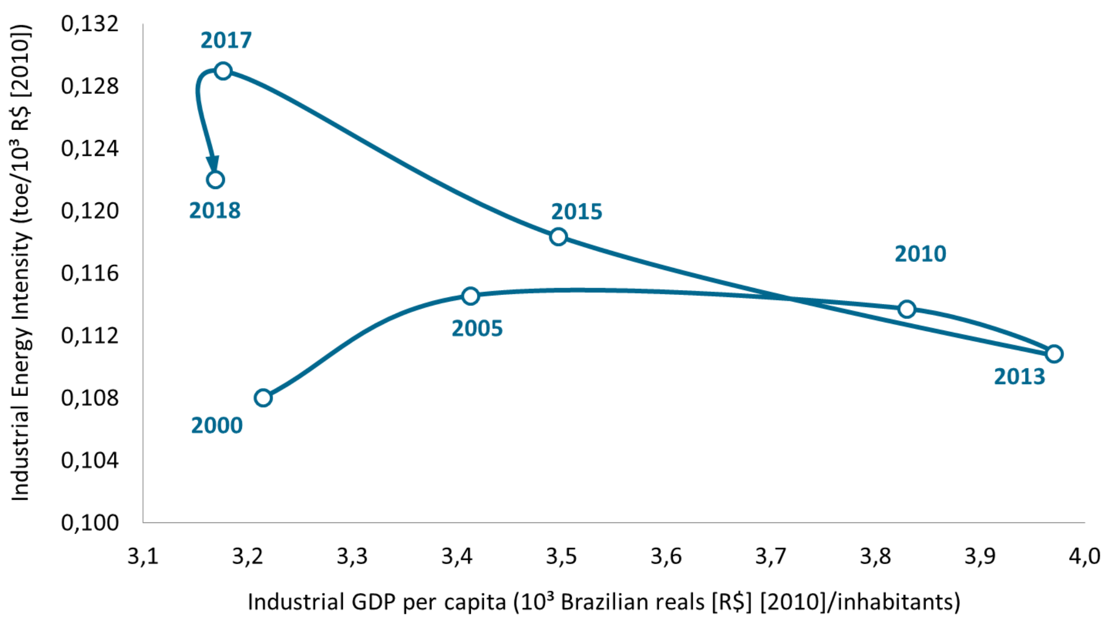
[7] At 2010 fixed prices, excluding the parts of the energy sector mentioned above.

This adverse scenario did not last long, however, and in 2010 industrial GDP grew by 10.9% while final energy consumption increased by 12.3%.

In 2014, the outbreak of a national economic crisis interrupted the growth trajectory of industrial GDP that had been observed since 2010. Combined with a weaker world economy, a degraded domestic scenario that featured a sharp fall in consumption as well as increases in unemployment, inflation and interest rates, reduced the domestic production of industrial goods in a manner that was almost universal, resulting in a decline in industrial GDP per capita of 5.4% a year between 2014 and 2017. During this period there was an increase in energy intensity of 3.9% per year. This came about because of structural changes in industry, with a higher share of energy-intensive activities, and an increase in the degree of idleness in the manufacturing industry as a whole, which began operating at non-optimal levels.

In 2018, industrial GDP per capita remained relatively stable. Intensity decreased by 5.4%, mainly due to the reduction of sugar production, which is energy intensive, and also due to efficiency gains in several sectors.

Figure 11 – Path of energy intensity and GDP per capita in industry



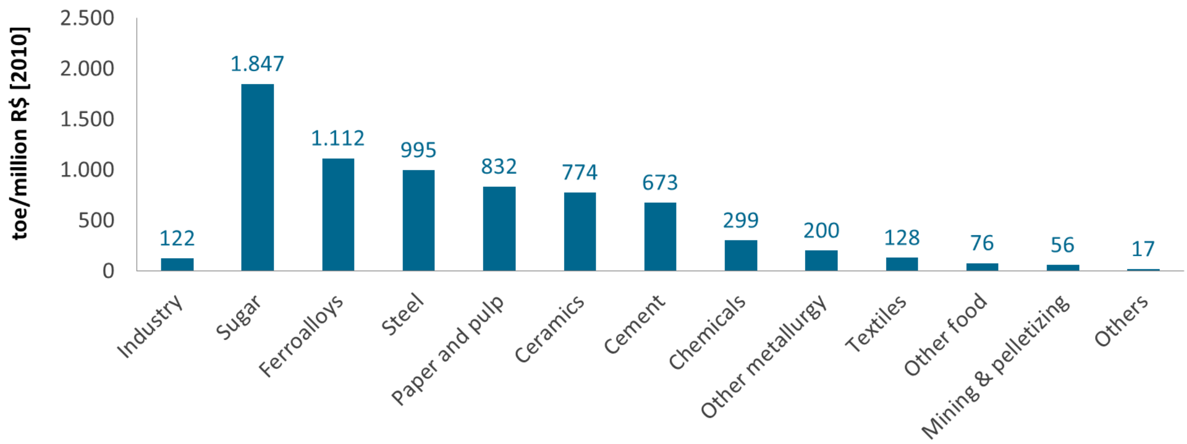
Source: compiled by EPE, using (2019a) and IBGE (2019a)

It is important to note that analysing changes in energy intensity in an aggregate manner does not take into account the relevant developments that occurred in individual industrial sectors.

3.1.3.1 Intensity by Sub-Sector

The eleven industrial sectors highlighted in Figure 12 account for over 90% of industry's final energy consumption and only 30% of added value. The energy-intensity indicator for sectors of industry in the year 2018 can be seen in Figure 12. By looking at this data, one can appreciate that the sugar sector is the most energy intensive, followed by ferroalloys, steel, paper and pulp, ceramics, cement, chemicals and non-ferrous metals. The other sectors have relatively low energy intensity. Therefore, changes in the overall structure of the industrial economy, and variations in the share that each sector contributes, have an impact on overall levels of energy intensity.

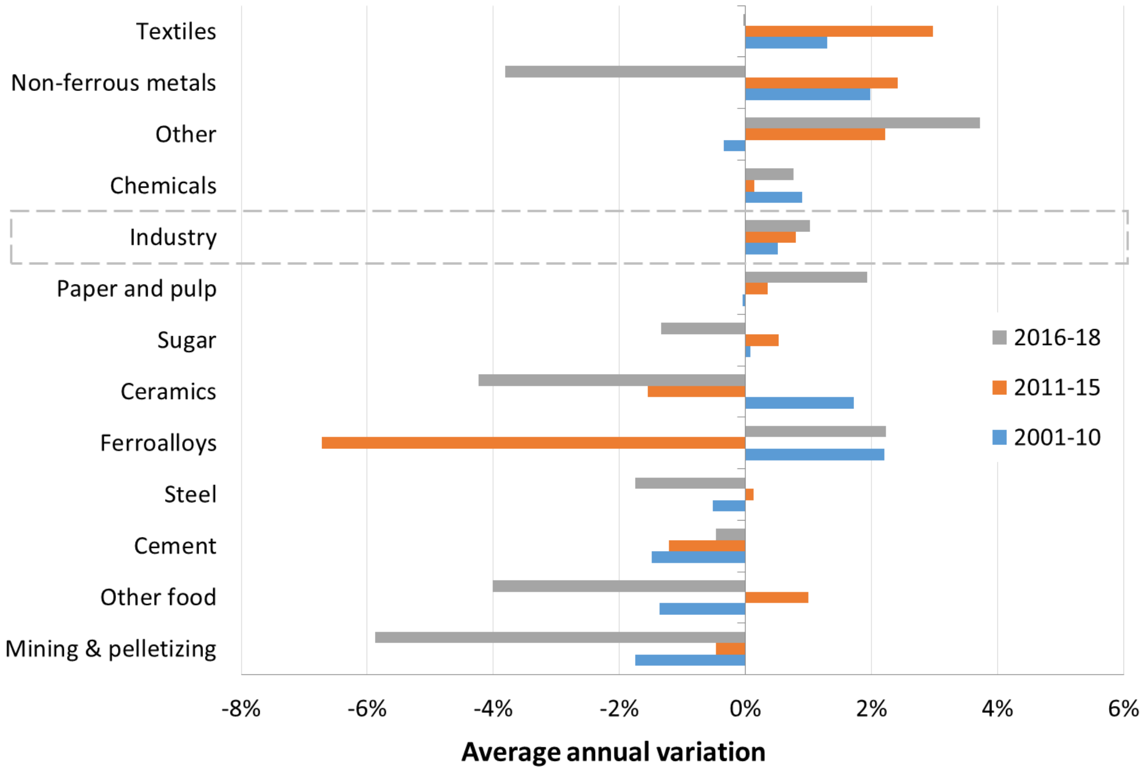
Figure 12 – Energy intensity of industrial sectors (2018)



Source: compiled by EPE, using EPE (2019a) and IBGE (2019a)

Figure 13 shows the change in energy intensity between 2001 and 2018 for the industrial sectors that are most relevant in terms of final energy consumption. With regard to the methodology that is used, it is worth noting that relative prices are fixed in the base year of 2010, and that intensity statistics are therefore not influenced by inflation.

Figure 13 – Changes in energy intensity in energy-intensive sectors



Source: compiled by EPE, using EPE (2019a) and IBGE (2019a)

Mining and pelletizing was the sector that registered the biggest reduction in energy intensity. However, part of this movement is due to the reduced share of pelletizing, while iron ore production, which is more energy-intensive, actually increased. The sector entitled "other metallurgy" also experienced the influence of sub-structural changes - aluminium production, which is electricity-intensive, fell in 2015-18, reducing the intensity of the sector as a whole.

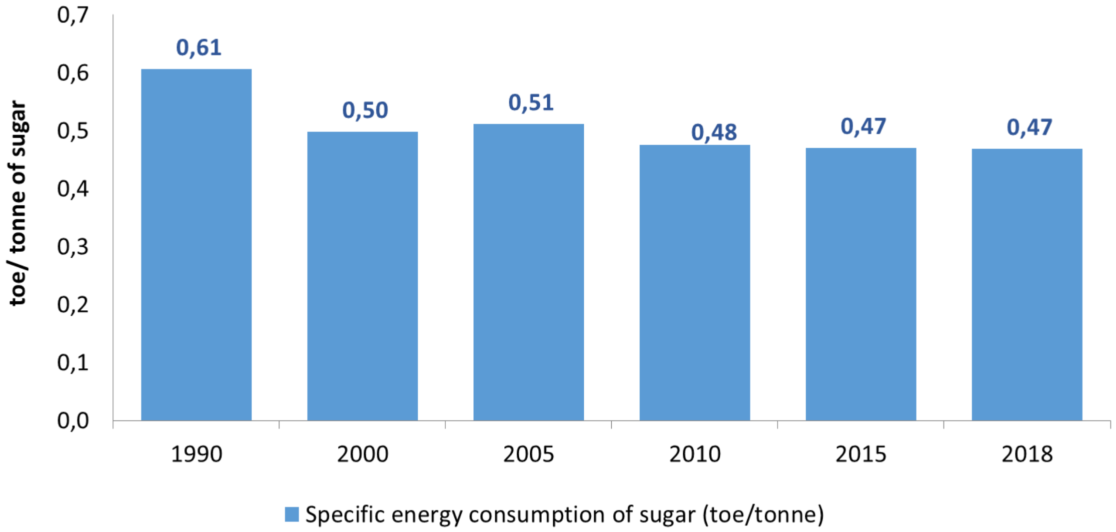
Wherever they are available, it is necessary to analyse specific energy-consumption indicators, as measured by the ratio of final energy consumption to physical output. Hereinafter, specific-consumption indicators will be presented for selected sectors.

3.1.3.2 Specific Consumption by Sub-sector

Sugar

The specific energy consumption of sugar production has been falling at rates varying from 1.9% per year in the 1990s, to 0.5% per year in the 2000s, and 0.2% per year between 2011 and 2018 - as shown in Figure 14.

Figure 14 – Specific energy consumption in the sugar industry



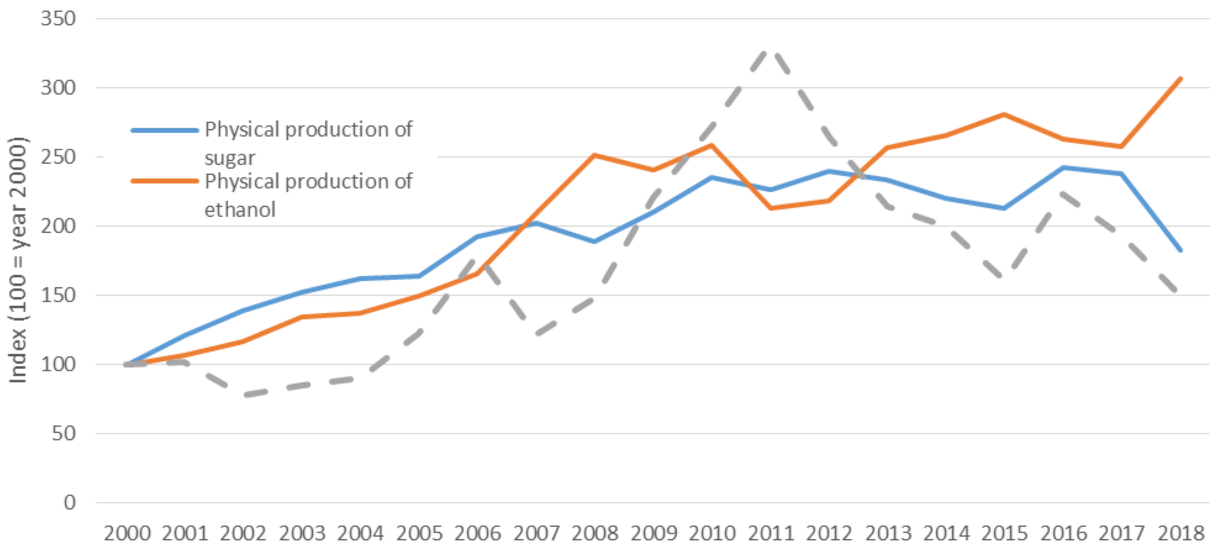
Source: compiled by EPE, using EPE (2019a) and Conab (2019)

The sector uses sugarcane bagasse in co-generation systems for the production of steam and electricity. In 2018, the share of bagasse represented 96% of the energy mix for the sector, while the share of electricity (largely self-produced from sugarcane bagasse) made up the remaining 4%.

In the 2000s, investments were made in new plants and in the modernisation of existing industrial facilities and boilers[8], supported by incentives from federal and state governments, and resulting in gains in energy efficiency. During this period, sugar production increased significantly, by 8.9% a year, as did international sugar prices, which rose by 10.5% per year, as shown in Figure 15.

[8] High-pressure boilers need less fuel to meet the energy demand of the sugar industry, and it is possible to export electricity to the grid.

Figure 15 – Index of changes in the sugar price and the physical production of sugar and etanol



Source: compiled by EPE, using EPE (2019a), Macrotrends (2019), Conab (2019)

As of 2011, the price of sugar began to fall consistently, causing a crisis in the sugar-ethanol sector. As a consequence, less competitive factories were closed, which contributed to a marginal reduction in the sector's specific energy consumption.

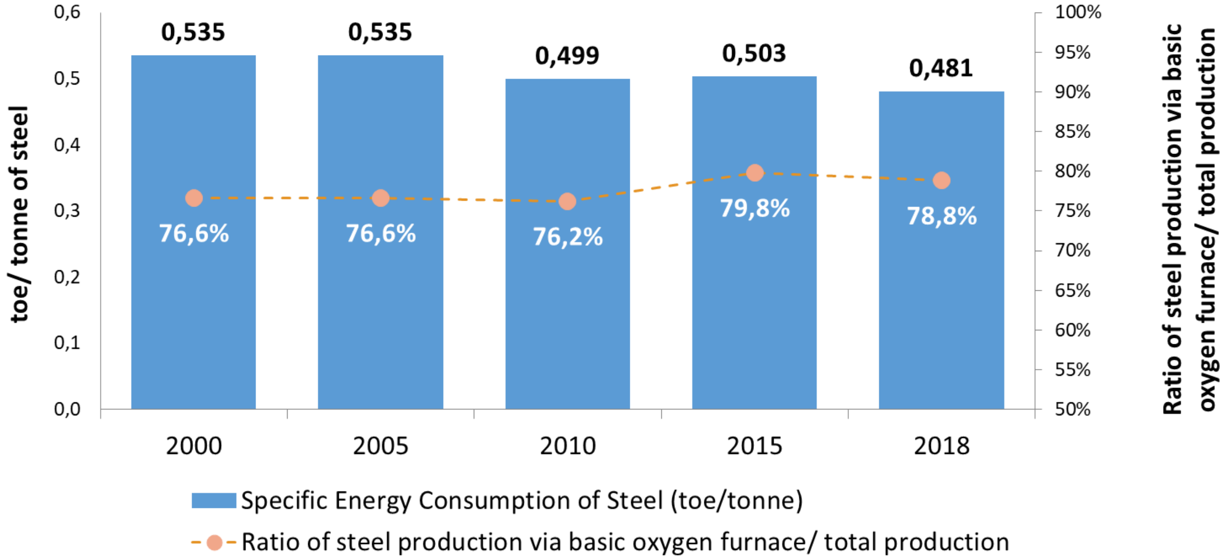
In 2018, sugar production fell by 23%, while ethanol production increased by 19%. Some sugar and ethanol plants have the flexibility to produce more or less sugar and ethanol, and this decision is driven by factors such as the price of sugar and gasoline.

Changes in the level of production and, consequently, in sugar's share of value-added in the industrial sector as a whole, have an impact on the overall level of industrial energy intensity.

Steel Industry

The specific energy consumption of the steel industry fell by 0.6% per year between 2011 and 2018, as can be seen in Figure 16. This is due, in part, to efficiency gains in industrial processes that have resulted from investments in the modernisation of old plants, from new units with high technological standards (more efficient) coming into operation, and the reduction or shutdown of production in less efficient plants as a result of the recent economic crisis in the country and the fall in international crude steel prices.

Figure 16 – Specific energy consumption in the steel industry



Source: compiled by EPE, using EPE (2019a) and IABr (2019)

It is worth noting that this reduction in the steel industry's specific consumption occurred even as oxygen steelworks' share of total production increased from 76.6% in 2000 to 78.8% in 2018. Oxygen steelworks are more energy-intensive than electric ones.

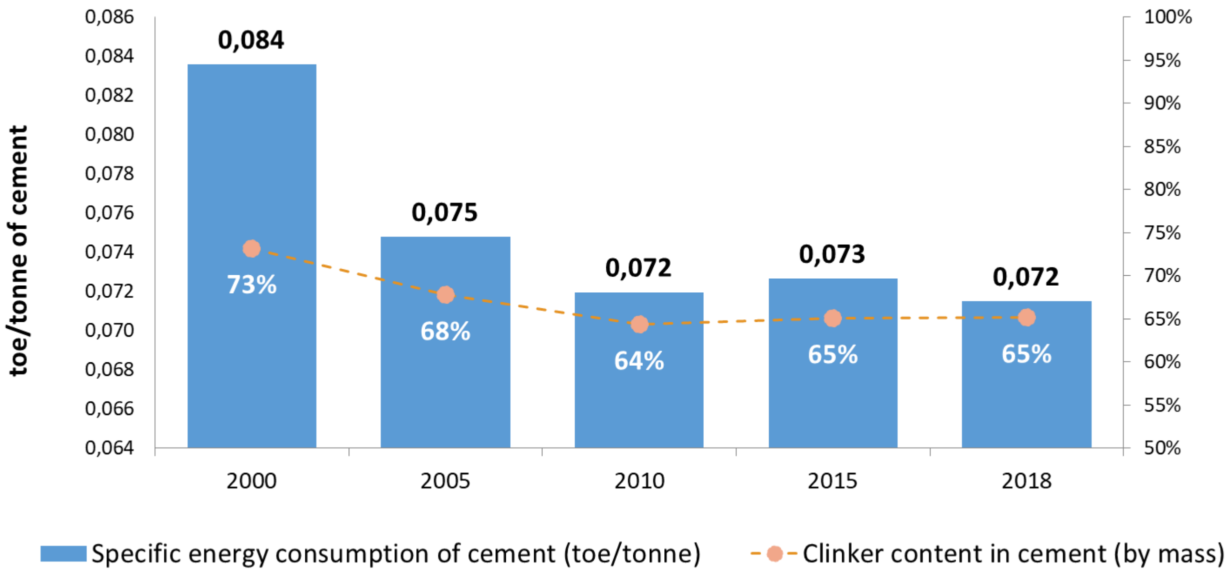
Regarding the energy mix of the steel industry, coke from mineral coal takes the largest share of final consumption, accounting for 44% in 2018, followed by charcoal and coal, which account for around 30%. Charcoal lost some of its overall share to coal, falling from 25% in 2000 to 16% in 2018.

<u>Cement</u>

As for cement production, its specific consumption fell by 0.9% a year between 2001 and 2018 Figure 17). This efficiency gain is largely related to the share of clinker in the composition of cement, which has been decreasing over time.

Clinker is a basic component of cement. Its production is energy-intensive and is the most demanding part of the process in terms of thermal energy. In the production of cement, by-products of other activities and alternative raw materials are added to clinker, such as slag from steel mills, ashes from thermoelectric plants, and limestone filler (SNIC, 2008). The use of additional materials reduces the amount of clinker used in cement production and, consequently, reduces energy consumption without necessarily altering the production level. Furthermore, the use of specific additional materials such as pozzolans can also reduce production costs and bring advantages such as increasing cement's resistance to water.

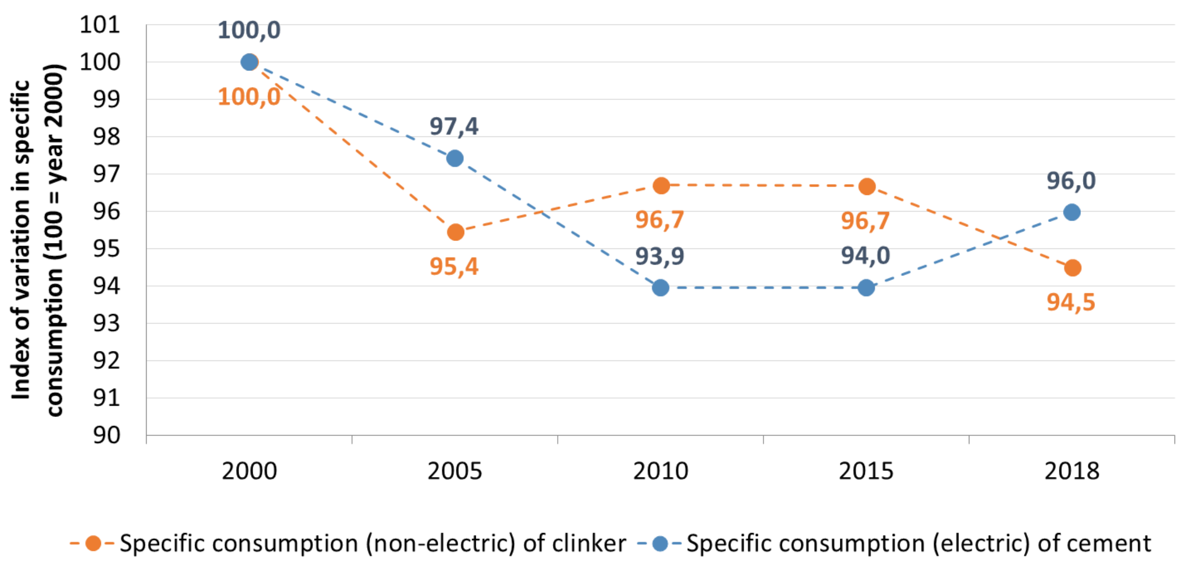
Figure 17 – Specific energy consumption in the cement industry



Source: compiled by EPE, using EPE (2019a)

Figure 18 makes possible a separate evaluation of the specific thermal and electric consumption from the production of clinker and cement. Most of the electricity consumption takes place in cement production (grinding), and most of the fuel is used in clinker production (furnace). It can be observed that specific clinker consumption fell by 5% over the whole period. It is worth highlighting that almost all production uses dry-process technology with pre-heaters and pre-calciners, which is the best technology available and has the lowest specific consumption.

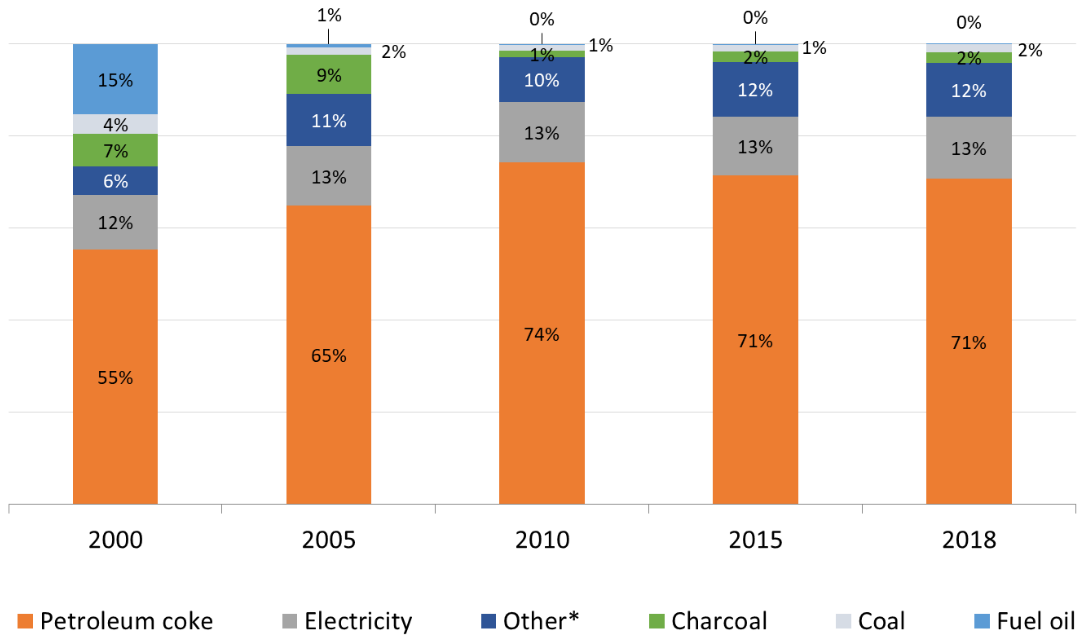
Figure 18 – Specific consumption in the cement industry - clinker and cement



Source: compiled by EPE, using EPE (2019a)

When it comes to cement, the continuous reduction in specific energy consumption between 2001 and 2010 is related to improvements made in the sector during this period, with investment in more efficient machines. Given the crisis that the country began to experience in mid-2014, the downturn in construction had a major impact on the cement industry, which saw a 25.7% drop in production between 2015 and 2018. As a result, the sector has operated with a high level of idleness in recent years, and this has contributed in turn to an increase in specific consumption, which continues to be 4% lower than the level of 2000.

Figure 19 – Cement production: final energy consumption by source



Source: EPE (2019a)

** Others include natural gas, firewood, diesel and co-processing products.*

The energy mix of the cement industry, which is illustrated in Figure 19, has undergone changes over time. The use of fuel oil fell close to zero in 2005, as a result of the cement industry's agreement with the Federal government in the 1980s to reduce demand for oil products.

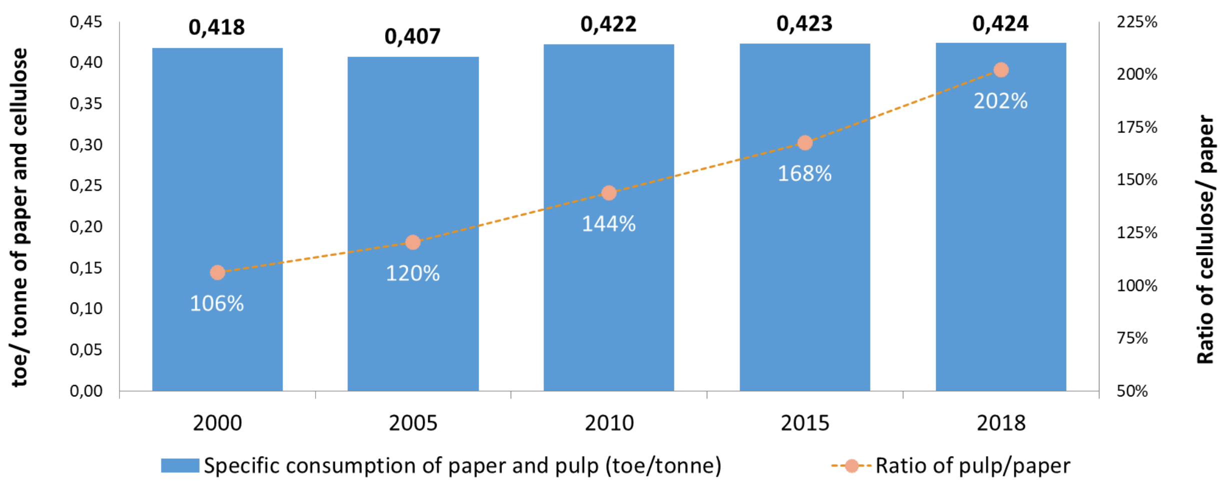
Petroleum coke is the main energy source, due to its low price and guaranteed supply. The co-processing of alternative sources - which are depicted in Figure 19 as part of the unspecified 'others' category - has grown. In 2018 it represented 9% of consumption. Co-processing has several environmental benefits, offering both an appropriate means of waste disposal and, when from renewable sources, reducing greenhouse gas (GHG) emissions.

Paper and pulp

Despite being irregular in the period under review, the specific energy consumption of this sector signalled a trend of growth (Figure 20). In 2000, specific consumption was 0.418 tonnes of oil equivalent per tonne (toe/t) of paper and pulp, reaching 0.424 toe/t in 2018 - an average growth rate of 0.1% per year.

One possible explanation for this is the ratio between pulp production and paper production, which has increased considerably over the past 26 years, from 92% in 1990 to 182% in 2016. The production of pulp is more energy-intensive than that of paper, above all due to the fuels that it uses, and it has been growing at a fast pace (5.1% per year, on average, between 2010 and 2018), driven by the strong positioning of the Brazilian product on the global market due to its high degree of competitiveness. Currently, Brazil is the world's largest exporter of pulp (FAO, 2017), and in 2016 the country exported almost 70% of the pulp it produced (Ibá, 2017). The same does not apply to paper production, which grew by 0.8% per year in the same period.

Figure 20 – Specific energy consumption in the paper and pulp industry



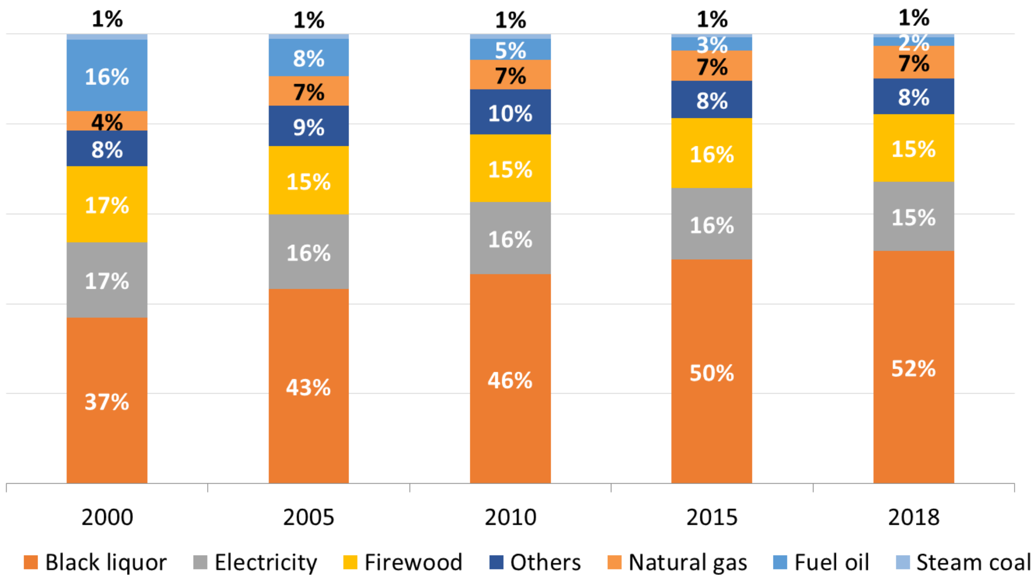
Source: Compiled by EPE, using EPE (2019a) and Ibá (2019)

Growth in the production of pulp increases the specific energy consumption of the paper and pulp sector, as well as that of industry as a whole. Although the indicators increased, there were also efficiency gains due to improvements in the production process over the years, and to new and more efficient pulp plants coming into operation.

Figure 21 shows the energy mix of the paper and pulp sector. In 2018, 86%[9] of this sector's energy demand was met with renewable energy, mainly black liquor, chips and wood waste. Production in (non-integrated) paper factories uses a less-renewable energy mix (as there are no renewable by-products of the process), and a greater proportion of electricity.

The greater share of pulp production relative to paper contributed to an increase in the share of black liquor in the sector-wide mix. Furthermore, some of the fuel oil used in the production processes was replaced by natural gas and wood chips.

Figure 21 – Paper and pulp production: final energy consumption by source



Source: EPE (2019a)

In this manner, an analysis of energy efficiency across industry sectors over recent years - both in terms of energy intensity and specific consumption - allows us to observe movements in both directions. Some sectors managed to reduce their specific consumption and energy intensity, as was the case with cement and steel. Others, such as paper and pulp, chemicals, and other metallurgy, increased in these respects. The sugar sector showed conflicting results when energy intensity and specific consumption were analysed, with an increase in the former and a reduction in the latter, even when taking into account the whole time-horizon between 2000 and 2018.

[9] It was assumed that the electricity consumed in pulp and paper production is 87% renewable, considering the mix of non-injected self-generation, and the electricity mix of the Brazilian Electric System in 2018.

3.1.3.3 Breakdown of Changes in Consumption

Industrial growth was different in each period, influenced as it was by changes in economic activity and in the share and intensity of each sector. Figure 22 provides a breakdown of the change in industrial energy consumption by activity effect, structure effect, and intensity effect, as per the LMDI I method (“logarithmic mean Divisia index method I”), with additive decomposition (Ang & Liu, 2001).

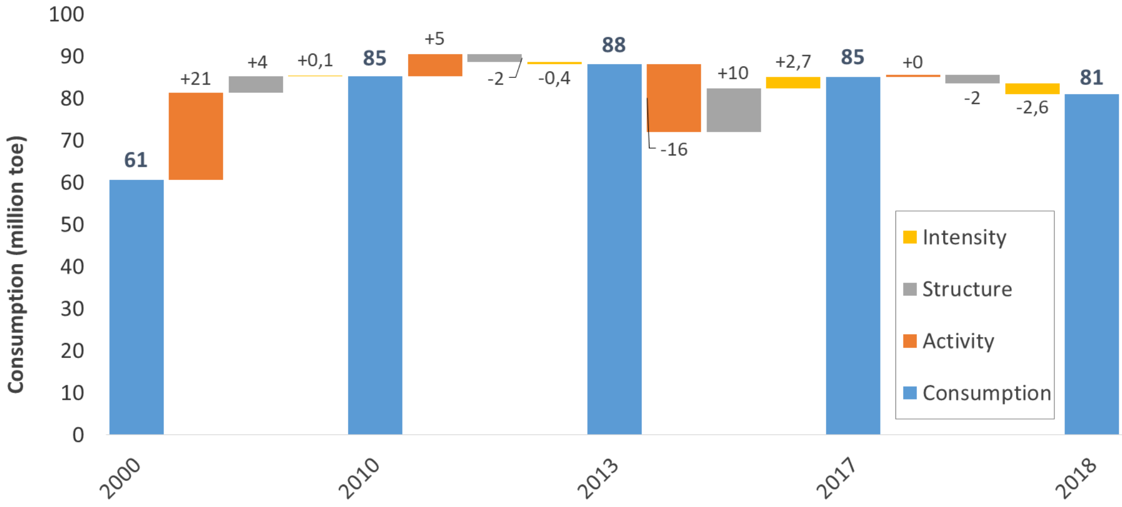
Between 2001 and 2010, industrial energy consumption increased by 3.5% per year, mainly due to the increase in industrial activity, and also due to the greater share of the sugar and paper and pulp industries, which are energy-intensive.

Between 2014 and 2016, consumption increased on average by 1.1% a year, influenced by growth in economic activity, but partially offset by structural changes, with a reduction in the share of sectors such as sugar, ferroalloys and steel, and an increase in cement, ceramics and other industries. The intensity effect was not representative in this period.

Between 2014 and 2017, with the economic recession, industrial activity fell by 4.6% a year, although industrial consumption fell by only 0.9% per year. The reduction in consumption due to the decline in economic activity was partially offset by increases in intensity in some sectors. This can generally be explained by the increase in idle capacity, a cyclical loss of productivity, and structural changes. Although most sectors contracted during the industrial recession, the paper and pulp sector showed significant growth, increasing its relative share and, since it is energy intensive, contributing to the overall increase in industrial consumption. There was also an increase in the relative shares of steel, sugar and ceramics, as well as a reduction in 'other industries'.

Finally, consumption fell by 4.8% in 2018 due to a decline in production intensity in non-ferrous metals (partly due to aluminium's lower overall share), food and beverages, cement, and ceramics. There was also a reduction in consumption due to structural changes, mainly through the reduction in sugar production that followed the fall in the international sugar price.

Figure 22 – Breakdown of changes in industrial energy consumption (2000-18)



Source: compiled by EPE, using EPE (2019a) and IBGE (2019a)

3.1.3.4 Industrial ODEX

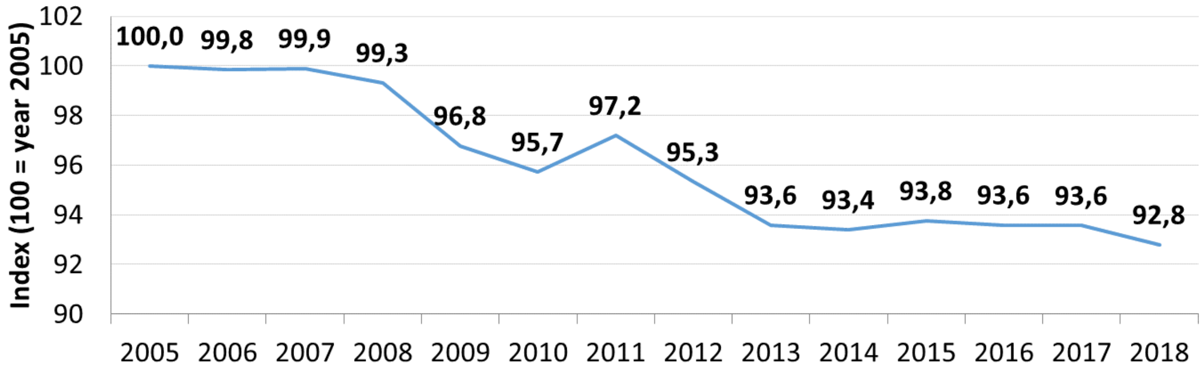
Specific consumption was examined for the steel, paper and pulp, cement, and sugar sectors,while energy intensity was examined for 'other food', textiles, chemicals, ceramics, ferroalloys, 'other metallurgy', mining, and 'other industries',based on available information.

It would be ideal not to use value-added, and only to use physical production for all sectors, with stratification in some sub-sectors. However, information on physical production and energy consumption is lacking at this level of disaggregation.

In the case of more diverse industrial sectors, such as chemicals and ferroalloys, the indicator may be further influenced by changes in the structure of sub-sectors. As the share of more energy-intensive sub-sectors increases, the indicator tends to rise, even where there is not a loss of efficiency.

Figure 23 shows ODEX for the industrial sector.

Figure 23 – ODEX for energy consumption in the industrial sector



Source: compiled by EPE

Relative stability in the indicator can be observed between 2013 and 2017, which corresponds to the period of industrial recession. Some sectors ran with idle capacity, thus deviating from their optimal level, while less-efficient plants were closed, for example in the steel industry.

In 2018, industry's ODEX was 93, which is to say it was 7% lower than the ODEX for 2005, with an average reduction of 0.6% per year. This represents an average gain in energy efficiency.

3.2 Energy sector

3.2.1 Overview of the sector

According to the National Energy Balance methodology, the energy sector adds final energy consumption in transformation centres, in extraction processes, in transfer[10], and in the transport of energy products.

Table 5 provides details of final consumption in the energy sector, which increased on average by 4.6% a year between 2000 and 2018, rising from approximately 14 million toe to over 26 million toe, mainly due to increases in the consumption of natural gas in the oil exploration and production (E&P) sector, and of sugarcane bagasse in ethanol production.

[10] Internal movement of production. Example: relief vessels.

Table 5 – Final energy consumption in the energy sector

Energy Sector	2000	2005	2010	2015	2018
Final Consumption of the Sector [10^3 tep]	12 847	17 653	24 580	27 763	28 705
Share of Final Energy Consumption	8.9%	10.7%	12.4%	12.7%	13.5%

Source: EPE (2019a)

In percentage terms, the share of the energy sector in relation to total final consumption in Brazil rose from 8.9% in 2000 to 13.5% in 2018, making it the third-largest energy-consuming sector in the country, behind only the transport and industrial sectors.

3.2.2 Analysis of sectorial indicators

Table 6 breaks down the final consumption of the energy sector into sub-sectors. In this breakdown, the ethanol and oil and natural gas industries (platforms, refineries and gas pipelines) stand out, accounting for 97% of the sector's consumption in 2018.

Consumption grew faster between 2001 and 2010 - at a rate of 6.4% per year - than in 2011-18, a period during which growth ran at 2.3% a year.

Despite the increase in consumption resulting from the pace of activity in oil exploration and production, the relative share of the oil and natural gas industry declined. In 2000 this sector accounted for just over half of the total amount (51%), but had fallen to 40% by 2018. This occurred due to the increase in ethanol production, which expanded its share from 44% to 52% in the same period.

Table 6 – Final energy consumption of the energy sector, by sector

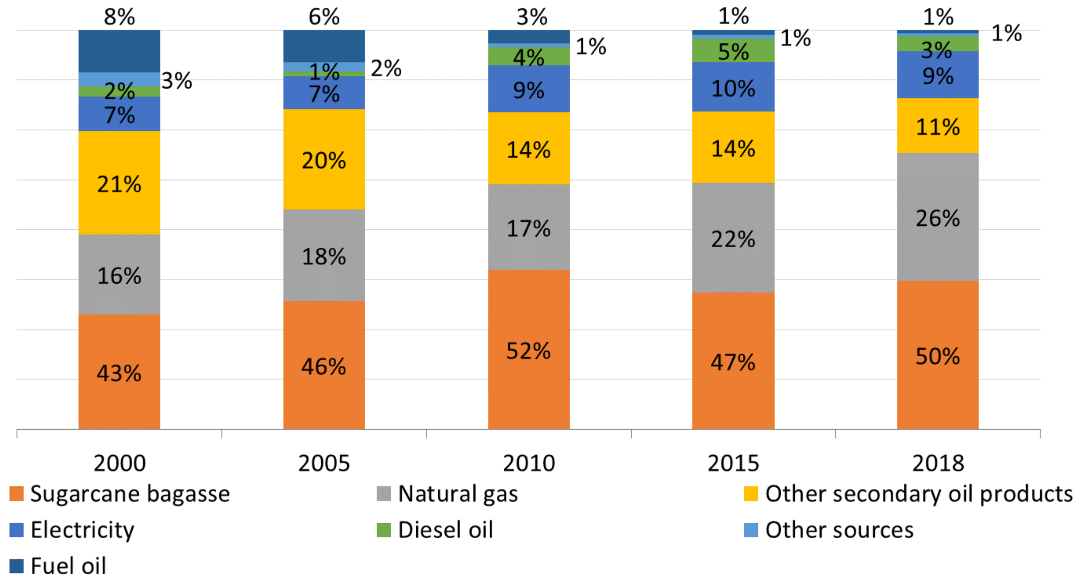
Final Energy Consumption by Sector [10^3 tep]	**2000**	**2005**	**2010**	**2015**	**2018**	**∆% per year. (2018/2000)**
Oil platforms	1 218	2 229	3 493	4 758	4 748	**7.8%**
Refineries	5 395	6 460	6 147	7 468	6 647	**1.2%**
Distilleries (sugar-ethanol sector)	5 663	8 287	13 196	13 746	14 957	**5.5%**
Electricity generation (public service and self-production)	236	334	464	725	673	**6.0%**
Gas pipelines	0	0	501	835	1 445	**-**
Coking plants and others	339	342	204	232	235	**-2.0%**
TOTAL	**12 850**	**17 653**	**24 005**	**27 763**	**28 705**	***4.6%***

Source: adapted from EPE (2019a)

Figure 24 shows the development over time of the share of the different energy sources that make up the final consumption of the energy sector. In ethanol production, it is possible to observe an increase in the share of sugarcane bagasse, which remains the main source. It is also possible to observe an increase in the share of natural gas, which is consumed mainly in

E&P and oil refining. Sources whose share has fallen are fuel oil and 'other secondary oil products', which include refinery gas and FCC coke[11].

Figure 24 – Energy sector: final energy consumption by source



Source: EPE (2019a)

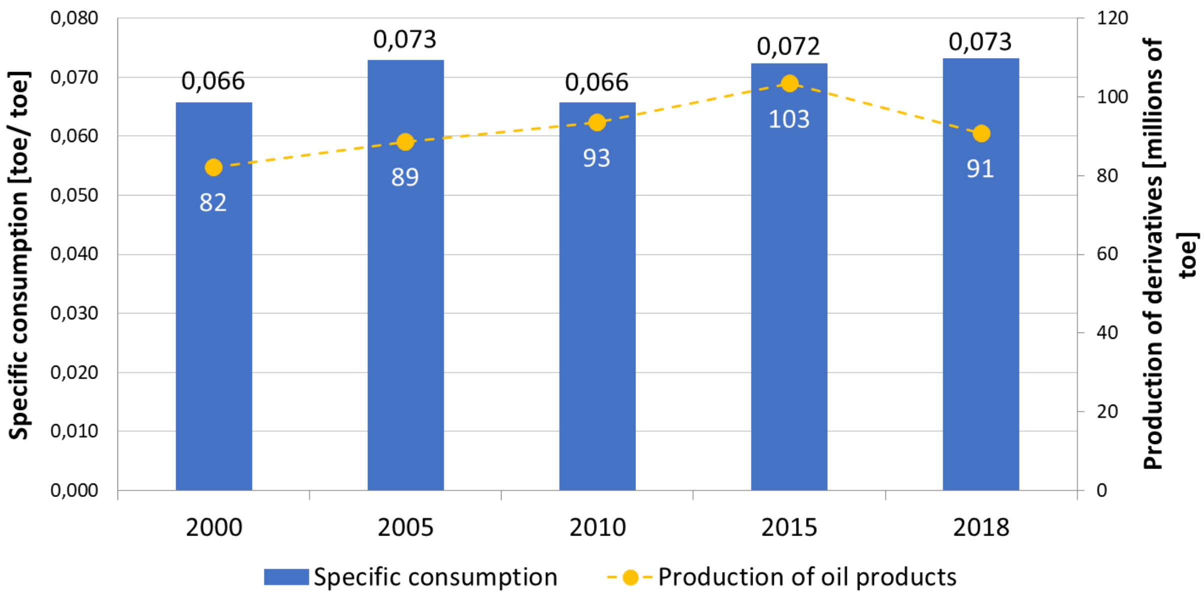
The change in the overall share of the different sources is a result of the structural changes that have taken place in the energy sector, with a greater share for E&P, distilleries and electricity generation, and changes in the consumption profile of refining, with the substitution of fuel oil with natural gas and, in E&P, with the substitution of natural gas with diesel oil.

In refining, the self-consumption of energy in the production of oil products varies between 0.067 and 0.073 toe consumed for every toe produced, and does not indicate a significant improvement in efficiency over the past two decades. It is noteworthy that there have been advances in environmental legislation in this period, with progressive restrictions on the concentration of sulphur in diesel oil. The removal of sulphur compounds to meet the standards of the Proconve[12] programme on air pollution utilises high-purity H_2 for in the hydro-treatment process, and obtaining this is intensive in natural gas (Cruz, 2010). Therefore, energy demand from refineries has increased to meet diesel specifications.

[11] FCC refers to fluid catalytic cracking units within refineries.

[12] Proconve stands for Programa de Controle de Poluição do Ar por Veículos Automotores (Motor Vehicle Air-Pollution Control Programme).

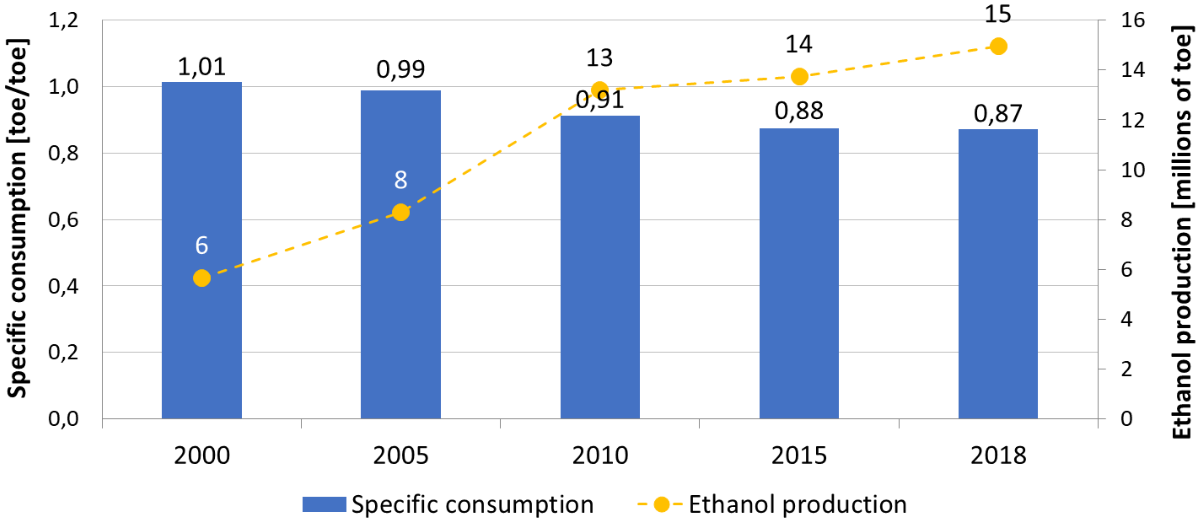
Figure 25 – Specific consumption for the production of oil products (toe/toe)



Source: adapted from EPE (2019a)

In distilleries, specific consumption decreased by 0.8% per year between 2001 and 2018 (Figure 26), which reflects efficiency improvements in the consumption of sugarcane bagasse for producing the steam that is required to produce ethanol.

Figure 26 – Specific consumption for ethanol production (toe/toe)



Source: adapted from EPE (2019a)

3.3 Shortcomings, challenges and necessary progress

Indicators were reported and analysed in as much detail as possible, based on available data. Still, data for consumption and activity by sub-sector would make it possible to exclude the structure effect in certain industrial sectors, such as the chemical industry, which has several sub-sectors with different levels of energy intensity.

With support from industry and industrial associations, this aspect of the analysis could be enhanced by expanding the provision of data on energy consumption and specific consumption for National Energy Balance data. In the specific case of the ceramics industry, for example, there is a lack of data on physical production and on value-added, both for the sector as a whole and for the sub-sectors of white and red ceramics. Analysis could also be enriched by gathering more information on the efficiency actions that are being carried out by industrial actors.

Regarding the efficiency gains that stem from public policies, increasing the compatibility and integration between the calculation methods of the different programmes would make it possible both to avoid double counting, and to better evaluate historical gains in different periods (for example, to monitor Brazil's Nationally Determined Contribution [NDC] towards the goals of the Paris Agreement on climate change). The same methods used to estimate historical gains could be used to estimate the future gains that will result from continuing with policies, and could be incorporated into energy planning. To do so, it would be necessary for different institutions to make an effort to improve the impact assessment of efficiency policies at the national level. The Procel Resource Application Plan (PAR) for 2018 raised the prospect of a project that would provide structure in this regard. Indeed, it pointed to the "Development and initial implementation of methods for evaluating results of energy efficiency actions implemented in Brazil," and went on to refer to guidelines and "Practical examples of measurement and verification (M&V) within the scope of the sub-programmes served by PAR". This aim is part of the programme's register of ideas for future consideration. The *ex ante* definition of indicators for monitoring new policies, as is the case in the More Productive Brazil programme, is useful for the purpose of evaluation.

Despite advances in efficiency gains and public policies, and even with the Procel Indústria programme's increased investments and the updating of minimum efficiency levels for engines, there is still great potential to make efficiency gains, including by using measures that generate financial returns.

One barrier to efficiency is a lack of knowledge about opportunities for efficiency (among top management and industry officials, and in the financial sector), which can be countered by making organised information available. The scope of such information may include, among other things, opportunities, tools for calculating efficiency gains and for analysing the viability of measures, contact with auditors and energy service companies (ESCOs), existing funding lines, case studies (successful or unsuccessful), and an information-exchange forum. Training courses and seminars also help to spread efficiency.

Another barrier is the limited number of auditors and ESCOs with experience in industrial processes. The prospect of increased demand for energy audits in the short and medium term may increase the supply of energy efficiency services.

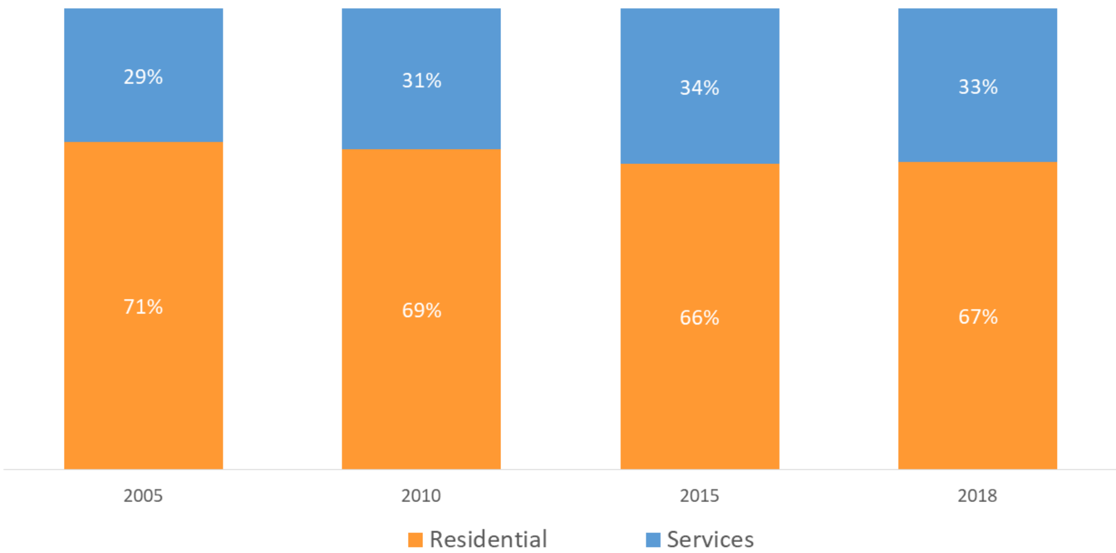
Therefore, programmes to support the implementation of energy-management systems, combined with the provision of information and training on energy efficiency, and together with minimum efficiency levels for equipment, can facilitate major advances in energy efficiency in Brazil. Moreover, institutional co-operation in the evaluation of efficiency gains from existing and future programmes makes it possible to strengthen the analysis of indicators.

4. BUILDINGS

Buildings include the residential, commercial and public sectors. Buildings account for 16% of the country's total energy consumption, and consume 51% of its electricity. Between 2005 and 2018, the overall energy consumption of buildings increased from 30.7 million toe to 37.8 million toe, an increase of 2% per year over the period. Buildings in the commercial sector had a higher growth rate of 3% over the period.

Figure 27 shows the development of the total energy consumption of buildings. Residential buildings are responsible for the largest portion of this consumption, accounting in 2018 for a 67% share of total energy consumption, and for 25% of electricity use.

Figure 27 – Comparison of the total consumption of buildings (106 toe)



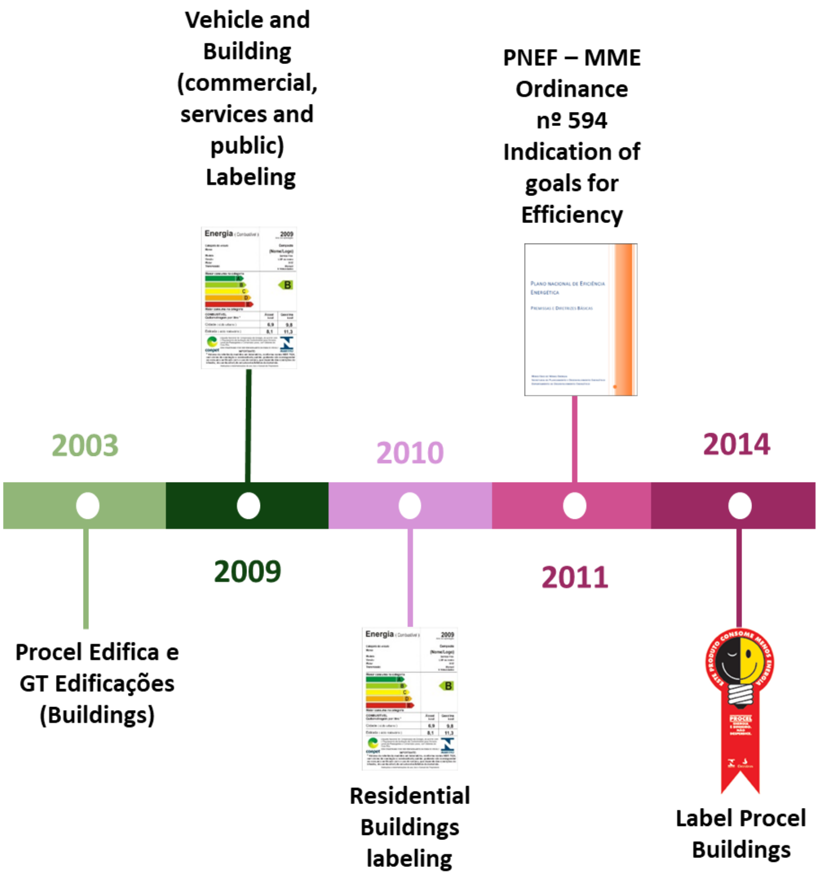
Source: compiled by EPE

The main source of energy used in buildings is electricity. Residential buildings consume 46% electricity, 26% liquefied petroleum gas (LPG), and 24% firewood. Commercial and public buildings consume mostly use electricity, which accounts for 92% of their total final consumption.

In Brazil, policies focused on energy efficiency began to be formulated in the 1980s, through the PBE and Procel. In the implementation of public policies, a major example that stands out is the Energy Efficiency Law, which this document has already referenced.

An overview of the history of specific policies in the buildings sector can be seen in Image 2.

Image 2 – Specific policies in the buildings sector



Source: compiled by EPE

Table 7 sets out the current initiatives and incentives and classifies them according to the types of buildings that they cover.

Table 7 – Current policies

Buildings		
Residential	**Commercial**	**Public**
Procel, Conpet	Procel, Conpet	Procel, Conpet
PBE	PBE, SEBRAE	PBE
Energy Efficiency Law and CGIEE	Energy Efficiency Law and CGIEE	Energy Efficiency Law and CGIEE
ANEEL's PEE, PNMC	ANEEL's PEE, PNMC	ANEEL's PEE, PNMC
Minha Casa, Minha Vida (My House, My Life) Programme		RELUZ
NBR 15220 and 15575, RTQ-R	RTQ-C	RTQ-C, IN 02, Efficient purchases
NDC, PNEf	NDC, PNEf	NDC, PNEf
CTEnerg and PEE	CTEnerg and PEE	CTEnerg and PEE
	BNDES	BNDES

Note: CGIEE stands for Comitê Gestor de Indicadores de Eficiência Energética [Energy Efficiency Indicators Steering Committee], Conpet denotes the Programa Nacional da Racionalização do Uso dos

Derivados do Petróleo e do Gás Natural [National Programme for the Rationalisation of the Use of Oil and Natural Gas Products], CTNErg denotes the Fundo Setorial de Energia Elétrica [Electric Energy Sectoral Fund], PBE stands for Programa Brasileiro de Etiquetagem [Brazilian Labeling Programme], PEE stands for Programa de Eficiência Energética [Energy Efficiency Programme], PNMC stands for Plano Nacional de Mudanças Climáticas [National Climate Change Plan], Procel denotes the Programa Nacional de Conservação de Energia Elétrica [National Electricity Conservation Programme], BNDES refers to the Brazilian Development Bank's Finem initiative with regard to the environment and energy efficiency, SEBRAE stands for Serviço Brasileiro de Apoio às Micro e Pequenas Empresas [Brazilian Support Service for Micro and Small Businesses], IN 02 refers to Normative Instruction SLTI no. 02/2014 from the Ministry of Planning, Budget and Management, PNEf stands for Plano Nacional de Eficiência Energética Portaria [National Plan for Energy Efficiency at Ports] no. 594 of October 2011, RELUZ is for Programa Nacional de Iluminação Pública e Sinalização Semafórica Eficientes [National Programme for Efficient Public Lighting and Traffic Signs], RTQ-R refers to Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edificações Residenciais [Technical Regulation on Quality for the Energy Efficiency Level of Residential Buildings], RTQ-C is for Regulamento Técnico da Qualidade para Eficiência Energética de Edifícios Comerciais, de Serviços e Públicos [Technical Quality Regulation for Energy Efficiency in Commercial, Service-sector and Public Buildings]. NDC refers to the Contribuição Nacionalmente Determinada brasileira - the Brazilian Nationally Determined Contribution, or NDC, which sets an overall goal of increasing electricity efficiency by 10% by 2030.

Source: compiled by EPE

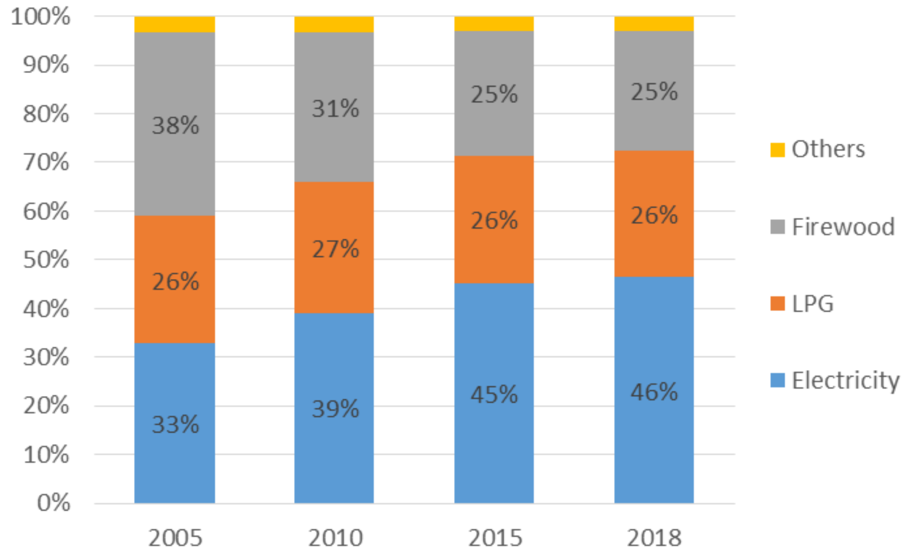
It is estimated that buildings built with the Procel Seal have resulted in a cumulative energy saving of 18.93 GWh since 2015 (Procel, 2019).

4.1 Residential buildings

4.1.1 Overview

Between 2000 and 2018, energy consumption in Brazilian households increased from 21.7 million toe to 25.2 million toe, an increase of 1.1% per year over the period. Electricity is the main source of energy used in homes. As shown in Figure 28, the share of this source increased by 11 percentage points over the time-horizon that was analysed.

Figure 28 – Final energy consumption by source in homes

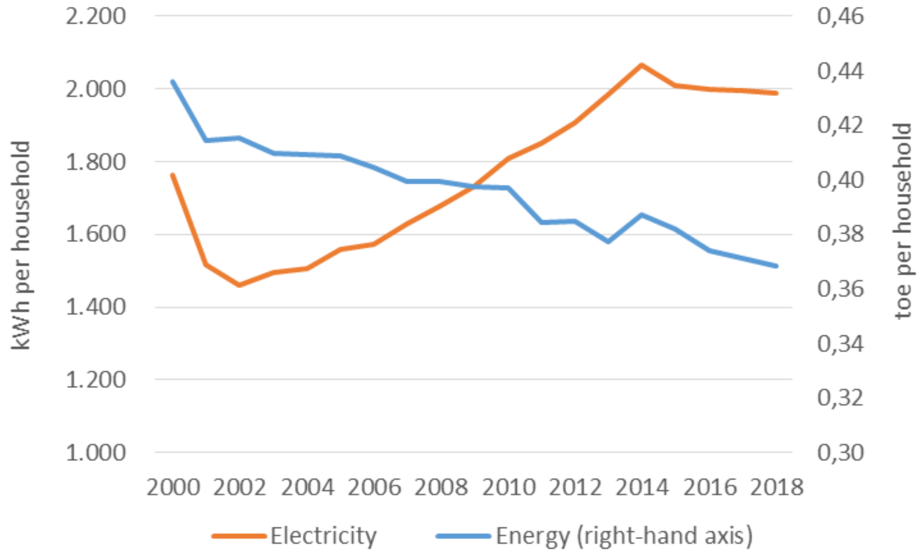


Source: EPE (2019a)

In 2001, due to electricity rationing in the country[13], there was a significant reduction in household energy consumption, as shown in Figure 29. The need to adjust demand to supply constraints stimulated changes in families' consumption habits and the promotion of energy efficiency measures in homes. In the years following the rationing of electricity, more energy-efficient electrical appliances were introduced to the market, thanks in part to the Energy Efficiency Act of 2011.

[13] In 2001, the Federal government set a mandatory target to reduce electricity consumption by 20% in residential accomodation in the Sudeste [Southeast], Centro-Oeste [Centre-West], and Nordeste [Northeast] regions, as well as in part of the Norte [North] region. This measure took effect between mid-2001 and early 2002.

Figure 29 – Electricity and energy consumption by household



Source: compiled by EPE

From 2002 to 2014, in a context of economic stability, growing household incomes, and increases in credit and in tax incentives for the purchase of electrical household appliances[14], the demand for electricity grew by 2.4% per year. During this period new and more efficient appliances were introduced in homes, leading to a reduction in the average consumption per unit of inventory and, as a result, to energy savings. In 2015, however, the Brazilian economic crisis reduced people's purchasing power, and this had an impact on electricity consumption in homes.

In turn, energy consumption per household showed a decreasing trend in 2000-18. During this period, average consumption fell by about 0.7% per year. Part of this result came thanks to the replacement of traditional biomass, such as firewood and charcoal, with modern fuels, especially LPG. The latter is a source of energy used by families for the same end uses as traditional biomass, but it has a greater efficiency of combustion.

4.1.2 Current policies for energy efficiency

The economic and institutional context of recent decades has created the conditions for an increase in energy consumption in homes, demonstrating the importance of measures to boost energy efficiency in this sector. In homes, the main energy efficiency measures are implemented through standards and labelling policies for equipment and electrical household

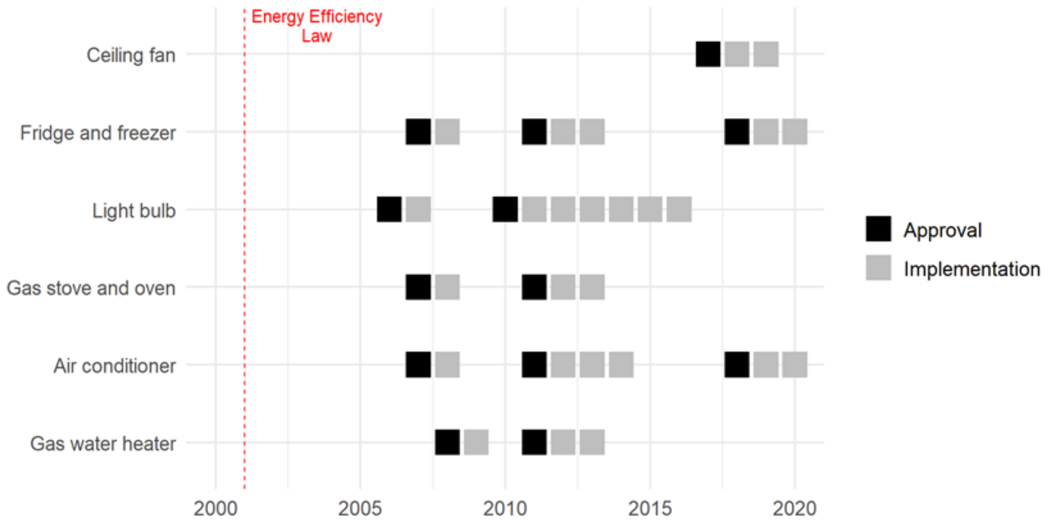
[14] In response to the global crisis of 2008, the federal government adopted counter-cyclical policies, including lowering the IPI (tax on industrial products) tax rates for white goods (stoves, tanks, refrigerators and washing machines) between 2011 and 2014.

appliances, some of which are mandatory and some of which are voluntary. These policies include:

- Minimum levels of energy efficiency (or of maximum consumption);
- Comparative labelling (compulsory or voluntary); and
- Endorsement labels.

In its early days in the 1980s, the PBE programme was developed on the basis of voluntary adherence by equipment suppliers, especially for products intended for families. Gradually, however, adherence became compulsory for some types of equipment. With the publication of the Energy Efficiency Law in the early 2000s, the PBE also began to demand - in a compulsory manner - equipment performance criteria based on minimum levels of energy efficiency (or maximum consumption).

Figure 30 – Period of approval and implementation for policies on minimum levels of energy efficiency for domestic equipment



Note: The Figure takes account of the dates that are contained in specific regulations and goal plans. For light bulbs, specific regulations and target plans for both incandescent and compact fluorescent bulbs were considered.

Source: Compiled by EPE based on MME data

With regard to policies on energy efficiency standards, Figure 30 shows that the implementation of minimum efficiency levels for residential equipment began in 2006, about five years after the publication of the Energy Efficiency Law. The home appliances that were prioritised were those with a greater specific consumption, with a high degree of uptake in homes, and/or appliances that can significantly impact electricity consumption at peak hours

- such as lamps, refrigerators, and air conditioning units. As shown in the figure, these policies are subject to periodic review. In this spirit, the revision of minimum levels of energy efficiency for air conditioning, refrigerators and freezers - established by Inter-ministerial Ordinances MME/MCT/MDIC on 1-2 July 2018 - is under way, and will be fully implemented by the end of 2020.

In addition to policies on standards and labelling, there are complementary initiatives that seek to promote energy efficiency through standards, certifications and programmes, which include not only equipment that consumes electricity, but also buildings and the way they interact with the people who live in them. Among the main initiatives, we highlight:

• The Selo Casa Azul [Blue House Seal];

• The review of NBR 15 220 and NBR 15 575; and

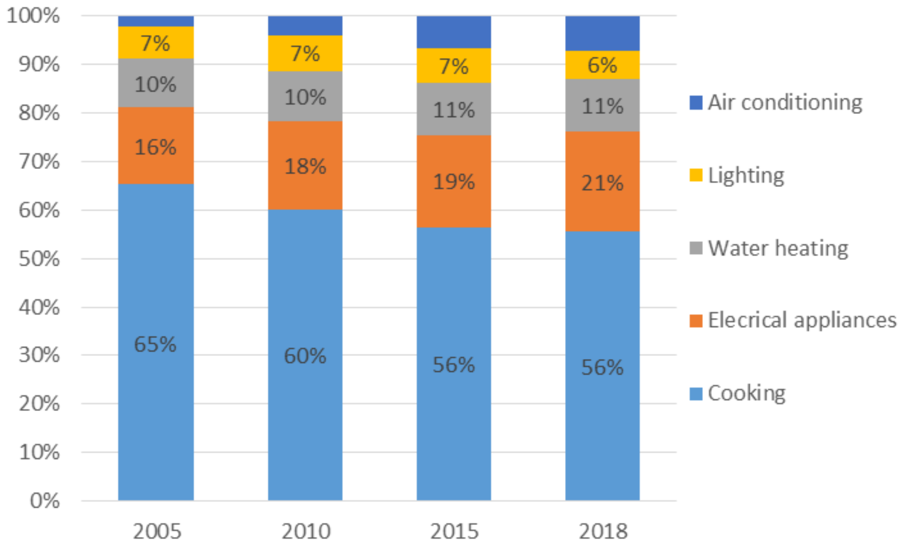
• Ordinance 643, in 2017, from the Ministry of Cities.

The Casa Azul Seal is a voluntary classification of housing projects funded by the Caixa Econômica Federal, a Brazilian public bank. It recognises efficient solutions in the construction, use, occupation and maintenance of buildings, including energy efficiency measures. Among other initiatives, performance standards NBR 15 220 and NBR 15 575 establish requirements for construction and criteria relating to the thermal performance of residential buildings, including social housing units, which in Brazil are called Habitações de interesse social (HIS). In 2017, Ordinance 643 from the Ministry of Cities - now the Ministry of Regional Development - set out provisions for the use of alternative energy generation systems for HIS units as part of the Federal government's Minha Casa Minha Vida programme. This includes solar heating systems, as well as electricity-saving technology, which can be a complementary element for energy efficiency in residential buildings.

4.1.3 Analysis of sectorial indicators

The main energy-consuming activity in homes is cooking, followed respectively by electrical equipment, water heating, lighting, and air conditioning. Despite this order staying the same between 2005 and 2018, a fall in the share of consumption in cooking stands out, as well as an increase in the use of electrical equipment over the years, as shown in Figure 31.

Figure 31 – Residential energy consumption by end use

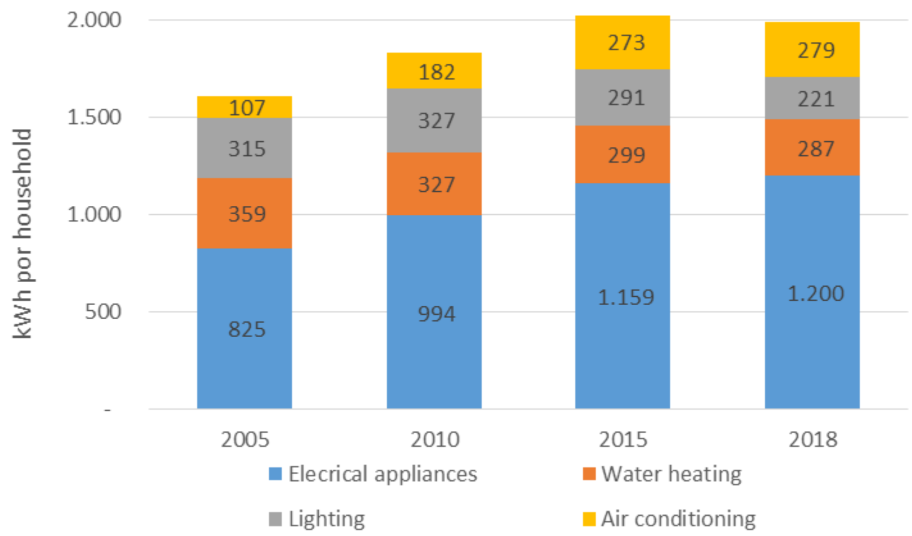


Source: compiled by EPE

The reduction in the share of cooking can be explained by an energy transition in households, where as incomes rise households replace traditional biomass with modern fuels. However, it is worth noting that this process is not always straightforward, as households can consume a multifaceted portfolio of fuels for various reasons, such as the availability and cost of substitute fuels, the risks associated with disruptions in supply, as well as cultural and social aspects and preferences.

With the exception of energy use for cooking, electricity is the predominant source for other end uses. Between 2005 and 2018, household electricity consumption increased by 1.7% per year, as illustrated in Figure 32. However, it is worth noting that between 2015 and 2018, consumption remained roughly stable. The use of electricity to heat water and provide lighting registered a downward trend in the same period. The reduction in the use of electricity to heat water is due to the increased uptake of solar heating systems, as well as the use of natural gas. In the case of lighting, the reduction in consumption is the result of energy efficiency policies implemented in recent years, namely ending sales of incandescent lamps with high average levels of consumption, and their replacement with more efficient devices such as compact fluorescent lamps and light-emitting diodes (LEDs) - as per Inter-ministerial Ordinance (MME/MCT/MDIC) 1 007 of 2010.

Figure 32 – Residential electricity consumption by end use

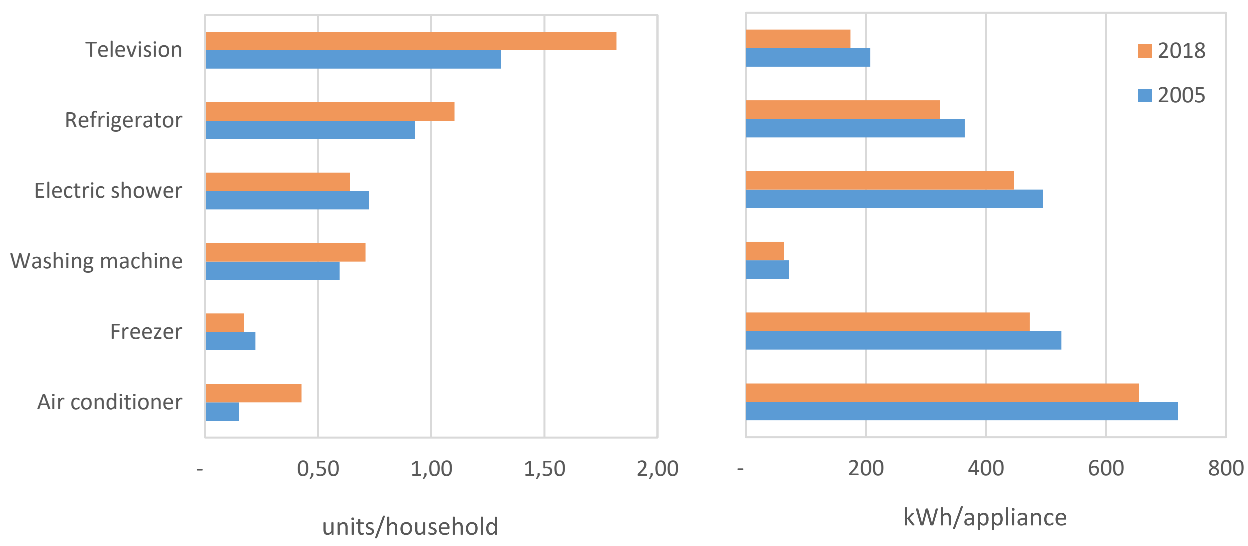


Source: Compiled by EPE

The increase in the share of electrical equipment can partially be explained by increased ownership levels. The spread of new and more energy-efficient equipment tends to reduce the average energy consumption of the stock of appliances in operation, as suggested by Figure 33. Air conditioners were the appliances with the highest growth in ownership, increasing by around 8.4% a year between 2005 and 2018. On the other hand, the number of freezers and electric showers fell over the period. In the case of freezers, the reduction is largely the result of changing household habits in recent decades, with households often ceasing to replace equipment that has reached the end of its useful life[15]. As mentioned above, the reduction in the ownership of electric showers is the result of the expansion of the residential distribution network for natural gas, and the use of solar technology - both in the standalone market and in social housing programmes.

[15] The freezer was a device historically related to the habit of stocking food to mitigate the effects of the inflationary process that occurred in Brazil until the early 1990s. In the current Brazilian context of greater price stability, this type of use tends to be less widespread.

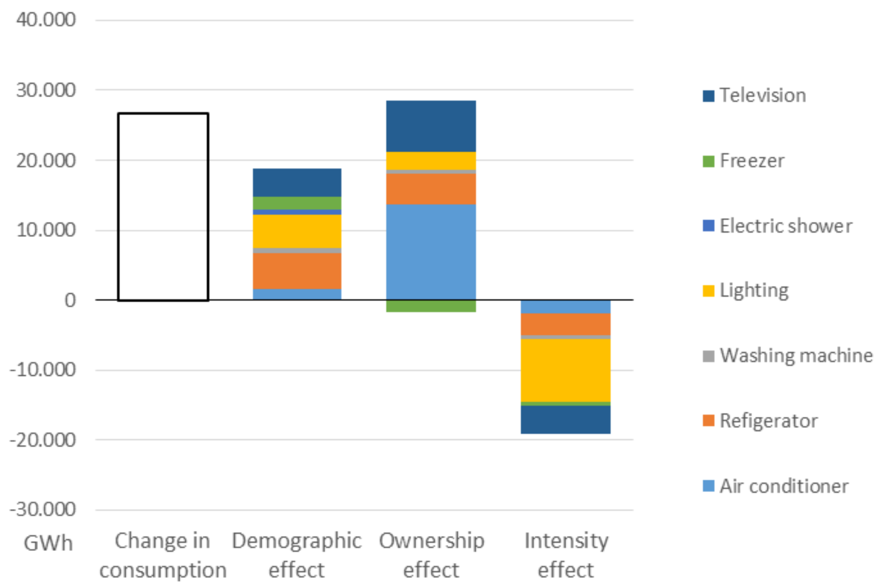
Figure 33 – Ownership and average annual consumption by equipment type



Source: Compiled by EPE

Figure 34 provides a breakdown of changes in electricity consumption for selected types of equipment. Changes in consumption reflect demographic effects - with an increase in the number of households and a growing population - as well as the ownership effect, and the intensity effect. The intensity effect, which is a proxy for assessing gains in energy efficiency, can be understood as the relative gain when replacing technologies or changing equipment-use habits. As seen in the Figure, the ownership effect was, in absolute terms, the main driver of the change in electricity consumption between 2005 and 2018, bearing in mind that air conditioning units alone accounted for 51% of this effect. On the other hand, 47% of the intensity effect, which tends to mitigate the increase in electricity consumption in residential properties, stems mainly from the introduction of more energy-efficient light bulbs, due to the banning of incandescent bulbs and the greater spread of LED technology.

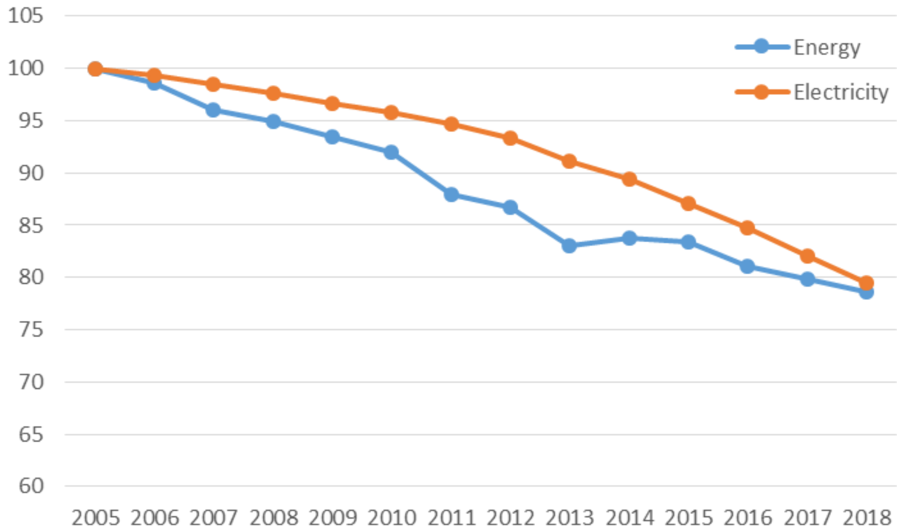
Figure 34 – Breakdown of changes in electricity consumption by equipment type 2005-18 (GWh)



Source: compiled by EPE

As noted in previous chapters, an alternative way of evaluating the trend of energy efficiency gains over time is through the ODEX indicator. In the case of the residential sector, this adds up the consumption trends of different end uses, or of types of equipment, based on their weightings in overall consumption. In the case of the residential sector, the trend for electrical equipment is calculated using changes in energy consumption by equipment type, while for water-heating and cooking, the trend is evaluated in function of changes in consumption per household. As shown in Figure 35, the ODEX calculated for electricity and energy consumption decreased by 20% between 2005 and 2018. However, it can be observed that the fall in the indicator has been more significant for electricity in recent years, which points to the importance of this source in the country's total energy savings.

Figure 35 – ODEX for residential accommodation



Source: compiled by EPE

The indicators of energy consumption in households analysed in this section suggest that, when we consider the main end uses as well as the main types of electrical equipment, we can observe a trend of energy efficiency improving in the Brazilian residential sector between 2005 and 2018. Public energy efficiency policies notwithstanding, this phenomenon is the result of complex interactions that include economic and social factors as well as families' behaviour.

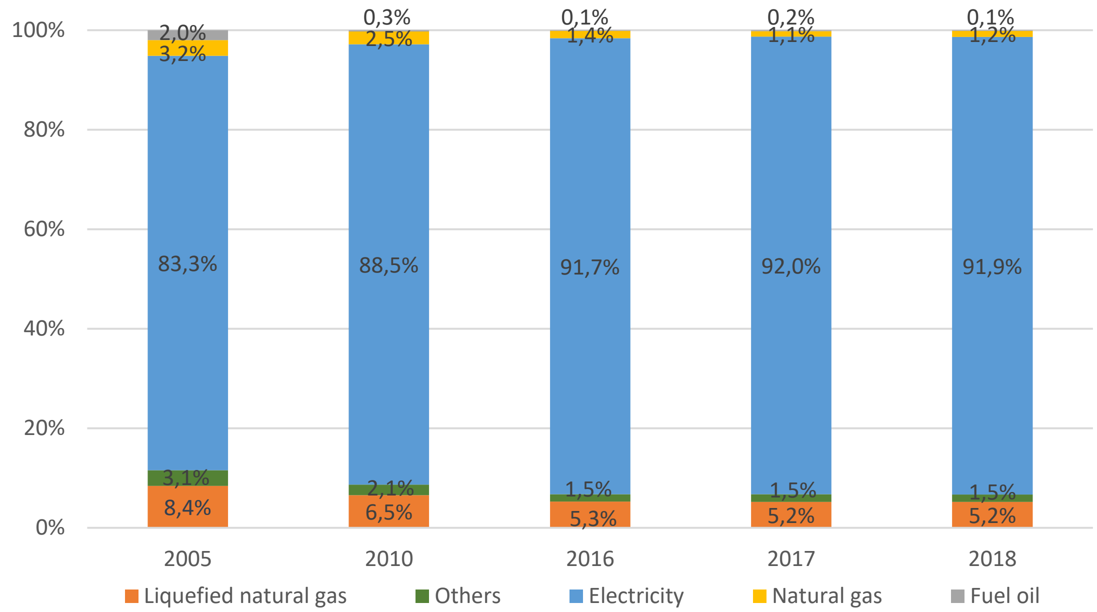
4.2 Services

4.2.1 Overview

According to the Brazilian Energy Balance classification, services span both the commercial sector and the public sector. These sectors comprise very distinct and diverse activities, either due to the nature of the service, or to the size of the establishment or company, the kind of remuneration involved, or the way in which technology is used.

Despite this diversity, some energy services feature prominently in the energy demand of these sectors. According to the Balanço de Energia Útil [Useful Energy Balance] for 2004, the main end uses are refrigeration, lighting and the powering of motors, for which the predominant technologies among systems already installed are electric. As a result, electricity demand accounts for most of the sector's energy mix, representing 92% of all final energy consumed, as illustrated in Figure 36.

Figure 36 – Development of final energy consumption by source in the services sector



Source: EPE (2019a)

It is of interest to note that electricity has continued to gain in importance within the sector's overall final consumption since 2005. This may be associated with several factors such as increased ownership of electrical equipment, the increase in automation and process control, among other factors.

Another relevant consideration in analysing the service sector is that a great deal of the demand for fuels is for on-site electricity generation, and is therefore not counted as final energy consumption. From a financial point of view, in fact, there are sectors that produce electricity for themselves as an alternative to using the grid at times when the time-of-day/seasonal rate is more expensive. There are other cases in which establishments generate electricity for themselves in order to mitigate potential power supply problems in critical sectors, such as emergency generation in hospitals, for example.

Although a great deal of the service sector's self-generation of electricity uses natural gas for fuel, the share of distributed generation using solar photovoltaic technology has been growing year by year. According to data from ANEEL's Registro de Geração Distribuída [Distributed Generation Registration System] (SISGD) from October 2019, the service sector accounts for the largest share of installed photovoltaic power, accounting 43%, followed by the residential sector, with 36%.

Table 8 – Energy-consuming units with photovoltaic generation in the service sector

Category of Consumption	Quantity	Installed Power (kW)
Services	**20 274**	**520 646**
Commercial	19 601	496 223
Public Lighting	7	123
Public Authorities	599	22 223
Public Service	67	2 077

Source: ANEEL (2019)

Overall, the growth of the service sector rests upon economic and demographic considerations. These considerations influence several factors, including: new construction, increased ownership of equipment, changes in habits, access to services, improvements and growth in the health system, and the expansion of networks of public lighting, water and sewage. Table 9 shows the development of final energy consumption from 2005 to 2018.

Table 9 – Final energy consumption in the services sector

Services sector [10^3 toe]	***2005***	***2010***	***2015***	***2018***	***2005-18***
Final consumption in the services sector	**8 903**	**10 366**	**12 631**	**12 611**	2.7%
Final consumption of the commercial sector	5 452	6 731	8 585	8 514	3.5%
Final consumption of the public sector	3 451	3 635	4 046	4 097	1.3%
Share of final energy consumption	4.9%	4.6%	5.2%	5.2%	-
Services sector GDP[1] (%)	3.7	5.5	-2.7	1.3	2.3

Source: EPE (2019a)

Note: The data is from BEN. It corresponds to commerce, communications, financial institutions, public authorities, rents, other services and Industrial Services of Public Utility, minus electricity generation.

From 2005 to 2015, growth in final energy consumption in the commercial sector was 4.6% per year, close to its historical rhythm of growth. In the past four years, however, and under the influence of the economic crisis, the sector pared back its growth in consumption by 0.3% per year. Against this backdrop, growth in the sector's final energy consumption in 2005-18 stood at 3.5% a year. With regard to electricity, and in relative terms, the effect of such a crisis led the commercial sector to an even bigger decrease, from an average rate of 6.0% to -0.3% per year over the same timeframe.

As for the public sector, the economic crisis, the indebtedness of states and municipalities, and also the cap on public spending may have influenced the reduction in demand for electricity from public buildings, shrinking the observed average growth rate - which stood at 4.7% in 2005-2014 - to a negative rate of 0.5% a year for the following four years. Another aspect of the softening of electricity growth in the public sector was the water crisis at the end of 2014 that led to reduced consumption in the sanitation sector in some regions of the country. In contrast, the public street-lighting sector maintained sustained energy growth over the analysed period. In this way, the conditions described above supported average electricity growth of 1.3% for the public sector in 2005-18.

4.2.2 Current energy efficiency policies

For the commercial and public sectors, the main energy efficiency policies are presented below:

- Procel Edifica, an energy efficiency programme for buildings by Eletrobrás/Procel: created in 2003;
- Procel's label for buildings and equipment;
- Minimum energy efficiency levels (or maximum consumption);
- ABNT/NBR 15220 - Norma Brasileira de Desempenho Térmico para Edificações [Brazilian Standard for Thermal Performance in Buildings];
- ABNT/NBR 15575 – For residential buildings of up to five floors;
- INMETRO, Technical Regulation on Quality (RTQ) for energy efficiency in commercial, service-sector and public buildings;
- INMETRO, Regulamento Técnico da Qualidade para o Nível de Eficiência Energética de Edificações Residenciais [Techincal Quality Regulation for the Level of Energy Efficiency of Residential Buildings] - (RTQ-R);
- INMETRO, RAC - Requisito de Avaliação da Conformidade para Edificações e suas Portarias Complementares [Conformity Assessment Requirement for Buildings, plus Complementary Ordinances]; and
- SL MPOG Normative Instruction No. 02/2014 of MPOG.

Figure 37 – Implementation timeline: energy efficiency policies for commercial equipment

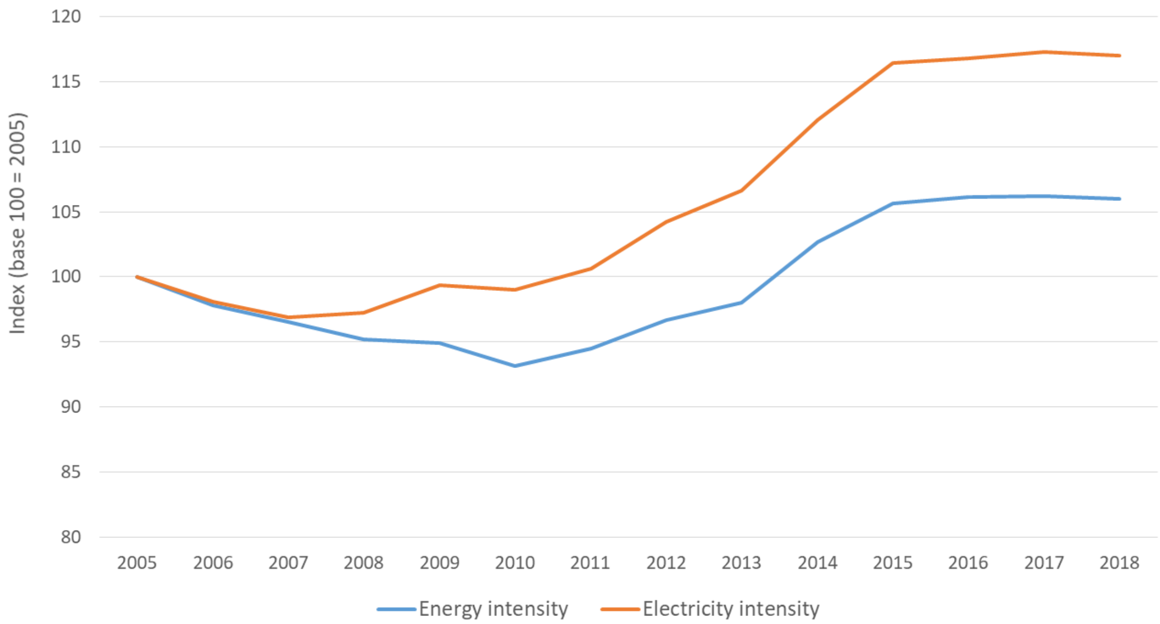
Source: Compiled by EPE, based on data from MME (2019), Procel (2018a), Conpet (2019) and INMETRO (2019)

4.2.3 Analysis of sectorial indicators

As described above, commercial establishments account for the lion's share of final energy use in the service sector, accounting for about two thirds of consumption, with the remainder being from service providers in the public sector. At a more detailed level of analysis, the sub-sectors of these consumption categories are among the most diverse in our network of analysis, spanning, for example, from sectors such as retail, hospitals, schools, supermarkets and laboratories, to street lighting, sanitation and public buildings. Still, such a diversity of shops and services corresponds to similar needs throughout the different regions of the country. In this manner, the sector has a certain spatial uniformity, which is linked, in general, to nationwide economic trends.

Using an index number, Figure 38 shows the development of growth rates for energy and electricity consumption in relation to growth in value-added in services at the national level, and at constant prices for 2005-18.

Figure 38 – Development of the energy-demand profile of the commercial and services sectors



Source: EPE (2019a)

The Figure shows a reduction in intensity indicators for electricity and energy as of 2005, suggesting that efficiency gains in the sector are possible. From 2007 onwards, however, electricity intensity deviates from the trend of the energy indicator due to an increase in the growth of electricity in relation to other sources, as described in the overview section of this document. It is important to highlight that in the subsequent years, both indicators increase, and that this does not necessarily represent inefficiency but actually reflects an increased channelling of useful energy from certain uses into different purposes, as is the case when harnessing refrigeration in order to enhance the thermal comfort of certain environments. In fact, the period in question was marked not only by significant sales of air conditioners, but also by high household consumption rates, ease of access to credit, and high overall retail sales rates. However, in recent years, under the effect of the economic crisis, this movement has reversed, with falls in income and employment and the closure of establishments and companies. Thus, similar rates of change in consumption and value-added can be observed at the end of the period of analysis, stabilising the two intensity indicators.

4.3 Shortcomings, challenges and necessary progress

The establishment of energy efficiency policies is an important way of encouraging good practices, and of reducing both consumption and energy expenses in the buildings sector.

Although the sector has important policies in place, it is necessary to make adjustments, and to co-ordinate actors in the sector in order that that new advances can occur, such as:

• A database, and greater transparency, when it comes to information on energy consumption. Make it mandatory for buildings to report their annual consumption;

• Develop a regulatory agenda with a defined timeline, increase requirements for minimum performance standards, and increase the scope of the PBE labelling programme;

• Implement the compulsory labelling of buildings;

• Create a single platform with centralised information from all actors and levels of government in order to manage and monitor energy efficiency indicators and programmes, with the aim of perfecting and monitoring the impact of public policies;

• An assessment tool for policies related to the energy efficiency of buildings; and

• A plan for communication and education.

In order to enhance the policies presented in this section and to promote their transparency, it is necessary for frequent and reliable data to be available. Specifically, this means data on consumption and stocks for buildings and equipment, on the use habits of occupants, and on use time and load factors. These data could be included in a single platform with centralised information from all actors. This would deliver transparency, and would also facilitate the evaluation of the results and impact of energy efficiency programmes for buildings.

A major challenge for the construction sector is to increase the minimum efficiency of the buildings that are being supplied to the market. For this purpose, compulsory labelling has been under consideration to enable new buildings and renovations of commercial, residential and public buildings to meet minimum levels corresponding to the type and stage of a project in a gradual, planned and transparent manner,.

The behaviour of building occupants, designers and installers determines the success of public energy efficiency policies for the buildings sector. In this sense, it is important to develop integrated communication plans, and to ensure an appropriate approach to engaging the different target audiences, highlighting the key benefits in terms of energy, economic savings, and the environment, and using the most efficient means of communication. It is important for this plan to include preliminary and subsequent assessments of the degree to which energy efficiency messages are assimilated and made permanent.

5. TRANSPORT SECTOR

5.1 Overview of the Brazilian transport sector

The transport sector is responsible for 33% of final energy consumption in Brazil (EPE, 2019a), and its performance is linked to a number of environmental, socio-economic, and technological aspects. Technological progress in engines, automation, the development of lighter and safer materials, inter-modal transfers, urban planning, and also the adoption of new sources of energy, are some of the pre-conditions that are taken into account in forecasting energy demand in the sector. Energy consumption in the transport sector is influenced by several factors, such as GDP per capita, the availability and expansion of logistics infrastructure, environmental policies, new technologies and connectivity, culture, behaviour, and social preferences. Factors of this kind contribute to the demand for the transport for freight and/or passengers.

The transport of passengers and freight is predominantly done by road. This road-dominated transport mix is the result of industrial policies that were adopted during the second half of the twentieth century. Although there have, at certain stages, been investments in railways and coastal transport, Brazil has historically prioritised the development of highways. In turn, it has also promoted the establishment of the automotive industry in Brazil, as well as the auto parts sector. Government support has taken the form of incentives for automotive manufacturers to set themselves up in the country, in addition to providing financing for the purchase of cars and lorries, opening new roads, providing fiscal and tax incentives, and offering further incentives in terms of currency exchange and tariffs. During this period, there was a gradual degradation of the railway network, with a U-turn on investments in the late 1990s (BNDES, 2002).

In the past few decades, and especially after the country's economic stabilisation, a number of investments have been made in infrastructure, both in urban mobility and freight logistics, but they have done little to change the profile of the national transport mix.

Between 1996 and 2018, the final energy consumption of the transport sector grew by 2.9% per year, which adds up to an increase of 88%. In this same period, the sector's share of national final energy consumption increased from 31.1% to 33%, surpassing the industrial sector, as can be observed in Table 10.

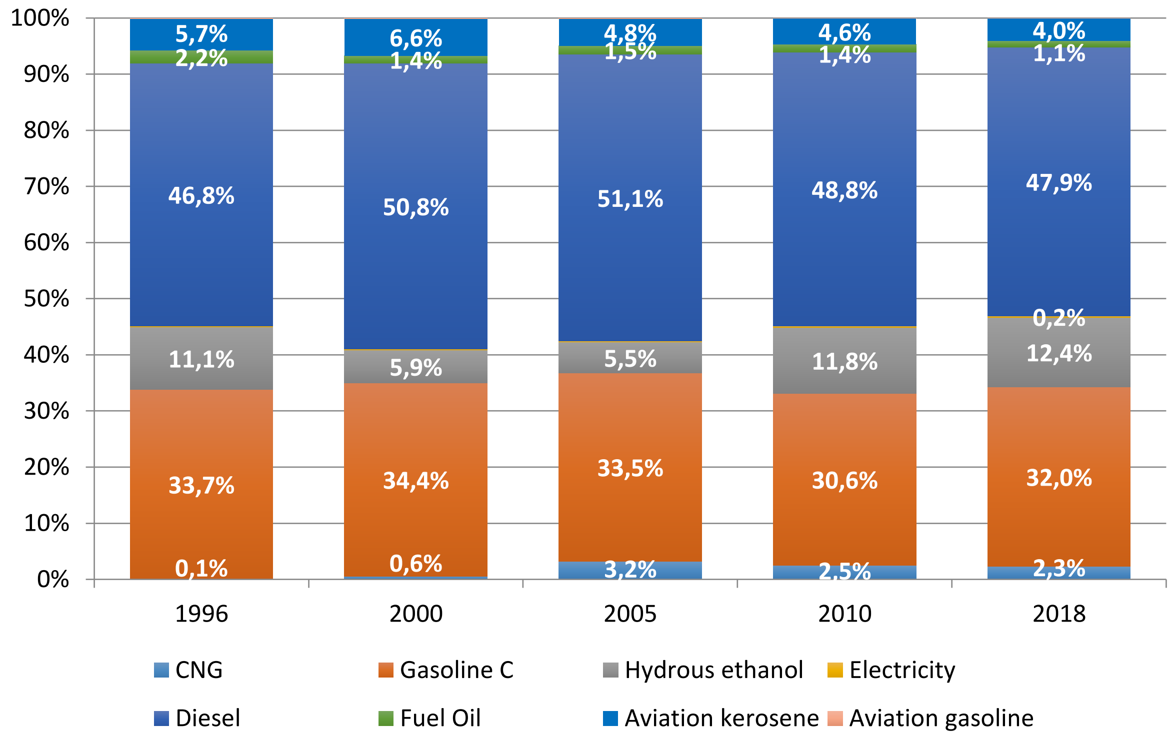
Table 10 – Final energy consumption in the transport sector

Transport sector	1996	2000	2005	2010	2018
Final consumption of the sector [10³ toe]	44 783	47 385	52 720	69 720	83 658
Share of final energy consumption	31.1%	30.1%	28.9%	31.2%	33%

Source: EPE (2019a)

The increase in energy consumption during the period came mainly from the increase in consumption of diesel B, gasoline C, and hydrous ethanol (Figure 39).

Figure 39 – Energy consumption in the transport sector by source



Source: EPE (2019a)

Consumption of Compressed Natural Gas (CNG) consumption grew notably, with the share of CNG reaching around 3% of the Brazilian transport energy mix in 2005, constituting an important instance of alternative technology adoption in the road transport sector. Nevertheless, since the second half of the 2000s, CNG's share in Brazil's overall energy mix for transport has fallen back, and currently represents 2% of the sector's energy consumption.

5.2 Energy efficiency in transport in Brazil

Given Brazil's continental dimensions, and the distribution of population and economic activity across the country, the transport system presents opportunities for improving energy efficiency. It can be observed that rail and waterways, although more suitable for transporting larger volumes of freight and passengers over medium and long distances, are not used to their full potential given the predominance of road transport. Yet modes of transport such as these, which are less energy-intensive, could significantly reduce energy demand and expand systemic efficiency gains.

Furthermore, it is worth considering how roads are used in Brazil. Features such as traffic in cities, the state of roads, the flow of users, and the way that people drive, present a range of inefficiencies. Public policies to improve the flow of traffic, the quality of road surfaces, and the organisation of transport in cities, and also to prioritise public transport in logistics corridors, are not yet at a level sufficient to create significant improvements in efficiency.

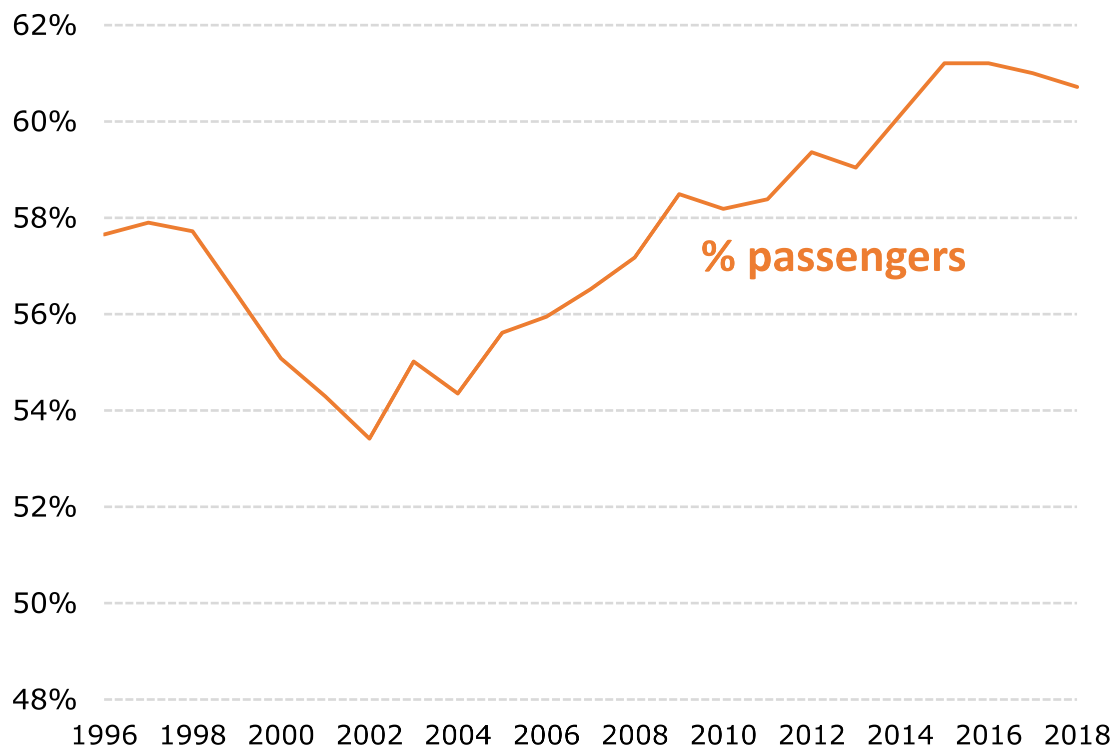
Although technological progress has yielded some efficiency gains - notably improvements in engines for cars, buses and lorries, and in the performance of aircraft, trains, boats and ships, the structure of the Brazilian energy mix has an important role to play when it comes to systemic efficiency.

The following sections will look at the development of passenger and cargo transport, and the main efficiency indicators of the transport sector in Brazil.

5.3 The development of passenger transport

Passenger transport is the largest consumer of energy in Brazil's overall transport sector. Between 1996 and 2018, its share varied between 53% and 61%, as shown in Figure 40.

Figure 40 – Share of passenger transport in the final energy demand of the transport sector

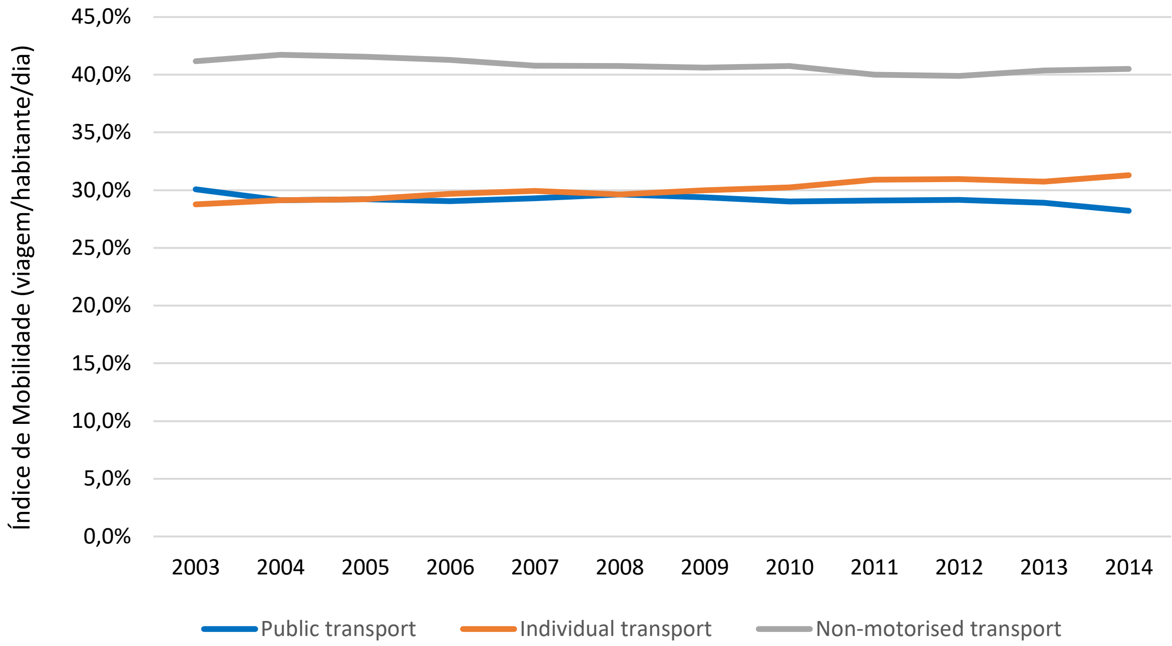


Source: compiled by EPE

The relative increase in energy consumption in passenger transport happened especially in the second half of the past decade, in which GDP per capita and the distribution of income increased, allowing more people to enjoy mobility services. A significant part of this increase in demand for mobility was met by road transport, stemming mainly from the increase in sales of cars and motorcycles (light duty road vehicles).

This expansion of the individual transport sector, which is represented by automobiles, light commercial vehicles and motorcycles, and to a lesser extent by public transport, can be observed in Figure 41. It shows the development of the mobility index (travel/inhabitant/day) as per the urban mobility information system of the Associação Nacional de Transporte Público [National Association of Public Transport] (ANTP).

Figure 41 – Evolution of the mobility index

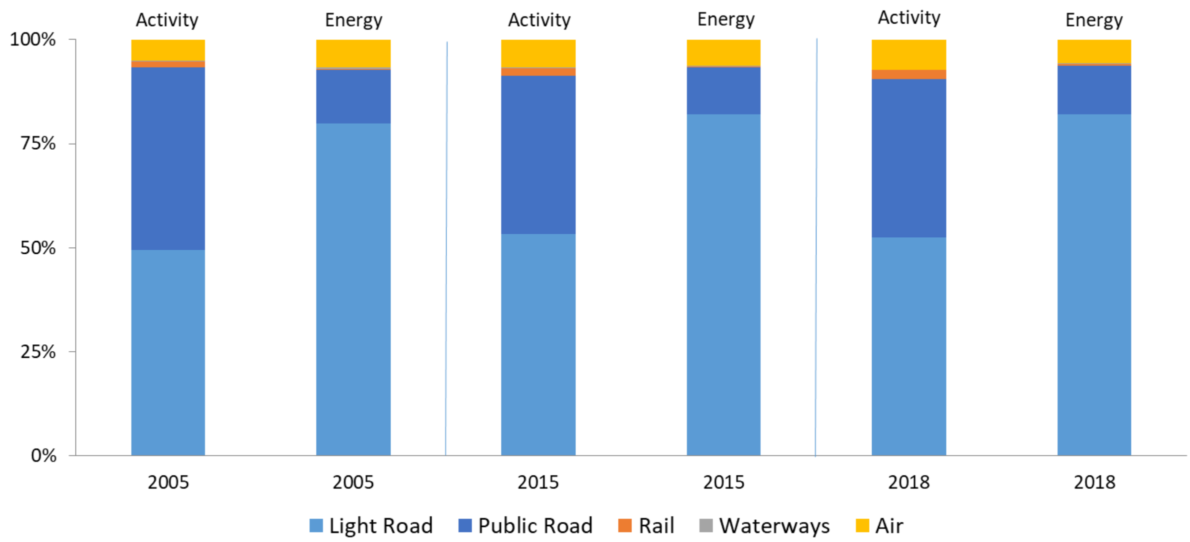


Source: Compiled from ANTP (2016)

According to ANTP (2016), the distribution between public transport (municipal buses, metropolitan buses, rail), individual transport (motorbike, automobiles), and non-motorised transport (walking, bicycle), did not change significantly between 2003 and 2014. However, the position of individual to public transport reversed. In 2003, collective transport was the second mode of transport on aggregate, accounting for 30% of journeys. By 2016, individual transport occupied second place, accounting for 29% of journeys. The expansion of motorbikes, for which the share in the mobility index went from 2% to 4%, contributed to this result (ANTP, 2016).

Passenger mobility is mainly achieved by means of road transport, which is reflected both in terms of energy and in passengers transported, as shown in Figure 42.

Figure 42 – Development of activity and energy consumption by passenger transport segment



Source: compiled by EPE

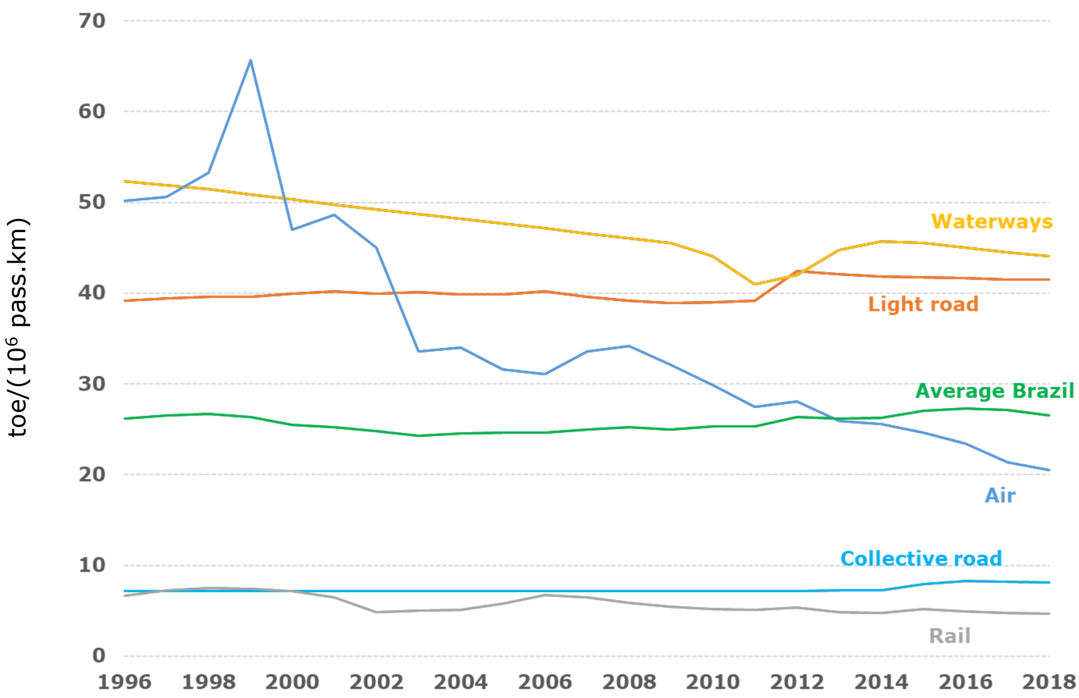
Note: Activity is measured in passenger-kilometres (p.km), and energy is measured in tonnes of oil equivalent (toe). The transport mix above did not take into account passenger transport by bicycle or on foot - it only included motorised transport.

Light duty vehicle road transport activity increased significantly between 2005 and 2015, alongside aviation transport activity, with growth following the increase in the average per capita income of the population, despite falling back slightly with the onset of the financial crisis in 2014.

The development of the energy efficiency of rail over the period is also worthy of note. Despite the growth in passenger transport activity between 2005 and 2018, and the increase in rail's share from 1.5% to 2.1%, the share of rail transport in total energy consumption increased by only 0.1%.

Finally, to analyse the energy efficiency of each transport mode, Figure 43 presents levels of energy intensity by mode.

Figure 43 – Energy intensity of each mode of passenger transport in Brazil



Source: compiled by EPE

It is important to note that, in general, passenger transport has not made significant advances in efficiency. As seen above, light duty road transport remains the most energy intensive mode of ground transport.

Public transport, on the other hand, is efficient in terms of energy intensity, given the improvements that have occurred in recent years in engine technology and in average occupancy rates. Recently, and especially in large cities, there has been growing concern about the certification of buses. Cities like Rio de Janeiro and Sao Paulo have required new bidders to buy vehicles with items such as automatic gear shift and air conditioning, in order to offer greater comfort to the population. These adaptations have led to a reduction in the average efficiency of buses. In addition, the economic crisis reduced the total number of journeys (ANTP, 2017) (SP, 2019), especially because of the increase in unemployment. Moreover, the spread of individual mobility apps, especially those in which passengers share the use of a car, also reduced the number of bus users (QUEST, 2019). These two events have both contributed to the increased energy intensity of this mode of transport.

In the case of rail, despite investment cycles in some periods of Brazilian history, the network has always been restricted to a few regions, given technical restrictions such as the difference in gauges and the lack of integration between branches.

According to data from the Confederação Nacional do Transporte [National Transport Confederation] (CNT, 2018), the current rail network is approximately 31 000 kilometres long, with the networks operated for passenger transport in São Paulo (CBTU) and Rio de Janeiro (Supervia) accounting for around a thousand kilometres. Between 2009 and 2017, the number of passengers transported averaged 1.27 million, albeit with a slight reduction of 0.5% per year over the period.

With regard to passenger rail, some investments have been made in recent years in the expansion of high- and medium-capacity rail systems such as subways, urban trains, light rail transit (LRT), and monorails, in addition to a gradual increase in transport capacity in the systems already in operation. With new more energy efficient equipment, there has been a reduction in energy intensity, but these gains have been tempered to a certain extent by the same factors noted for passenger road transport.

For aviation passenger transport, there has been strong growth in travel due to increases in the Brazilian population and in per capita income, and also due to investments to improve airport infrastructure. In 2008, 43.9% of passengers on long-distance inter-state journeys were transported by air, while road transport accounted for 56.1%. In 2017, aviation passenger transport catered to 67.5% of the passengers in this market (ANAC, 2019), indicating greater activity in the sector. It is important to highlight that there was also a reduction in energy intensity, which indicates efficiency gains.

5.3.1 Light duty vehicles

The Associação Nacional dos Fabricantes de Veículos Automotores [National Association of Automotive Vehicle Manufacturers] (ANFAVEA) reports the number of cars sold each year, as shown in Table 11. From 1996 to 2010, growth was considerable, adding up to 98.9%. Another noteworthy period was 2010-18, when annual sales were affected by the economic and political crisis in the country, falling by 25.6%.

Table 11 – Licensing of light duty vehicles

Sales [units]	1996	2000	2005	2010	2015	2018	2018/1996
New light vehicles	1 673 136	1 403 644	1 619 840	3 329 029	2 480 533	2 474 356	+1,8%/year

Source: ANFAVEA (2019)

Between 2000 and 2018, the fleet of light duty vehicles in Brazil grew on average by 4.5% per year, reaching 37.1 million units. Within this total, flex-fuel vehicles, which entered the market in 2003, accounted for around 76.4% in 2018 (see Table 12).

Table 12 – Brazil's automotive fleet[16]

Fleet	2000	2003	2005	2010	2015	2018	Δ% per year (2018/2000)
Quantity [million units]	16.7	18.4	19.6	27.0	*35.9*	45.2	+4,5%
% of flex-fuel vehicles	0.00	0.26	6.03	45.15	*69.15*	76 .38	N.A.

Source: EPE (2019b)[17]

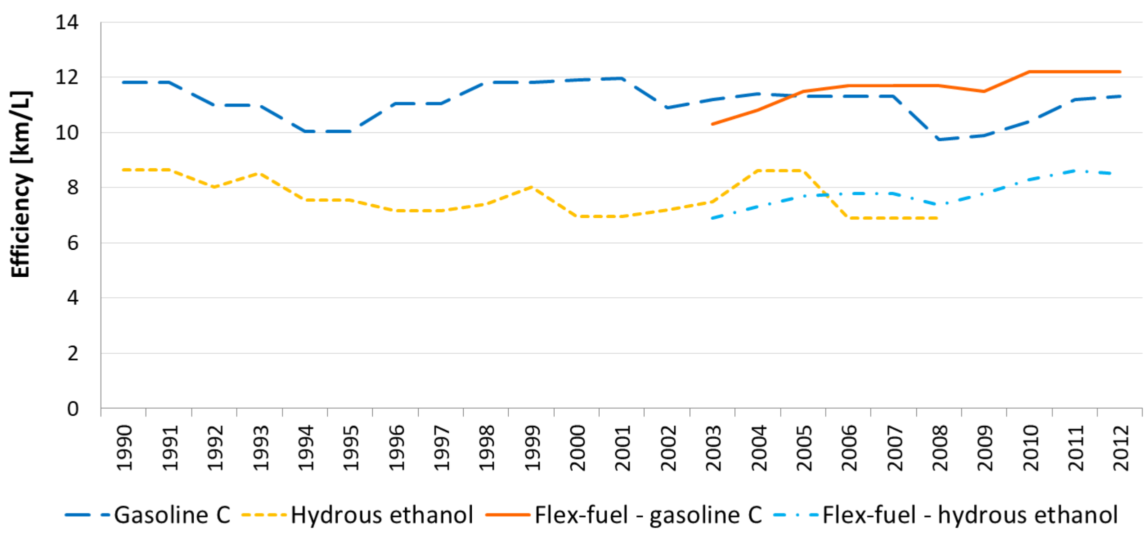
5.3.2 Performance of light duty vehicles

As mentioned above, analysis of energy efficiency in the transport sector is difficult to perform as it involves diverse parameters and the monitoring of their development, including specific consumption in kilometres per litre [km/L] per vehicle type.

The development of the average performance of the light duty vehicle fleet is not only influenced by improvements stemming from the introduction of new vehicles, but is also a function of factors such as, among other aspects: the way that drivers drive, the state of maintenance of vehicles and roads, and environment and intensity of use.

Figure 44 presents a historical breakdown of estimated vehicle performance, differentiating the type of vehicle and the fuel used.

Figure 44 – Development of the efficiency (specific consumption) of light duty vehicles



Source: MMA (2014)

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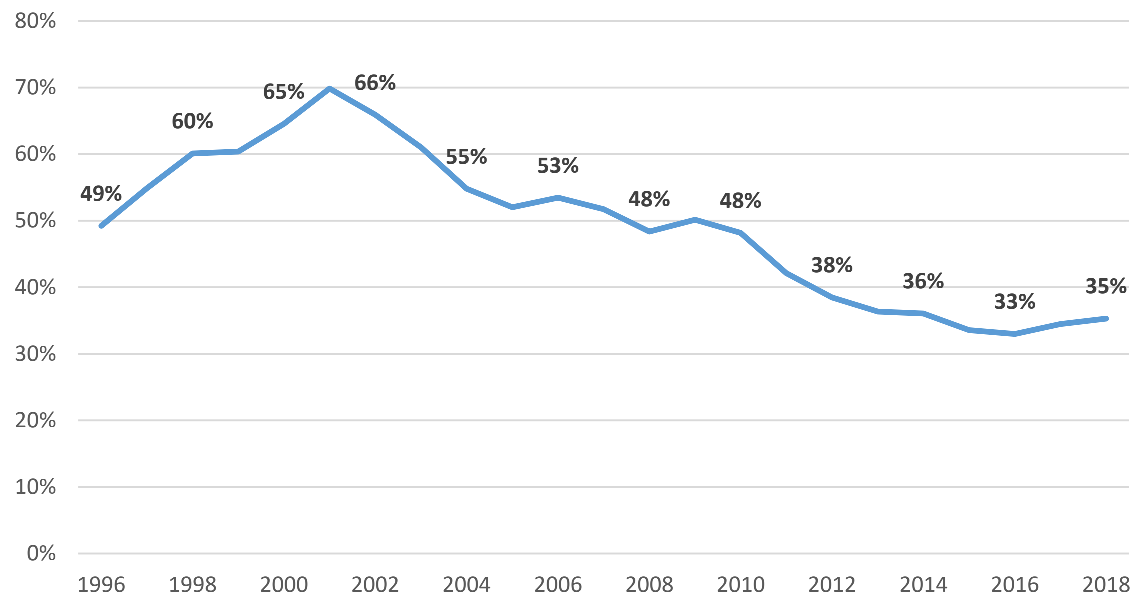
[16] Includes cars and light commercial vehicles.

[17] There is currently no consensus in Brazil on the national car fleet, due to uncertainty regarding vehicle scrapping over the years. The EPE studies the issue and employs a typical vehicle scrapping curve.

There was a 17% in increase in the efficiency of flex-fuel vehicles between 2003 and 2009, from 10.3 km/L to 12 km/L when consuming gasoline. In the same period, gasoline vehicles showed a 15% reduction in efficiency, falling to 9.5 km/L in 2009.

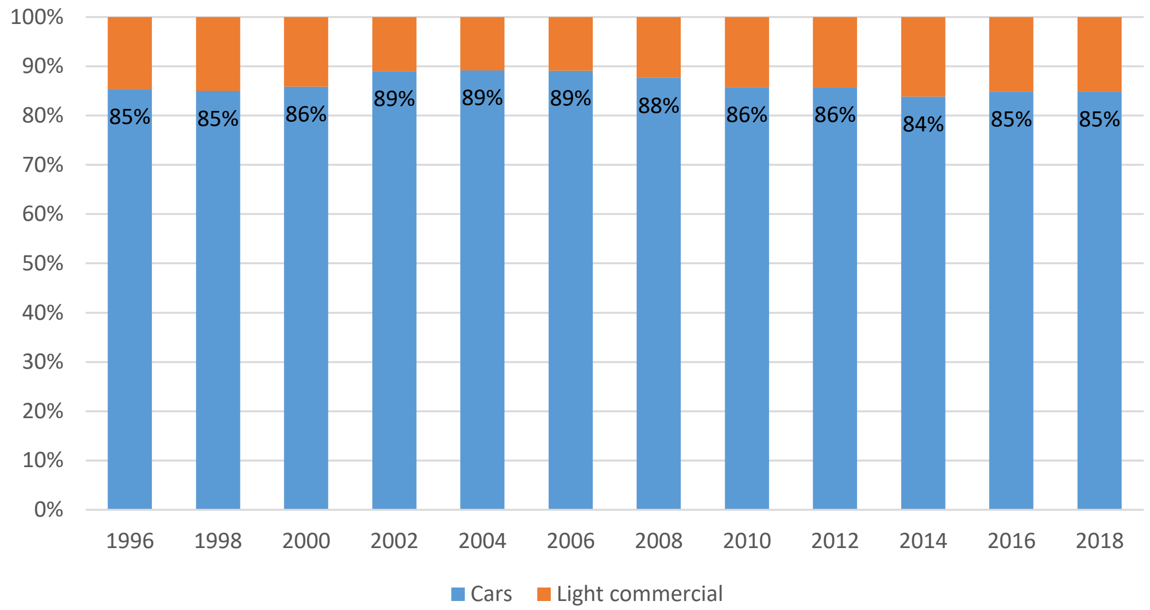
In order to analyse average vehicle efficiency, it is important also to take into account the reduction in sales of 1 000 cc cars from 2001 onwards, and the increased share of sales both of vehicles with bigger motors (Figure 45) and of light commercial vehicles (Graph 46), which tend to consume more fuel by distance travelled.

Figure 45 – Share of 1000 cc cars in the total licensed fleet



Source: ANFAVEA (2019)

Figure 46 – Proportion of light commercial vehicles and automobiles in the licensing of light vehicles



Source: ANFAVEA (2019)

Dedicated energy efficiency programmes and policies have been introduced in Brazil, with specific measures for the transport sector, and these have improved the indicators for the sector, albeit modestly. Following the launch of the Programa Brasileiro de Etiquetagem Veicular [Brazilian Vehicle Labelling Programme] (PBEV) in November 2008, the range (km/L) of new Otto cycle vehicles for sale on the domestic market began to be measured in the laboratory, with standard urban and open-road driving cycles, and with commercial fuels (gasoline C, hydrous ethanol and natural gas). The main objective of the programme was to enable consumers to compare the energy efficiency of vehicles in the same category, thus helping to reduce information asymmetry in the market (INMETRO, 2016).

The development of the PBEV programme made it possible to enhance the analysis of the average specific consumption of new vehicles sold in Brazil. However, given the level of detail in the statistics that it produces, analysis of the impact that these vehicles actually have on the average specific consumption of the new vehicle fleet ideally requires the same level of detail for new vehicle sales, something that is not always possible. For example, two vehicles in the same category and of the same make and model, but that are different versions, may result in different classifications, depending on the gear transmission, whether or not air conditioning is used, the type of power steering, and the type of engine used (gasoline, ethanol or flex-fuel).

In its first edition, published in 2009, PBEV included the voluntary membership of five brands and 54 models/versions of vehicles. In its sixth edition, which was published in 2014, the programme had considerably increased its scope, with the addition of 36 brands and 496 models/versions. In 2017, the ninth edition of PBEV was launched, in which cars from 33 brands were listed, and which encompassed a total of 864 models and versions.

It is also worth noting that the considerable increase in manufacturers' membership of the scheme in recent years was driven by a Federal Government programme created in 2012, entitled Inovar-Auto, which created tax incentives designed, among other things, to improve the energy efficiency of vehicles. To benefit from the incentives, manufacturers had to adhere to PBEV and, in the medium term, meet energy efficiency standards across their product line (CETESB, 2012).

The Inovar-Auto automotive scheme ended in December 2017, with all vehicle manufacturers operating in Brazil approved as part of the programme. Compared to the car fleet licensed in 2012, cars sold in Brazil in 2017 had cut aggregate fuel consumption by 15.9%.

The current cycle of automotive policy began in January 2018 under the name “Rota 2030”, or Route 2030. The programme, which is based on Law 13 755/2018, follows a similar strategic line to Inovar-Auto, but the main focus is to encourage research and development (R&D) projects throughout the industrial supply chain, including auto-parts manufacturers and strategic systems for vehicle production. It is, therefore, not limited to auto-makers.

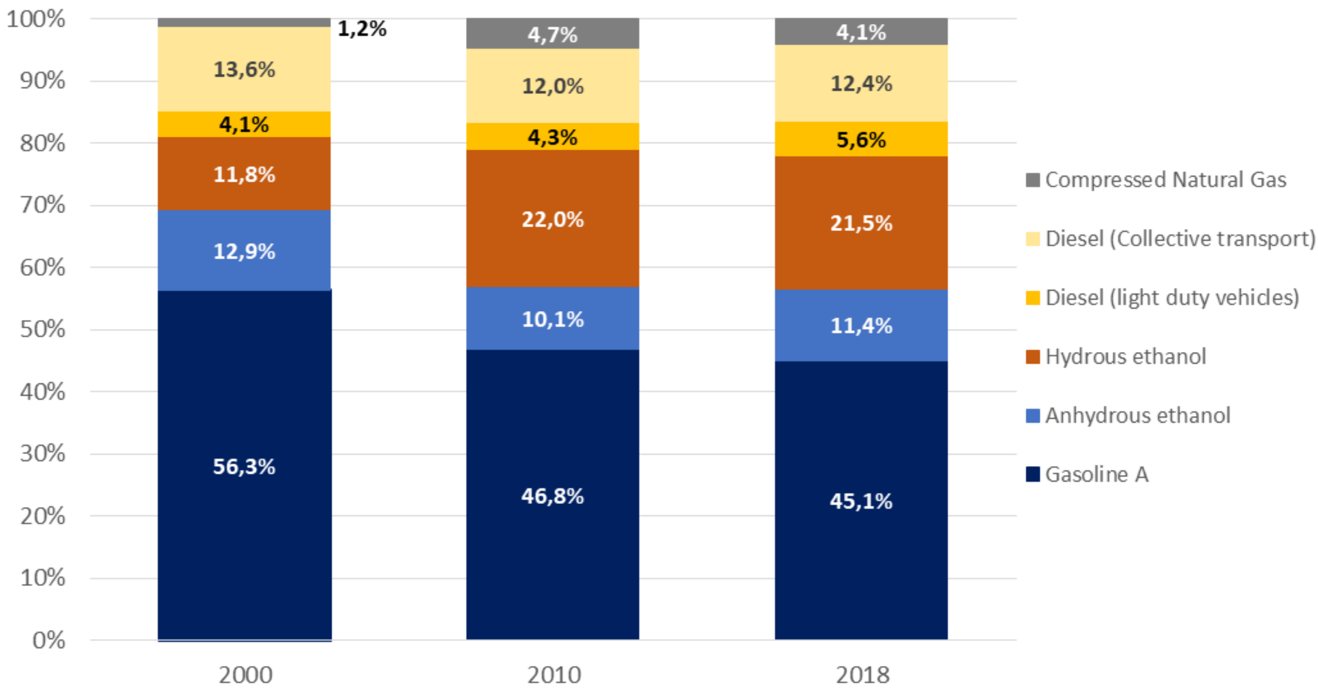
The programme's guidelines are: (i) to establish mandatory requirements for the sale of vehicles in Brazil; (ii) to increase energy efficiency, structural performance and the availability of assistive technologies; (iii) to increase investments in R&D in the country; (iv) to stimulate the production of new technologies and innovations; (v) to automate the manufacturing process and increase productivity; (vi) to promote the use of biofuels and alternative forms of propulsion, and to add value to the Brazilian energy mix; (vii) to guarantee technical training and professional qualification in the mobility and logistics sector; and (viii) to guarantee that the level of employment in the mobility and logistics sector will either expand or remain stable.

There are some prerequisites for accessing Rota 2030 tax incentives, such as making an actual profit, having an R&D cost centre, being current on Federal taxes, and making minimum investments in R&D.

5.3.3 Final consumption in passenger transport

Figure 47 shows the development of final fuel consumption in passenger transport between 2000 and 2018. During this period, the advent of flex-fuel technology in light duty vehicles showed up in the increase in demand for hydrous ethanol, whose share grew from 11.8% to 21.5%. Also of note is the expansion of CNG, which is used in vehicles that have been converted with the installation of a CNG kit (equipment that allows the use of this fuel in parallel with gasoline and/or ethanol), and which is competitive mainly for vehicles that travel long distances on a daily basis and that receive local tax benefits (IPVA discounts, for example).

Figure 47 – Development of fuel[18] consumption by light duty vehicles and buses



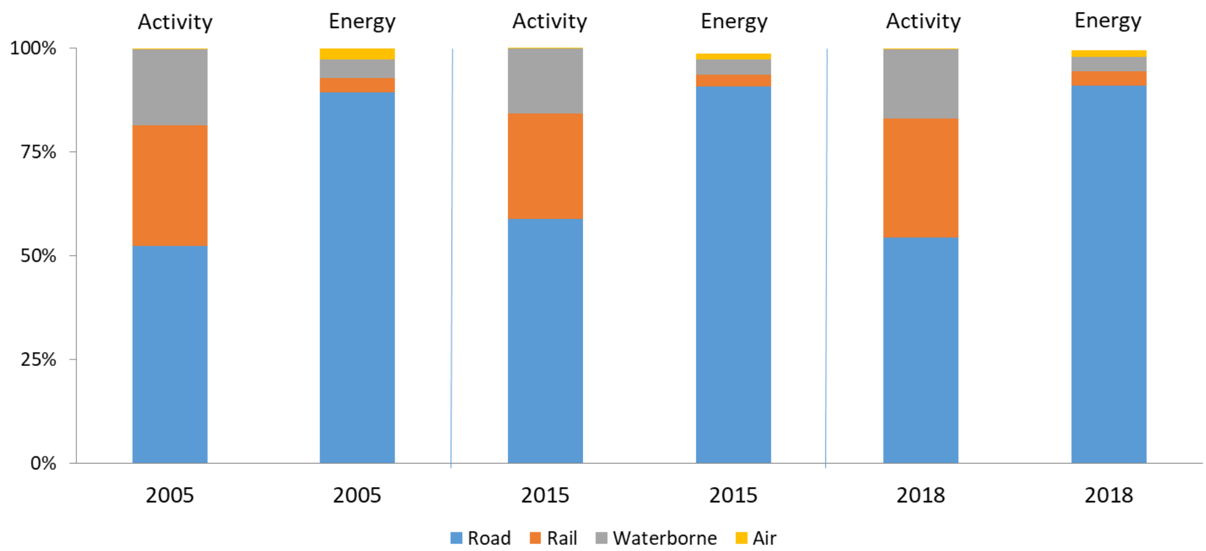
Source: EPE (2012), EPE (2019a)

5.4 Development of freight transport

Freight transport represents approximately 40% of energy demand in the Brazilian transport sector. Although rail and waterways play a role in freight transport in Brazil, as well as in passenger transport, the Brazilian freight transport sector is based mainly on roads. As can be seen in Figure 48, its share is over 50%, having increased from 52% in 2005 to 59% in 2015.

[18] It is assumed that the fuels consumed in road transport were used entirely in passenger transport, except for diesel, whose consumption was broken down between collective (buses), light (light commercial vehicles, e.g. vans and pickup trucks), and freight, using NT estimates. SDB-Abast No. 1/2012.

Figure 48 – Freight transport: development of activity and energy consumption by sector



Source: Compiled by EPE

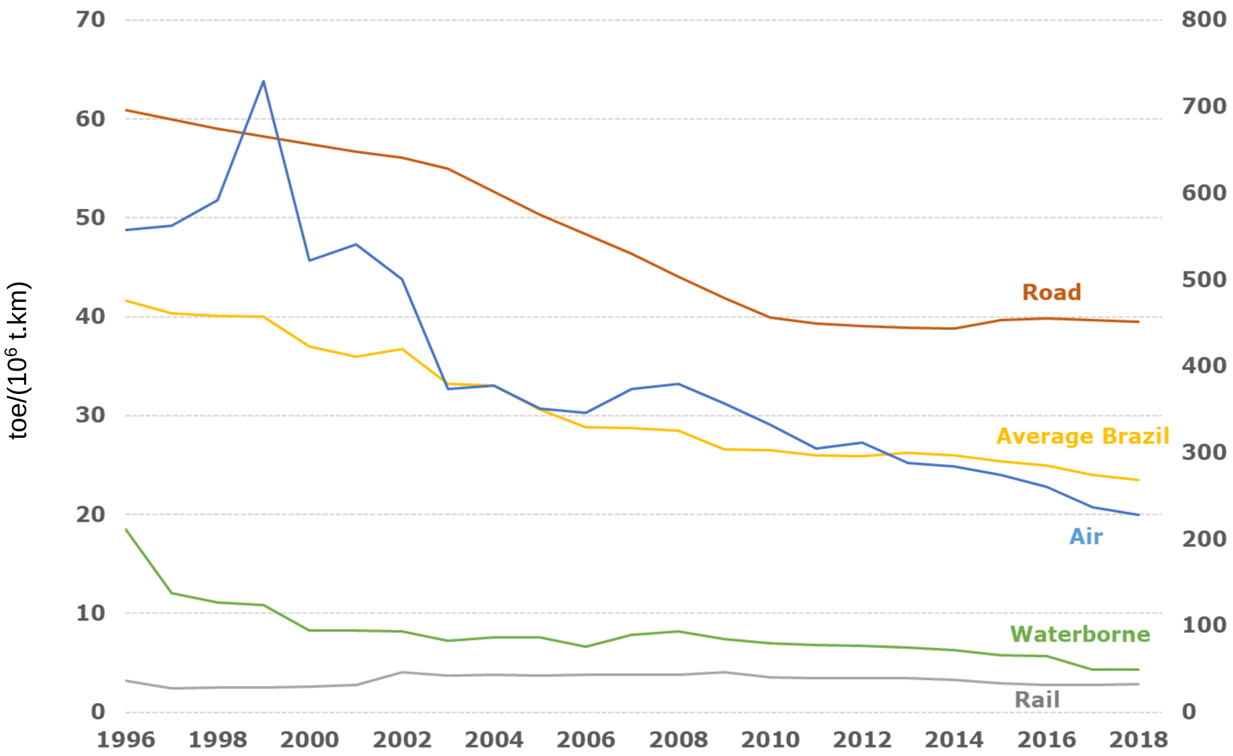
Note: Activity is measured in tonne-kilometres (t.km), and energy is measured in tonnes of oil equivalent (toe). The transport mix outlined above did not take into account pipeline transport, which the National Energy Balance methodology considers to be part of industrial consumption. It also did not take into account the transport of cargo by bicycle, which, although relevant at the last link in the chain, is not significant for the country in terms of t.km, due to the smaller weight and shorter distances involved.

The transport of freight by road is the most versatile mode, as it can be used for all segments of the production chain, and it is the only mode of transport that is able to deliver products to end customers. Aviation transport is very energy intensive. It has a very high unit cost, is commercially viable only for products that are lower in weight and high in added value, and accounts for a low share of the freight transport mix. It should also be noted that rail and waterways are the most efficient means of transport in terms of energy use. However, although these characteristics represent logistical advantages, these modes of transport have seen their share of the overall mix decline over the years, as priority has been given to the development of the road sector. Finally, it is also worthy of note that infrastructure investments in waterways, ports and rail are long-term investments, and their implementation and/or expansion would represent significant changes in Brazil's national infrastructure.

Throughout the 2000s, given the government's improved fiscal situation and Brazil's macroeconomic stabilisation, which was associated with the commodity boom that boosted Brazilian exports, there was a gradual increase in government investments in transport infrastructure. Among the programmes in this regard were the Programa de Aceleração do Crescimento [Growth Acceleration Programme] (PAC), an investment programme that in 2007 included 970 transport infrastructure projects, of which 865 were for highways, 13 for railways, 23 for ports, 43 for waterways, and 26 for airports (PAC, 2007).

Figure 49 shows the development of the average efficiency of Brazilian freight transport over recent years.

Figure 49 – The energy intensity of each mode of freight transport in Brazil



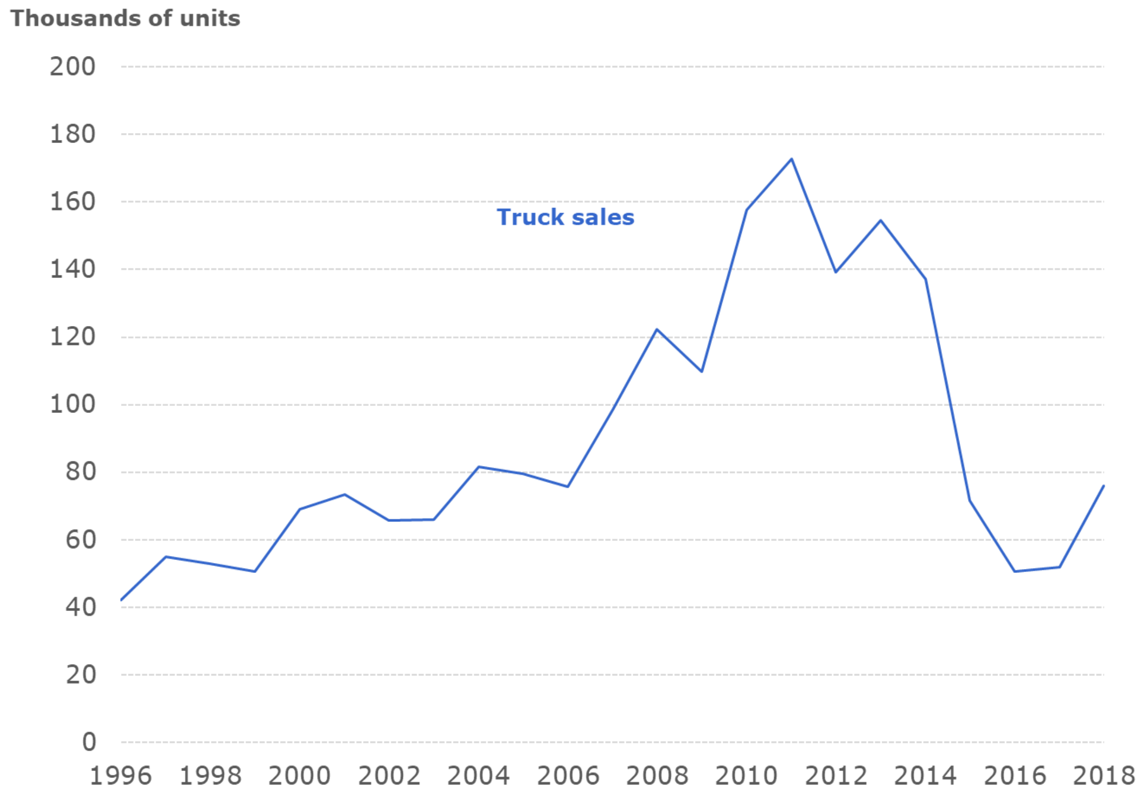
Source: Compiled by EPE

Note: Aviation transport is represented on the secondary axis, while the others are represented on the primary axis.

5.4.1 Freight transport by road

As previously mentioned, in the context of continuous growth in domestic demand and of increases in agricultural exports, civil construction and consumption, roads met the growing demand for freight transport. From Figure 50 illustrates that in response to this demand, there was a significant increase in the licensing of lorries, rising from 80 000 in 2005 to over 100 000 per year between 2008 and 2014, and falling back to 76 000 vehicles in 2018.

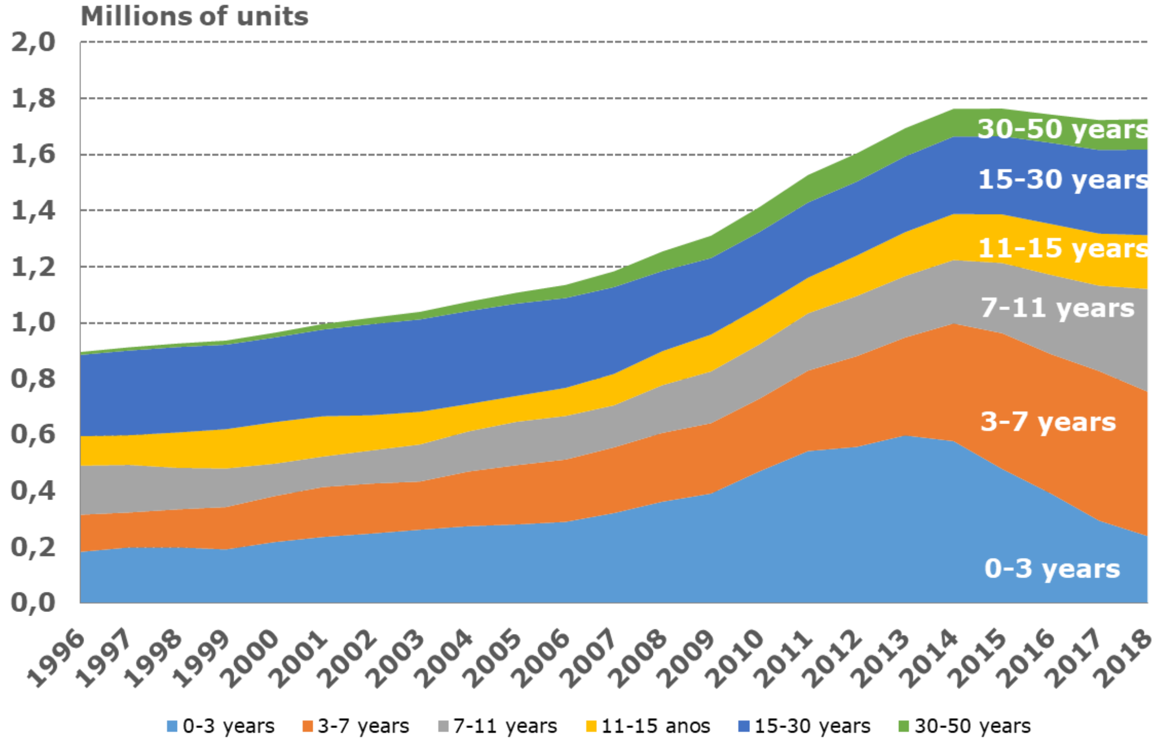
Figure 50 – Licensing of new trucks in Brazil



Source: compiled by EPE from Anfavea (2019)

Sales growth between 2005 and 2014 of around 6% per year increased the truck fleet from about 1.1 million vehicles to approximately 1.7 million.

Figure 51 – Estimated truck fleet by vehicle age



Source: compiled by EPE

The development of the truck fleet - at a rate of 3.5% a year between 2005 and 2018 - led to higher diesel consumption. The energy consumption of diesel for road freight went from 20 million toe to 30 million toe, growing by 3.2% a year. The small difference between growth rates can be explained by the greater share of new trucks in the Brazilian fleet, as shown in Figure 51.

Generally speaking, new trucks are usually more efficient than old ones, due to the wear and tear on used equipment, which worsens performance. Therefore, the increase in the number of new lorries in the Brazilian fleet that are equipped with new imported technologies, especially those coming from Europe, has contributed to improvements in the energy efficiency of road freight transport.

It is worth noting that the efficiency of new trucks has also improved significantly in Brazil due to the gradual increase of restrictions on atmospheric emissions. In this context, the Conselho Nacional de Meio Ambiente [National Environment Council] (Conama[19]) has sought to expand restrictions through the Programa de Controle de Emissões Veiculares [Vehicle Emissions

[19] The National Environment Council (Conama) is the consultative and deliberative body of the National Environment System - SISNAMA. It was created in 1982 through Law No. 6.938/81. Regulated by Decree No. 99.274/1990. Its purpose is to advise, study and propose to the Governing Council government policy guidelines for the environment and natural resources.

Control Programme] (Proconve). Part of the increase in energy efficiency stems from the implementation of the Proconve P-5 programme (corresponding to Euro III) as of 2005/2006 (IEMA, 2015).

Finally, structural improvements to some of Brazil's main highways[20] have come from highway concessions. Concession operators are obligated to widen and maintain these roads, which has also contributed to the increase in the energy efficiency of road freight transport.

5.4.2 Freight transport by rail

Aside from road transport, another important factor in improving energy efficiency in transport has been the recent increase in rail in the national mix. Despite large investments in the rail sector, only a few projects have actually come online, including the central section of the Ferrovia Norte-Sul [North-South Railway] (FNS). Yet the northern section[21] in particular has helped with the transport of agricultural commodities from the Centro-Oeste [Centre-West] region's grain-producing areas, due to the interconnection with the Estrada de Ferro Carajás [Carajás Railroad] (EFC).

When it comes to the efficiency of equipment, however, it is not possible to infer efficiency gains in trains for the period between 2005 and 2018.

5.4.3 Freight transport by waterway

Despite the potential in Brazil, which has the largest continuous navigable coast in the world, coastal transport does not account for a significant share of the national transport mix.

While various government policies since the year 2000 have encouraged the expansion and establishment of new shipyards, with the manufacture of new vessels, and consequent reduction in the average age of the fleet, the volume of cargoes carried by coastal transport is still relatively low. This is despite an increase in port traffic in the oil sector - due notably to the increased production of pre-salt oil. It is not possible to observe more significant gains between 2005 and 2018 either in the average efficiency of equipment (vessels), or in systemic

[20]Among the various stretches of road that have been awarded as concessions, parts of the BR 101, BR 116 and BR 040 highways are notable examples (MInfra, 2019).

[21] A stretch located between Palmas and Açailândia, awarded as a concession in 2009, and which started operating in 2012. In 2018, this stretch of the Ferrovia Norte-Sul (FNS) alone moved 2% of all railroad activity in Brazil and had a significant impact on freight transport in Brazil. With the doubling of 559 km out of 892 km of the railway, its flow capacity reached 230 million tonnes. Between 2013 and 2018, the railway's activity increased from 52 billion t.km to 184 billion t.km. This represented 13.5% of the activity on all modes of transport in Brazil in that year. This increase was made possible not only by the duplication of the line, but also by investments made in the port terminals connected to the railway (MInfra, 2019).

efficiency, given the low contribution of this mode of transport to the overall transport mix in Brazil.

5.4.4 Freight transport by air

Air transport is one of the main contributors to the high atmospheric emissions of the transport sector. Due to the high energy intensity of this sector, a lot of effort has been directed internationally into reducing emissions. In 2009, in addition to targets for cutting emissions, the International Air Transport Association (IATA) announced, in addition to emissions reduction targets, improvements to the average energy efficiency of aircraft of 1.5% per year from 2009 to 2020 (IATA, 2009). With new aircraft that have better aerodynamics and engines, this goal is achievable. Increasing computerisation and new communication systems, have also allowed airlines to optimise their processes, increasing aircraft occupancy in Brazil and reducing the energy intensity of aircraft.

5.4.5 Final energy consumption in freight transport

Despite the heavy reliance on road transport, which has a relatively high energy intensity, total energy intensity in freight transport in Brazil has fallen, especially due to the introduction of new technologies, which co-exist with conventional technologies.

In order for there to be a significant reduction in total energy intensity, and an increase in the energy efficiency of freight transport, a balanced and efficient transport mix is essential. This requires the introduction of new and more efficient technologies, and an increase in investments - both in the maintenance of existing infrastructure and in expansion projects - to increase the overall share of less energy-intensive modes of transport such as rail and waterways.

6. AGRICULTURAL SECTOR

6.1 Overview of the sector

In the period between the last two agricultural censuses (2006 and 2017), which were conducted by IBGE, the crop-cultivation sector stood out for its growing production of soybean, while livestock farming stood out for an increase in the production of poultry. The agricultural sector's relative share of the Brazilian energy mix remained at around 4.7% between 2000 and 2015 (Table 13). This share fell from 4.7% in 2015 to 4.3% in 2018, along with a reduction in the production of the main crops (except soy), and in the size of the cattle herd.

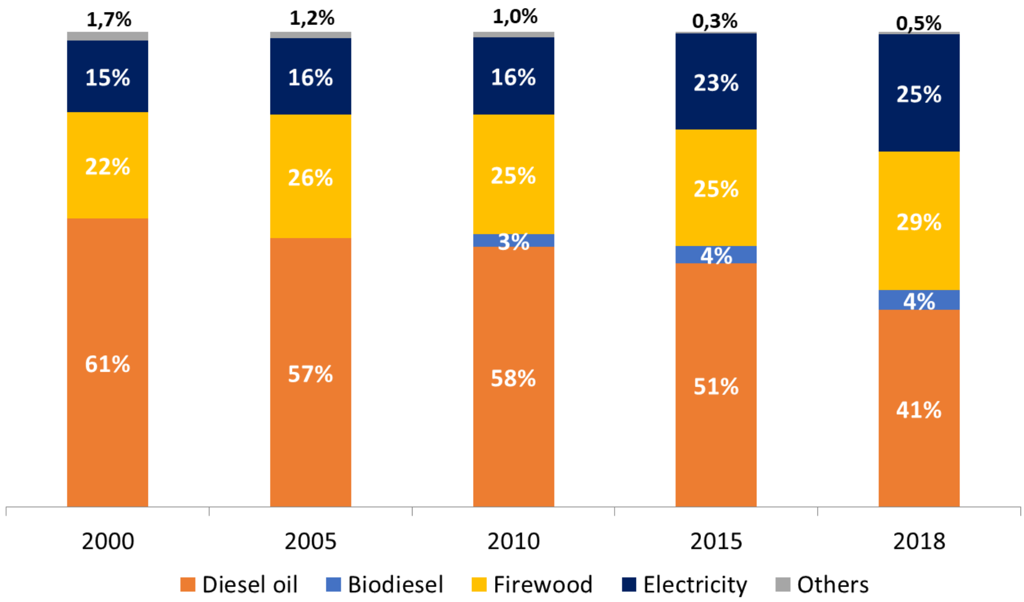
Table 13 – Final energy consumption in the agriculture sector

Agriculture sector	2000	2005	2010	2015	2018
Final consumption of the sector [10^3 toe]	7.322	8.361	10.010	11.451	10.439
Share of final energy consumption	4.7%	4.6%	4.5%	4.7%	4.3%

Source: EPE (2019a).

Diesel oil (blended with biodiesel), electricity, and firewood are the main energy sources used in the agriculture sector. In addition, demand for agricultural energy includes, in smaller proportions, LPG, charcoal, and fuel oil. These are added together under "other" in the Figure 52.

Figure 52 – Agricultural sector: final energy consumption by source



Source: EPE (2019a)

Although diesel's share fell between 2000 and 2018, as seen in Figure 52, fuel remains the main energy source of the agricultural sector at the national level, accounting for 4.332 million toe in 2018. Biodiesel, which has been blended with diesel since 2010, reached 4% of final consumption by source in 2018 (i.e. 435 000 toe).

Within the energy mix of the sector, the level of firewood consumption increased from 1.638 million toe in 2000 to 3.054 million toe in 2018. In terms of its overall share of the energy mix for the sector, the firewood used for the drying and processing of grain displayed a trend of growth between 2000 and 2018, rising from a 22% to 29% of the total in 2018. In the same period, electricity's share grew from 15% to 25%, mainly due to irrigation systems in agriculture and refrigeration in the livestock sector.

6.2 Current policies

Agriculture policies seek to ensure that rural producers are able to expand their activities and competitiveness, and to enjoy greater integration with the international market. Data from the IBGE Agricultural Census show that the area of agricultural establishments has expanded since the last survey in 2006. In 2017 it covered more than 350 million hectares - roughly 45% of the country. This area was distributed between temporary and permanent plantation areas, natural and planted pastures, and natural and planted forests. According to data from the IBGE's Pesquisa Pecuária Municipal [Municipal Livestock Survey] (PPM), stock numbers - in head of livestock (which includes totals for cattle, pigs and poultry) - also increased at high rates of around 2% a year between 2000 and 2018.

There are a number of programmes and policies in place under the Plano Agrícola e Pecuário [Agricultural and Livestock Plan] (PAP) for 2019-20 that can contribute to energy efficiency in the sector. Among the main ones are Agricultura de Baixo Carbono [Low-Carbon Agriculture] (ABC), MODERAGRO, MODERINFRA, MODERFROTA, Prorenova Rural, Pronaf, Pronamp, PCA and INOVAGRO, whose objectives were presented in EPE (2017).

According to the 2017 Census, however, only 15% of agricultural establishments had accessed any of the funding made available for investment, funding, marketing and/or maintenance. For under half of these 784 228 establishments, only one line of financing[22] is relevant in terms of their participation in these programmes (with almost 80% of

[22] Pronaf (National Programme for Strengthening Family Farming): the Pronaf Agro-industry sub-programme provides financing that targets the implementation, expansion or modernisation of production infrastructure, processing, industrialisation and services in rural businesses or nearby rural community areas, aiming at income generation and improvements in the use of family labour.

establishments participating), notwithstanding the range of different rural-development initiatives available at the federal, state and municipal levels.

6.3 Analysis of final energy consumption indicators by segment

The recent level of agricultural development in the country contrasts with the objectives established by current policies, given recent consumption levels of diesel, electricity and firewood. In the future, satisfactory results from programmes may change the trend of energy consumption for the farming of crops and livestock.

Electricity consumption exclusively for agricultural use has been on an upward trend. This can be observed in Table 14, which shows the development of electricity demand in the agricultural sector.

Table 14 – Electricity demand in the agricultural sector

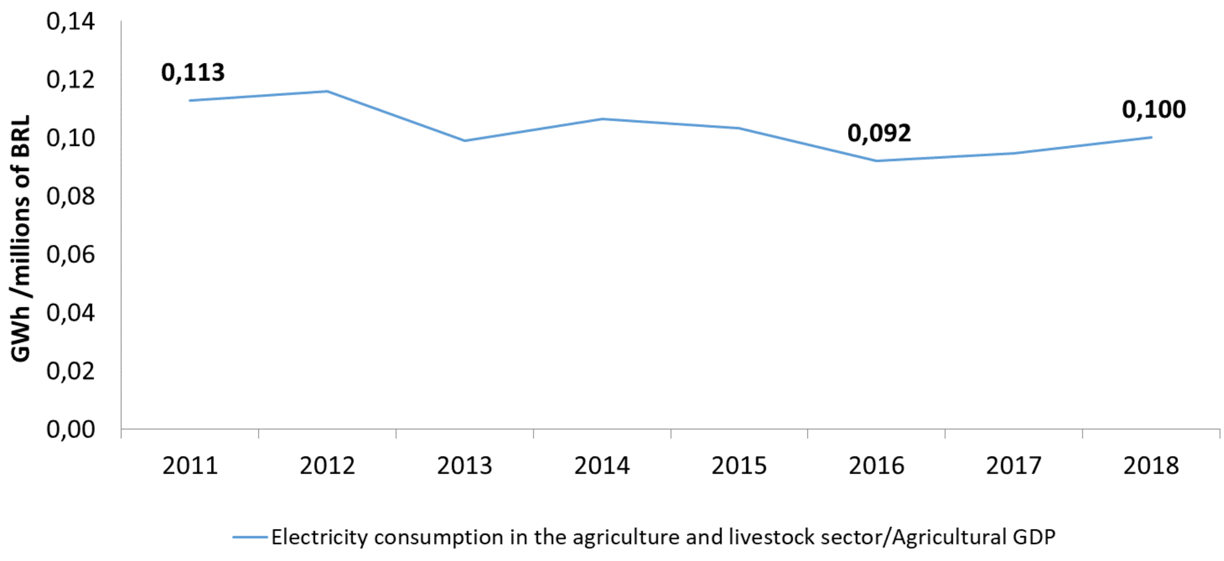
Year	2011	2012	2013	2014	2015	2016	2017	2018
Brazil (GWh). Agriculture	21 460	23 268	23 786	26 581	26 790	28 242	28 736	29 844

Source: compiled by EPE

From these data, it is possible to create a value-added indicator for electricity consumption for this sector.

Figure 53, which shows the electrical intensity, displays a decreasing trajectory of this indicator since the year 2011. Figure 54, which is more comprehensive, shows a decreasing energy intensity since 2000.

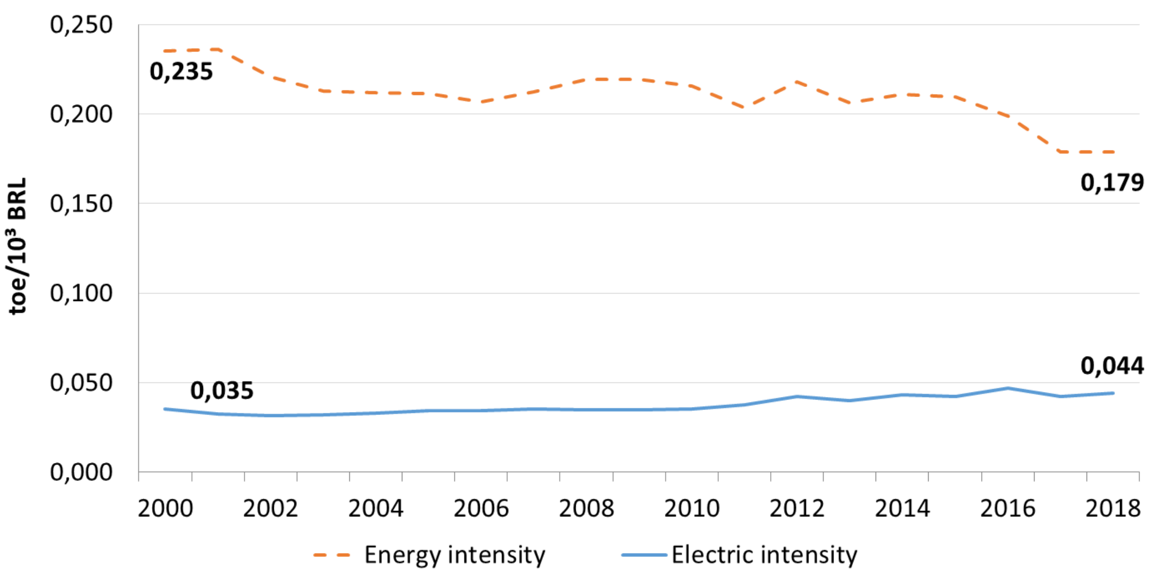
Figure 53 – Electricity intensity in the agricultural sector



Source: compiled by EPE

As shown in the Figure 54, the ratio between total energy consumption and value-added declined between 2000 and 2018, which is to say that agricultural energy intensity fell from 0.235 toe/10^3 BRL to 0.179 toe/10^3 BRL.

Figure 54 – Energy intensity and electrical intensity in the agricultural sector



Source: EPE (2019a)

In contrast to the energy intensity curve, electricity intensity has been on an upward trend, starting from 0.035 toe/10^3 BRL in 2000, and reaching the level of 0.044 toe/10^3 BRL in 2018. This can be explained by an intensification in livestock farming, which can be observed in the relative growth in poultry and pig farming. In this sense, there is a trend towards higher final energy consumption than that for cattle raising, which extends across a large part of the country.

6.3.1 Crop farming

Table 15 shows the increase in crop production in Brazil, which has essentially been a function of the increased productivity, stemming in part from the increased mechanisation of crop farming. Meanwhile, the growth of cultivation in less suitable areas has increased the need for irrigation in order to maintain this trend of productivity growth.

Table 15 – Development of harvests for selected items

Production 10^3 tonnes	2000	2005	2010	2015	2018	∆% per year. (2018/2000)
Sugar cane	326 121	422 957	717 464	750 290	746 828	**4.7%**
Maize	32 321	35 113	55 364	85 283	82 288	**5.3%**
Soybean	32 821	51 182	68 756	97 465	117 888	**7.4%**
Rice	11 135	13 193	11 236	12 301	11 749	**0.3%**
Wheat	1 726	4 659	6 171	5 508	5 419	**6.6%**

Source: IBGE (2019b)

The crop whose production has increased the most since 2000 is soybean, with an average annual growth of 7.4%. Wheat appears in second position, registering an increase of 6.6% per year. Maize, sugarcane and rice showed respective gains of 5.3%, 4.7% and 0.3% per year.

With the exception of rice (because of its reliance on irrigation), all the main crops shown in the table above showed a growth rate that exceeded the increase in energy demand for the agricultural sector overall.

The productivity indicator (quantity produced/planted area) suggests a fall in energy demand in the last year of the timeline, as shown in Table 16, for the production stages of crop-planting, crop-development, and harvesting in the cultivation of sugarcane, soybean, rice and wheat. However, it is apparent that there had already been higher levels of production in previous years for sugarcane and maize. This indicates that the energy efficiency of domestic agriculture increased over the timeframe of analysis for the country's five main crops, as illustrated below.

Table 16 – Agricultural indicator: productivity for selected crops

Agricultural yield [t/ha]	2000	2005	2010	2015	2018	∆% per year. (2018/2000)
Sugarcane	67.9	72.9	79.0	74.2	74.4	0.5%
Maize	2.7	3.0	4.4	5.5	5.1	3.6%
Soybean	2.4	2.2	2.9	3.0	3.4	1.9%
Rice	3.0	3.4	4.1	5.8	6.3	4.1%
Wheat	1.5	2.0	2.8	2.2	2.6	3.1%

Source: IBGE (2019b)

With regard to annual increases in agricultural productivity, sugarcane and soybean - with respective rates of 0.5% and 1.9% - performed below the level of wheat, maize and rice, whose yield indicators increased by 3.1%, 3.6% and 4.1% per year over the same two-decade timeframe. This indicates that the growth in the sugarcane and soybean harvests in particular occurred more because of the increase in the planted area than due to growth in productivity.

6.3.2 Livestock and poultry farming

Table 17 shows the development over time of Brazil's stocks of cattle, pigs and poultry. Of these, pig farming is the activity that has had the highest growth rate, registering an average increase of 1.7% per year. Poultry farming comes next, with approximately 1.5 billion head of birds in 2018. Cattle rearing stands in third position, with an average annual increase of 1.3%.

Table 17 – Development of selected stocks

Stock numbers [millions of head]	2000	2005	2010	2015	2018	∆% per year. (2018/2000)
Cattle	169.9	207.2	209.5	215.2	213.5	**1.3%**
Poultry	183.5	186.64	210.8	221.9	246.9	**1.5%**
Pigs	31.6	34.14	38.9	39.8	41.4	**1.7%**

Source: IBGE (2019c)

In livestock production, the intensification process has been very significant for poultry and pigs but practically non-existent for cattle. According to the latest IBGE Agricultural Censuses (2006 and 2017), there has been a large expansion in poultry and swine stocks, in contrast to the reduction in the cattle.

7. CONCLUSION

This Technical Note consolidates EPE's third work cycle in the development of the database of energy efficiency indicators, which represents a key step in the dissemination and discussion of national energy efficiency indicators in Brazil.

Energy efficiency practices can be one of the most effective strategies for meeting energy demand. Moreover, a number of benefits arise for society if waste is avoided and energy-based services are performed with lower inputs of energy. The end user benefits from lower energy costs, and there are gains in competitiveness and benefits for society as a whole, including a reduction in greenhouse gas (GHG) emissions.

Monitoring progress in energy efficiency is one of the elementary building blocks for identifying and directing appropriate measures in this regard. It constitutes a systemic approach that is necessary for the promotion of efficient energy use in Brazil.

In this context, the ODEX calculated in 2018 shows that the country became 14% more energy-efficient between 2005 and 2018, with the residential and transport sectors standing out with the largest gains.

Finally, it is important to highlight that building up a database is of fundamental importance in supporting energy efficiency measures. The collection, preparation and maintenance of statistical data related to energy efficiency in the country requires an institutional structure that is invested with this task - a body that makes sure to monitor the actual results of energy efficiency programmes, and to feed information into a database that interested parties can access freely. Furthermore, working more closely with the main actors in energy-consuming sectors is of utmost importance in improving the flow of information and enhancing its quality.

8. BENCHMARKING ENERGY EFFICIENCY – BRAZIL IN THE GLOBAL CONTEXT

8.1 Introduction

This is a joint chapter developed in cooperation with EPE and the IEA. It builds on analysis developed by both institutions to provide a global perspective on energy efficiency in Brazil. It focuses on three sectors: heavy industry, households, and light duty vehicles in transport.

The report comes at an important time. The IEA's 2019 Energy Efficiency Market Report (EEMR) finds that globally the pace of improving energy efficiency, as measured by energy intensity, is slowing. This represents a lost opportunity. In 2018, energy efficiency delivered USD 1.6 trillion more value in GDP for the same amount of energy compared to 2017. However, the global economy would have seen a further USD 2.6 trillion of economic output (for the same amount of energy) if the annual rate of improvement in energy intensity had remained at 3% since 2015.

Many factors affect energy intensity. These factors can be grouped into three categories: activity, structure, and efficiency. Globally, while we see continued efficiency improvements, they have not been strong enough to offset powerful activity and structural developments. This presents a call to action for policymakers around the globe to identify strategies to rapidly accelerate progress on energy efficiency.

This chapter provides an opportunity to pick up where the IEA's EEMR and the earlier chapters of this report leave off. It provides insights into the activity, structure and efficiency effects that influence the energy intensity of the industry, households and transport sectors in Brazil. By benchmarking Brazil with other countries, it provides perspectives that can inform policymakers on which countries are most similar in terms of structure, how Brazil compares in terms of energy intensity and where there are opportunities for exchange and improvement both in Brazil and in other countries.

The report draws on a number of sources in order to benchmark Brazil with other countries. As not all data reflect official country sources, there are some differences between the numbers in this chapter and official data from Brazil and other countries. To further enable benchmarking across countries, most indicators focus on the year 2017, for which more comprehensive data are available. Continuous data collection efforts across countries are needed to support this type of benchmarking analysis. We trust that this will be a first of many collaborations designed to advance effective policy through strengthening of data collection and analysis.

8.2 Summary of findings

Brazil has a long history of effective energy efficiency programmes. These include appliance standards and labelling, building codes and labelling, standards for industrial equipment, economic instruments including the PEE (Program for Energy Efficiency, Brazil's energy company obligation), and a range of other programmes under the Procel umbrella. These progammes are reflected in Table 18 alongside policy coverage in other countries. They place Brazil in a strong position to continue to progress on energy efficiency by building on existing programmes, updating codes and standards, and expanding programmes to areas that do not yet have mandatory coverage.

Table 18 – Mandatory energy efficiency policies in the G20

	National energy use or efficiency target	Mandatory policies							Other measures		
		Appliance standards	Industrial equipment standards	Residential building energy codes	Commercial building energy codes	Car fuel efficiency standards	Truck fuel efficiency standards	Mandatory industrial firm/sector actions	Market-based instruments	Financial or fiscal incentives	Information and capacity building
Argentina	Present	Present	Not identified	Not identified	Not identified	Not identified	Not identified	Not identified	Not identified	Not identified	Present
Australia	Present	Present	Present	Present	Present	Not identified	Not identified	Not identified	Present	Present	Present
Brazil	Present	Present	Present	Present	Not identified	Not identified	Not identified	Not identified	Present	Present	Present
Canada	Present	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present
China	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
France	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present	Present
Germany	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present	Present
India	Present	Present	Not identified	Present	Present	Present	Present	Present	Present	Present	Present
Indonesia	Present	Present	Not identified	Present	Present	Not identified	Not identified	Present	Not identified	Present	Present
Italy	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present	Present
Japan	Present	Present	Present	Present	Present	Present	Present	Present	Not identified	Present	Present
Korea	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present	Present
Mexico	Present	Present	Present	Present	Present	Present	Not identified	Not identified	Not identified	Present	Present
Russia	Present	Present	Not identified	Present	Present	Not identified	Not identified	Not identified	Not identified	Present	Present
Saudi Arabia	Present	Present	Present	Not identified	Not identified	Not identified	Not identified	Present	Not identified	Not identified	Present
South Africa	Present	Present	Not identified	Present	Not identified	Not identified	Not identified	Not identified	Present	Not identified	Present
Turkey	Present	Present	Present	Present	Present	Present	Not identified	Not identified	Not identified	Present	Present
United Kingdom	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present	Present
United States	Present	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present
European Union	Present	Present	Present	Present	Present	Present	Not identified	Present	Present	Present	Present

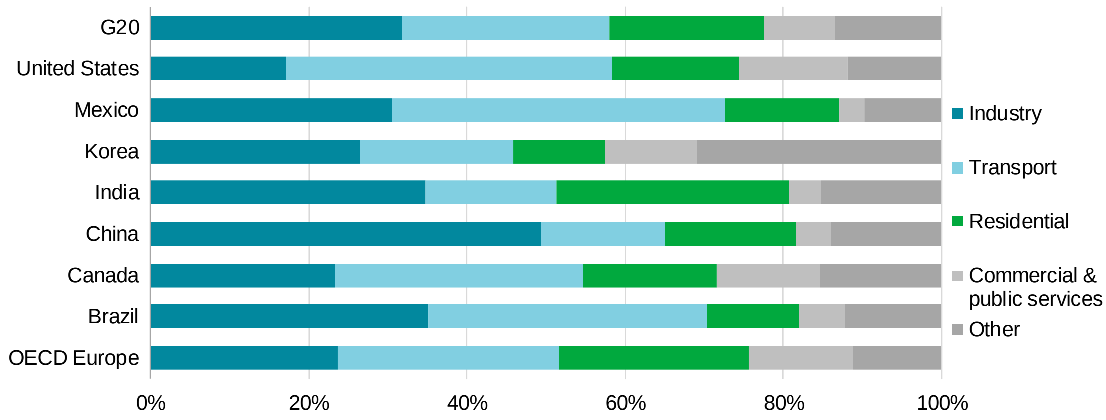
Present in some form

Not identified or not implemented

Source: IEA (2019a), Policies Database

The sectors covered in this report represented almost 80% of total final energy consumption in Brazil in 2017. Industry accounted for 33% of total final consumption in 2017, transport accounted for 33%, and households for 11% as shown in Figure 55.

Figure 55 – Total final energy consumption by sector, 2017



Sources: EPE (for Brazil) and IEA (2019b), World Energy Balances for all others

In order to advance towards achievement of the Sustainable Development Goals (which is the path presented in the IEA's Sustainable Development Scenario), all countries, including Brazil, would need to accelerate progress on efficiency. In Brazil, the following present some of the most important opportunities, based on the structure of the sector and progress already made on energy efficiency:

Industry

Brazil has made progress in several areas of industrial energy efficiency. Aluminium recycling rates are higher than the global average, and the cement sector has transitioned to dry process kilns for clinker production. Moreover, high shares of renewables power many industrial processes, and particularly pulp, paper, printing, food and tobacco reducing the environmental impact of production. Opportunities to further increase efficiency include increasing recycling and expanding energy efficiency learning networks and energy management systems in all energy-intensive sectors.

Households

Brazil has decades of experience with energy efficiency standards and labelling, as well as with programmes delivering energy savings among households. As ownership of household appliances grows, and household size increases, it will be important to continue to update and build on this policy framework. In particular, introducing a seasonal performance metric for air conditioners along with strengthened standards and labelling for buildings can ensure access to cooling while mitigating impacts on the electricity system and the environment.

Transport

The light duty vehicle fleet in Brazil is unique due to the high share of flex-fuel vehicles. At the same time, Brazil has structural similarities to other major emerging economies, including a large share of smaller, lighter, less powerful vehicles, which leads to a more fuel-efficient sector. As ownership of light duty vehicles grows, maintaining this structure of smaller vehicles, along with other improvements in fuel economy and “avoid-shift-improve” measures can help mitigate the impact on demand for fuel (both biofuels and imported petrol and diesel). An interesting point of investigation would be to compare, in detail, the fuel efficiency of similar vehicle types across emerging economies to identify opportunities for technological advancement. It is also important to note, as has been mentioned in earlier sections, that investment in alternative transport solutions such as bus and rail transport (including light rail and subways), as well as transport management strategies, are also important solutions to reduce the energy intensity of the sector.

Across all sectors, improving data collection and reporting internationally would be valuable to aid further benchmarking efforts. These efforts are a critical tool in understanding where the potential for energy efficiency lies, to set targets, and to measure savings. Moreover, such analysis can help understand the additional benefits of energy efficiency, such as job creation, competitiveness, increasing shares of renewable energy and strengthened energy security.

8.3 Industry

Summary

- In 2017, the industry sector represented 33% of the total final energy use in Brazil (EPE, 2019a). As in the other G20 countries assessed, there is significant potential in this sector for improving energy efficiency. In particular, more than 40% of the energy savings opportunities identified by the IEA's Efficient World Scenario[1] (EWS) in Brazil could be made in the industry sector (IEA, 2018a).
- Brazil's industry sub-sector energy use is characterised by a very high share of food and tobacco (representing 27% of industry final energy use) followed by the iron and steel, and pulp and paper sectors, representing 19% and 15% of industry final energy use respectively (EPE, 2019a).
- Brazil's high share of renewable energy in manufacturing energy use (63%) has the positive effect of reducing the environmental impact of heavy manufacturing, and particularly in the pulp, paper and printing, and food and tobacco sub-sectors.
- The high capital cost of equipment is a potential barrier to improving energy efficiency in energy intensive sectors. A dimension that could also be encouraged is the promotion of energy management systems and learning networks. These can ensure the introduction and sharing of best practices and help unlock savings potential in all sectors.
- Some good practices already in place in Brazil are aluminium recycling and dry process kilns for clinker production. Building on this experience to increase recycling in all energy intensive sectors, such as in the pulp and paper sector, could further increase energy efficiency. This is because production from recycled material requires several times less energy than primary production.
- These actions will have to rely on transparency and accessibility of energy performance and emissions data. Improving data collection and reporting internationally to aid further benchmarking efforts and quantify savings will be essential to value the benefits of improved energy efficiency.

This chapter focuses on the industry sector, with a particular focus on the most energy-intensive manufacturing sectors: iron and steel, cement and clinker, aluminium and alumina, and pulp and paper. An explanatory annex provides details on the data, calculations and assumptions, and should be used to understand the limitations of the data available.

As part of its 2019 G20 Presidency, the Government of Japan instituted a programme of work to examine the process and benefits of benchmarking levels of energy efficiency across energy-intensive industry sub-sectors and targeted end-uses amongst G20 countries. This chapter builds on the work led by the IEA following Japan's initiative. It aims to provide insights into energy consumption, energy intensity, specific consumption and efficiency, as well as to inform policymakers in considering pathways to improving the efficiency of industrial processes and technologies. It highlights the relevance of structural differences between Brazil and other countries and regions. Understanding these differences can inform policymakers in designing energy efficiency strategies. In order to establish reliable and consistent indicators, more consistent and detailed data will be necessary.

Industry classifications used by the IEA

For purposes of this chapter, industry consists of:

- Mining and Quarrying
- Construction
- Industry not elsewhere specified
- Manufacturing

Manufacturing, in turn, consists of the following sectors. The sectors in bold are the ones highlighted in this chapter:

- **Iron and Steel**
- Chemical and petrochemical
- **Non-Ferrous Metal (includes aluminium and alumina)**
- **Non-Metallic minerals (includes cement and clinker)**
- Transport equipment
- Machinery
- Food and Tobacco
- **Paper, Pulp and printing**
- Wood and wood products
- Textile and leather

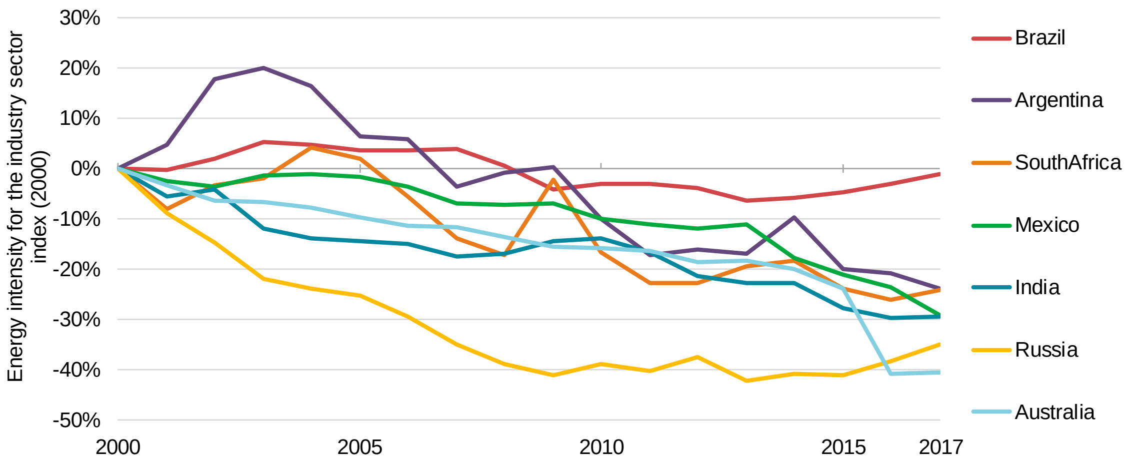
8.3.1 Energy efficiency in industry: the global context

Economic growth, growing population and increases in activity have pushed up energy demand in industry in recent years. From 2000 to 2017 improvements in energy efficiency in industry saved 20% of additional energy use in IEA countries and major economies. During the same period, the shift from heavy manufacturing to services (structural change) also played an important role in reducing the energy intensity of industry in most developed and emerging economies alike.

At the same time, more recent trends show a slowdown in these improvements. Globally, technical efficiency improvements in industry fell from 4% of final energy use in 2015 to 2% in 2018. Structural changes that saved 0.1% of final energy use in 2017 were responsible in 2018 for 0.1% of additional final energy use. A key force behind these changes were increases in production levels in energy-intensive industries such as petrochemicals in the United States and steel in China.

Figure 56 reflects these trends. It presents the evolution of energy intensity (energy required to produce one unit of Gross Value Added - GVA) in the industry sector from 2000 to 2017, with 2000 as the reference year. It does not reflect activity or structural effects, but provides a more high-level comparison of total final energy consumption of the industry sector per unit of output (GVA). A downwards trend indicates more output per unit of energy compared to the year 2000, while an upwards trend indicates less output per unit of energy compared to the year 2000.

Figure 56 – Industry intensity (energy per unit of GVA) index in Brazil, Argentina, South Africa, Mexico, India, Russia, Australia, 2000 to 2017



Source: IEA (2019b), World Energy Balances

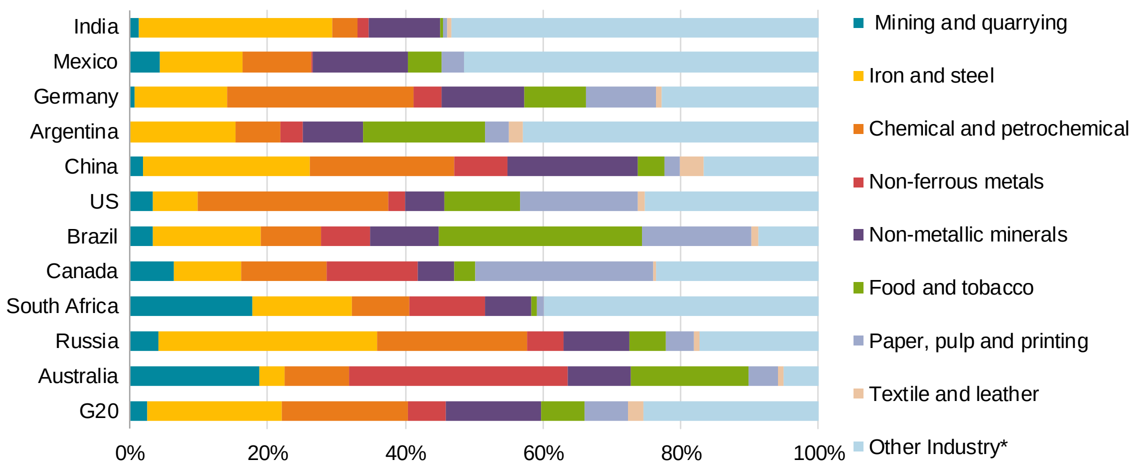
The countries displayed were selected among the BRICS[23] along with Mexico, Argentina and Australia. These were chosen to enable comparisons with countries with similar economic development, geography and resources.

[23] Brazil, Russia, India, China, South Africa

Today, 60% of global GDP takes place in emerging and developing economies and 40% in advanced economies. This represents a fundamental shift in the global economy as an increasing share of production and consumption shifts from advanced to emerging and developing economies. In addition to this, emerging economies have become the manufacturing engines of the globalised economy. For example, the United States imports more steel than it produces, much of it coming from Brazil and Mexico in the form of the most energy-intensive steel products, which are semi-finished products (US Department of Commerce, 2019).

Historically, Brazil has had a strong sugar, alcohol and silviculture sector. Today the two main sectors in terms of final energy use are the food and tobacco, and paper, pulp and printing sectors. They are followed by iron and steel, non-metallic minerals (largely cement), chemicals and petro-chemicals and non-ferrous metals (largely aluminium and alumina production), as illustrated in Figure 57.

Figure 57 – Final energy consumption, share of different subsectors of the industry in Brazil and selected countries, 2017



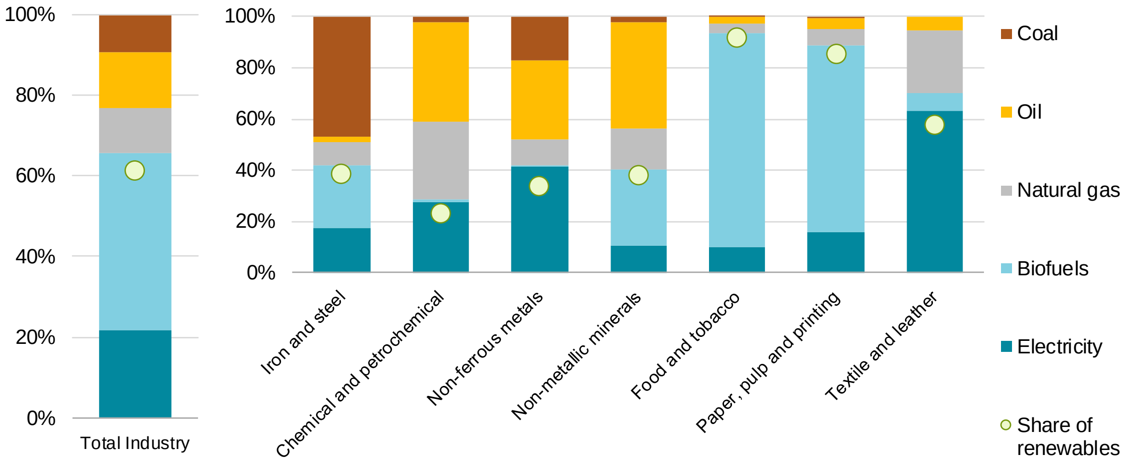
Source: IEA (2019b), *World Energy Balances*

Note: "Other industry" includes the following sectors: construction, transport equipment, machinery, wood and wood products and industry not elsewhere specified.

The energy mix fuelling Brazil's industry and manufacturing sector is unique in the high share of renewable energy used. The share of renewable energy in Figure 58 was calculated by adding final consumption of renewable energy (direct use of renewables reported) to the share of renewable energy in electricity production (hydro, solar, wind, geothermal and biofuels).

In 2017, renewables were responsible for 80% of electricity production, mainly through hydro, which accounts for 65% of electricity production. For this reason, electrification has the potential to greatly reduce emissions in addition to improving efficiency in most cases.

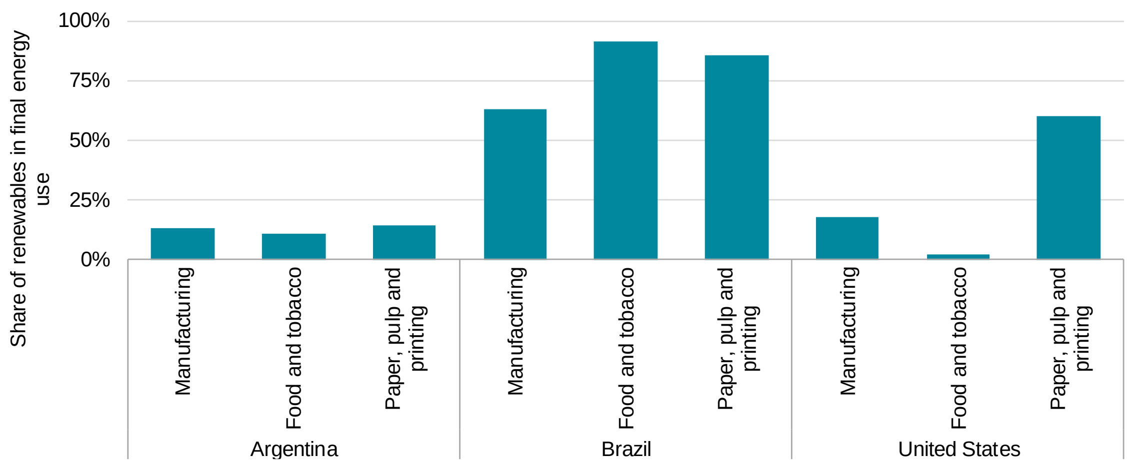
Figure 58 – Final energy use by fuel in the industry sector and share of renewable energy in Brazil, 2017



Source: IEA (2019b), World Energy Balances

The two sectors responsible for the highest portion of energy consumption in the manufacturing sector – food and tobacco, and pulp, paper and printing – are also the sectors with the highest share of renewable energy. Renewable energy fuelled more than 80% of these processes in 2017. This share of renewable energy is high compared to countries such as the United States or Argentina, as illustrated by Figure 59.

Figure 59 – Share of renewable energy in final energy use in selected manufacturing sectors in Argentina, Brazil and the United States, 2017



Source: IEA (2019b), World Energy Balances (shares include electricity)

8.3.2 Major energy consuming manufacturing sub-sectors

This section focuses on four major energy-consuming sectors, which have been selected for a combination of their high levels of energy consumption and the availability of quality data for Brazil and other countries. In some instances, the report does not disclose the identity of the countries due to concerns over data privacy and competitiveness as well as limitations in accuracy. All examples focus on G20 countries or a subset of G20 countries for which data are available.[24]

8.3.2.1 Iron and Steel

In 2017, Brazil accounted for 2% of the total iron and steel production in the G20 countries. Figure 60 demonstrates the share of steel production by process route. Following Brazil, countries are organised, from left to right, according to the share of production in electric arc furnaces processing scrap, which is the most energy efficient technology among the ones displayed.

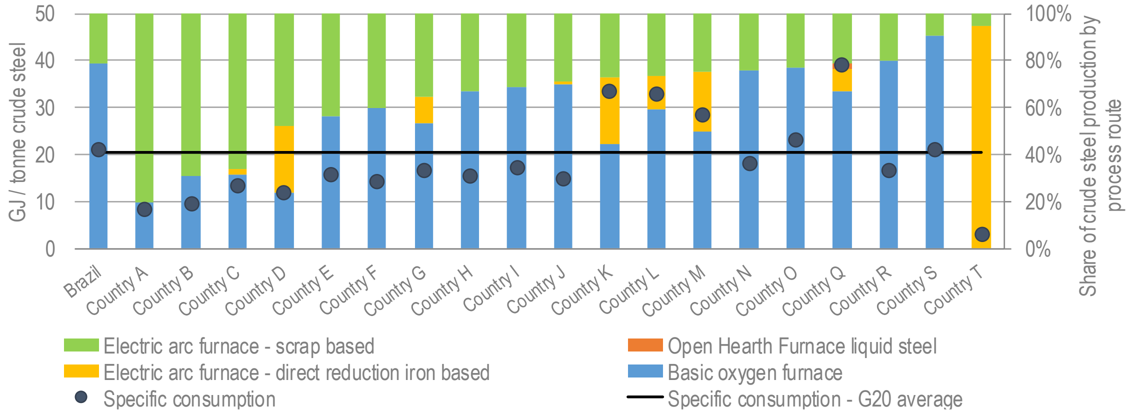
Several factors contribute to the energy intensity of the iron and steel sector. The aggregated specific consumption of steel depends highly on the production routes used, and primary and secondary production shares vary greatly across countries.

In Brazil, basic oxygen furnaces produced almost 80% of crude steel in 2017, followed by electric arc furnaces – scrap based (about 20%). The share of crude steel by process route was similar to countries such as Argentina, Australia, the United Kingdom, Korea and Japan.

Brazil's iron and steel sector's specific consumption was at the level of the G20 countries average in 2017. At the same time, charcoal powered 10% of production, mitigating greenhouse gas emissions of the sector.

[24] The G20 members are: Argentina, Australia, Brazil, Canada, China, Germany, France, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the United Kingdom, the United States and the European Union.

Figure 60 – Share of steel production by process route and specific consumption of steel production, 2017



Source: World Steel Association (2018), IEA (2019b), World Energy Balances

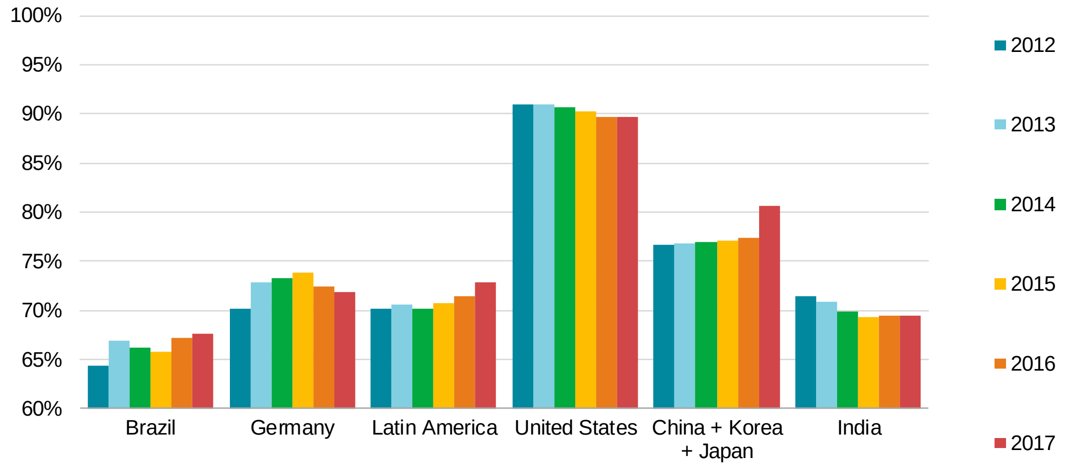
Given the structure of Brazil's production routes, some approaches for reducing the specific consumption of the iron and steel sector include:

- Increasing metals recycling, specifically the production of crude steel in an electric arc furnace from metal scrap. This requires increases in scrap collection and improved sorting methods, particularly for the steel used in construction and other by products.
- Taking advantage of opportunities for industrial symbiosis – including using the waste or by-products from one process to produce another product of value – to help close the material loop, reduce energy use and reduce emissions in the case of carbon capture and utilisation. One example is to use steel blast-furnace slag in cement production and carbon from steel waste gases to produce chemicals and fuels. Another is to apply industrial waste gases to other industrial uses, which is a widely adopted practice in Brazil (IEA, 2019c). While not directly reducing energy use in the iron and steel sector it would nonetheless improve efficiency in the industry as a whole.
- For new plants, considering regulatory and financial mechanisms to encourage the adoption of the most efficient technologies will represent great saving opportunities both in terms of energy and finance as these technologies tend to be cost-effective. These efficiency technologies include: coke dry quenching, waste heat recovery, top-pressure recovery turbines, electrification, and the use of hydrogen. Improving best practices in plants, with reduction of internal scrap or energy management systems is also a key vector to improve efficiency.

8.3.2.2 Cement and clinker

Brazil represented around 1.6% of the world clinker capacity and 1.3% of cement production in 2017 (USGS, 2019). The share of clinker to cement, illustrated in Figure 61, is relevant to defining the specific consumption of the sector. The higher the share of clinker in the sector, the higher the specific consumption of the sector as a whole.

Figure 61 – Clinker to cement equivalent ratio, weighted average of grey and white clinker in Portland and blended cements (%)



Source: CSI (2018)[25], EPE for Brazil

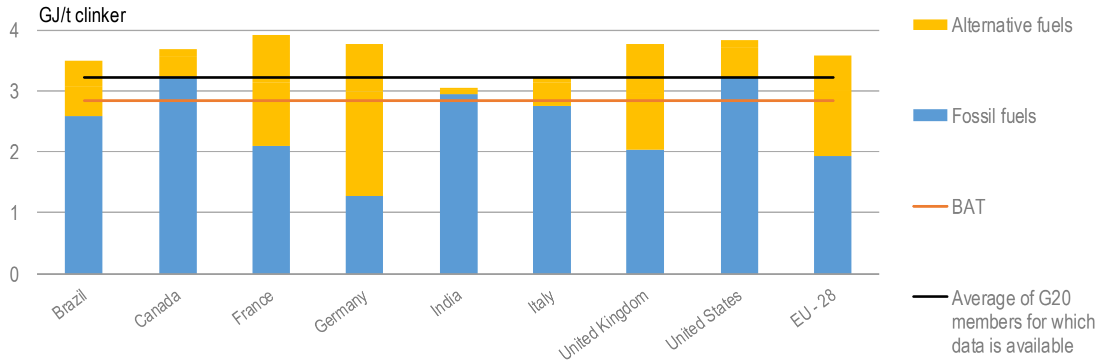
In Brazil, the clinker to cement ratio was 68% in 2017, lower than Germany's (73%) and the average in Latin America, which is also the average of all cement in Europe (CEMBUREAU). However, this represented a 5% increase in the clinker-to-cement ratio compared to 2012. This has the effect of increasing the specific consumption of the sector, due to the increase in more energy intensive clinker production.

For this reason, it is important to look at the specific consumption of clinker production to understand the level of specific consumption in Brazil compared to other countries. **Figure 62** shows the specific consumption to produce a tonne of clinker in Brazil and several G20 countries. The energy source is split between fossil fuels and alternative fuels.[26]

[25] Please see annex for more details

[26] Alternative fuels are defined as "Biomass and Alternative fossil and mixed wastes" from the Cement Sustainability Initiative (CSI) Getting the Numbers Right (GNR) Emissions Report - indicator 25aAGFC. For more information please see annex.

Figure 62 – Thermal specific consumption per tonne of clinker in selected G20 countries and Brazil, 2017



Source: CSI (2018)

Note: BAT refers to Best Available Technology

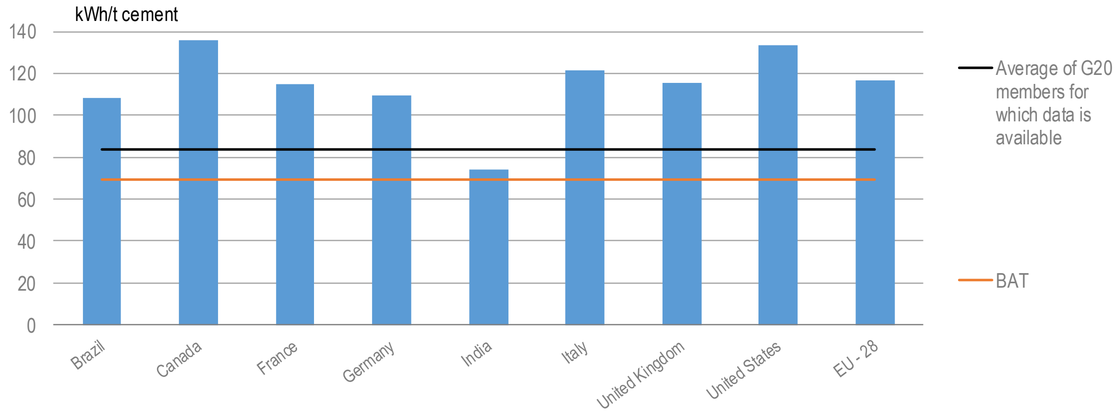
Brazil's intensity was slightly above the G20 average, and comparable to Canada, the United Kingdom and Italy, displayed in Figure 62. Across all the G20 countries presented here, there is potential to improve energy efficiency by incorporating Best Available Technologies, marked by the horizontal red line.

Regional factors such as moisture content and burnability of raw materials, typical clinker composition and average capacity of cement plants affect clinker thermal intensity. Additionally, thermal specific consumption increases with use of alternative fuels, and clinker substitutes.

Alternative fuels accounted for 26% of thermal energy use per tonne of clinker produced in Brazil in 2017, slightly below the average of the G20 countries for which data were available (Figure 62). This was mainly due to lower levels of waste re-use. At the same time, the use of biomass (12%) was higher than the average for other G20 countries.

Another measure of energy efficiency is the electric specific consumption per tonne of cement produced, shown in Figure 63. In Brazil, electric specific consumption hovered just above the G20 average, and was comparable to Germany, France and the United Kingdom, displayed in the graph. The results obtained by using best available technologies, represented by the horizontal red line, show that improvements can still be made across all countries.

Figure 63 – Electric specific consumption per tonne of cement, 2017



Source: CSI (2018)

Globally, the specific consumption of thermal energy and electricity have continued to gradually decline as dry-process kilns – including staged preheaters and precalciners (considered state-of-the-art technology) – replace wet-process kilns, and as more efficient grinding equipment is deployed. The thermal specific consumption of clinker is estimated to have fallen to 3.4 GJ/tonne on average globally in 2017, representing an annual decrease of 0.4% since 2014.

In Brazil, cement production was almost exclusively done through dry process with preheaters and pre calciners, lowering the need for energy significantly. This represents a significant improvement that has already been implemented.

Examples of efficiency policies in cement and clinker

As part of its 13th Five-Year Plan (2016-2020), China aims to reduce the thermal energy intensity of clinker production to 3.07 GJ/t clinker on average by 2020, which would shrink the gap between the current level and best available technology thermal energy performance by two-thirds.

Between 2011 and 2015, 85 cement plants in India participated in the first cycle of Perform, Achieve, Trade (PAT), a market-based mechanism to improve energy efficiency. They achieved energy demand reductions equivalent to 9% of India's 2014 cement sector energy consumption, and the cement sector is now involved in the second PAT cycle, with higher targets and coverage.

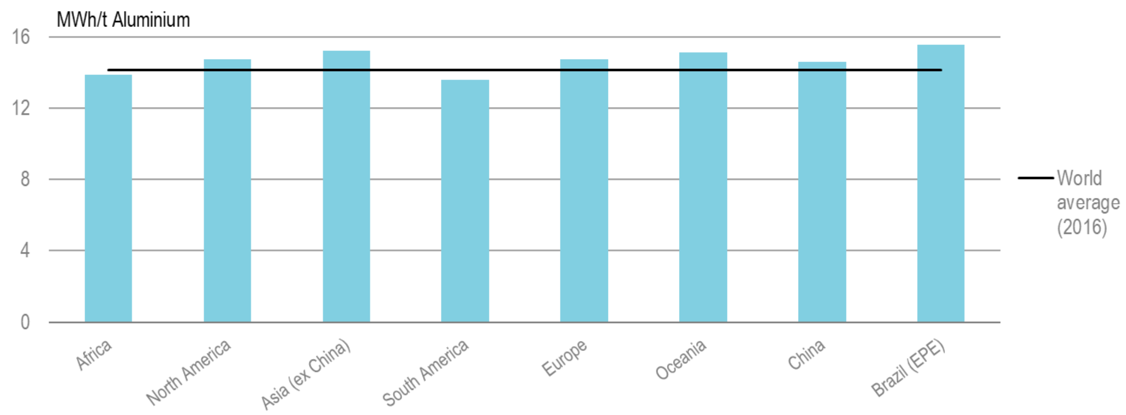
In Europe, the mandate to develop cement standards within the European Committee for Standardisation was recently widened to allow possible low-carbon alternatives to ordinary Portland cement (OPC) clinker that rely on different raw materials or mixes.

8.3.2.3 Aluminium and Alumina

Brazil accounted for 2% of alumina and 1.3% of aluminium production globally in 2017. Primary production is approximately ten times more energy intensive than recycling. On average, production of 1 tonne of primary aluminium required 14 megawatt-hours (MWh) of energy in 2016 globally, equivalent to almost the per capita annual use of energy in Brasil in 2014[27]. In 2016 production in Brazil amounted to 790 thousand tonnes of aluminium and 10,886 thousand tonnes of alumina. To provide an accurate picture of energy efficiency of the sector, we present these productions separately.

Specific consumption per tonne of primary aluminium smelting was slightly higher in Brazil than other countries, as presented in Figure 64.

Figure 64 – Specific consumption per tonne of primary aluminium smelting, 2016



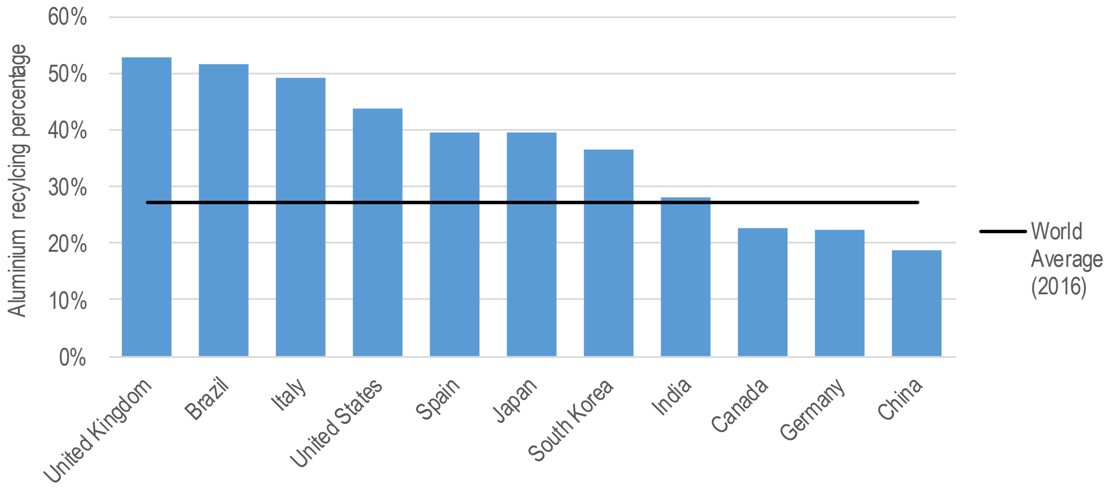
Source: International Aluminium Institute (2019). EPE for Brazil

However, aluminium recycling in Brazil was much higher than the world average in 2016, the last year for which data are available for comparison (Figure 65). This indicates that Brazil has a great opportunity to ensure its sector is one of the most efficient, as energy efficiency improvements can contribute to additional savings. This could be achieved by the promotion of energy management systems that would make sure best practices are in place and would provide more data to determine where the potential savings can be made.

This would have additional benefits such as paving the way for Brazil's aluminium sector to be one of the most competitive in the world as cost of electricity represents about one-third of the cost of smelting aluminium.

[27] World Bank, https://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE?locations=BR

Figure 65 – Aluminium recycling percentage per country, 2016

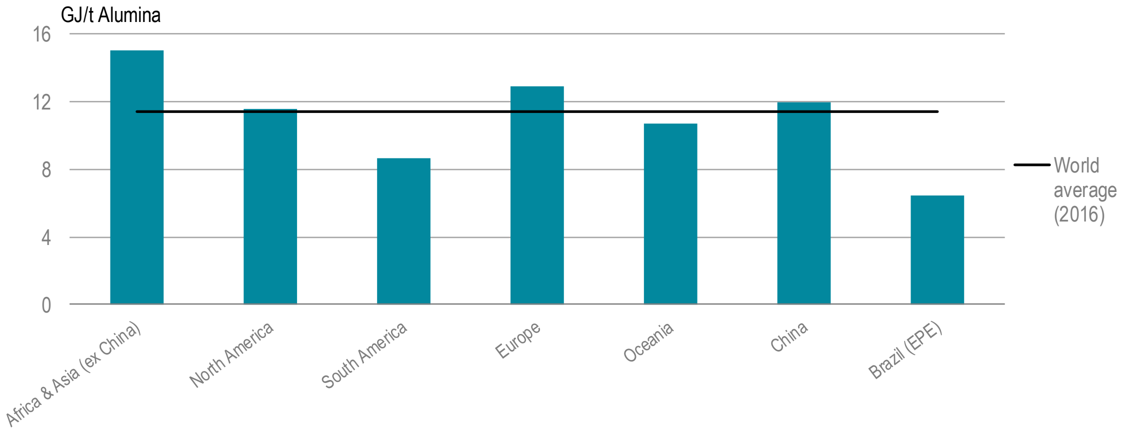


Source: ABAL (2016)

Energy Management Systems
Energy management systems (EnMS) such as the ISO 50 001 are key to unlock energy efficiency potential. EnMS ensure the main aspects of best practices for energy use are in place in companies through: - Mapping of energy uses - Evaluation of potential savings and necessary actions - Ensuring the right data and indicators are collected and monitored - Following the progress of energy savings - Focussing on continuous improvement In the energy intensive sectors, EnMS are essential to ensure all aspects of energy management are taken into account. For less energy intensive sectors, policies that encourage the adoption of EnMS can engage a large number of energy users across a wide range of sectors and promote better practices.

As mentioned above, Brazil produces much more alumina than aluminium, as most of the alumina is destined to export. It is more similar in that way to regions with similar profiles of production such as Oceania.

Figure 66 – Specific consumption per tonne of alumina, 2016



Source: International Aluminium Institute (2019) and EPE

There is significant energy savings potential in increasing the share of secondary production. The combined share of aluminium produced from recycled new and old scrap needs to reach nearly 40% globally (at least 70% of which from old scrap) by 2030 to attain the Sustainable Development Scenario pathway (IEA, 2018b).[28]

Achieving this share will require better scrap collection and sorting, particularly for old scrap, since stronger material efficiency efforts under the SDS will reduce the availability of new scrap. With a share of 50% aluminium produced from recovered scrap recycling, Brazil is taking the right steps to achieve this. Innovation in the aluminium subsector will also be essential to reduce emissions from primary production (IEA, 2019d).

8.3.2.4 Pulp and paper

Brazil accounted for 5% of global pulp production and under 2% of global paper production in 2016. As pulp production is more energy intensive than paper production it is essential to keep in mind the shares of each in total production when comparing specific consumptions.

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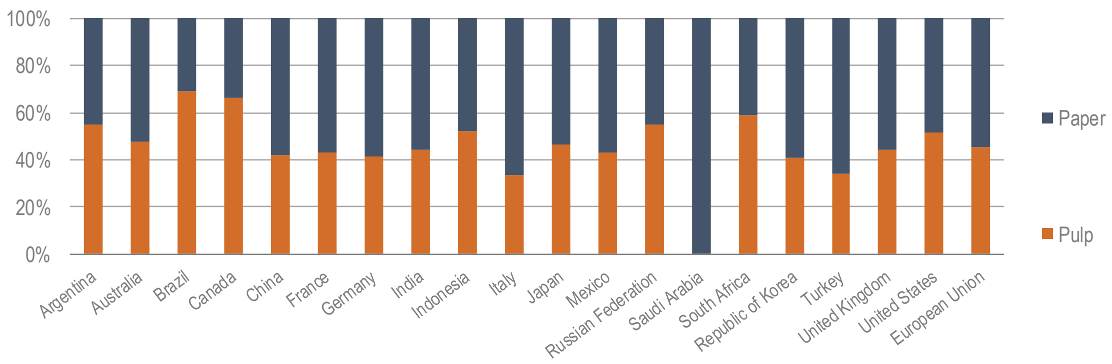
[28] The IEA's **Sustainable Development Scenario** provides an integrated strategy to achieve the key energy-related elements of the United Nations Sustainable Development agenda, including energy access, air quality and climate objectives. The emissions trajectory of the Sustainable Development Scenario is fully in line with achieving the long-term objectives of the Paris Agreement. For more information please see https://www.iea.org/weo2018/scenarios/

Figure 67 – Share of pulp and paper in tons production, 2016

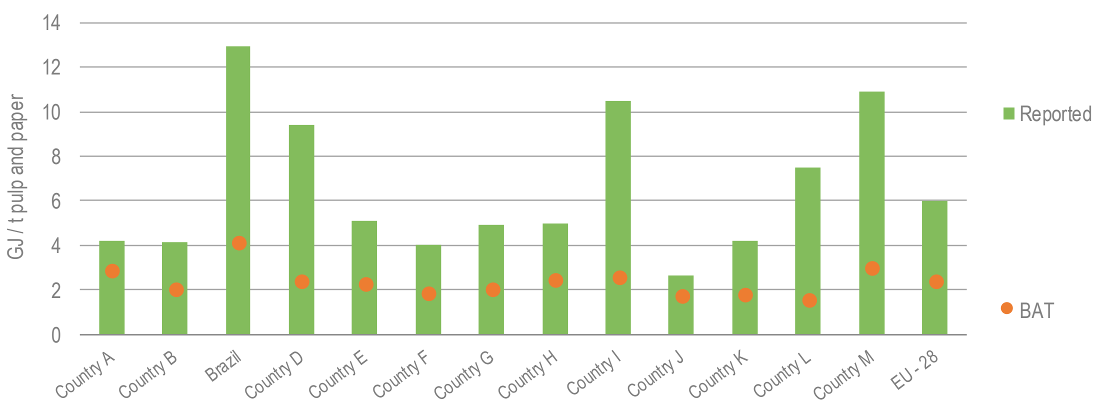


Source: FAOSTAT (2018)

Brazil has one of the highest pulp to paper ratios among the countries presented in Figure 67, affecting its specific consumption for this sector. Because data are not available to separate energy use for pulp and paper production, the analysis here provides a view of thermal energy per tonne of pulp and paper, and electric energy per tonne of pulp and paper.

Figure 68 shows Brazil has a much higher specific consumption for pulp and paper production than most other countries presented. This is strongly influenced by the high share of pulp production, which mainly uses thermal processes and inflates the overall specific energy figure. The spread between BAT and reported specific intensity also illustrates that all countries have significant potential to improve the specific consumption of the pulp and paper production, and to learn from each other in this area.

Figure 68 – Thermal energy use per tonne of pulp and paper, 2016

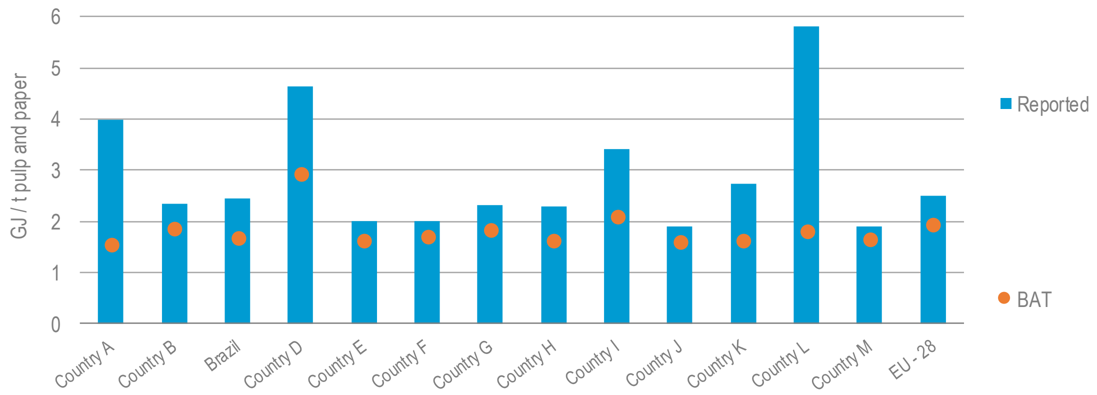


Source: Multiple sources (see explanatory note for details)

Note: the pulp and paper data had several limitations that influenced the results. In particular energy use data for pulp and for paper are not available at the disaggregated level (i.e. only the sum of energy used for pulp production and energy used for paper production is available). The *assumptions made to establish these specific consumptions and the BAT level are detailed in the annex, which should be used to analyse these results.*

Figure 69 presents the specific consumption of electricity. When only electricity use for pulp and paper production in Brazil is considered, the specific consumption is much more similar to other countries. Again, all countries have potential for improvement when compared to BAT intensity.

Figure 69 – Electricity use per tonne of pulp and paper



Source: Multiple sources (see explanatory note for details)

Note: the pulp and paper data had several limitations that influenced the results. In particular energy use data for pulp and for paper are not available at the disaggregated level (i.e. only the sum of energy used for pulp production and energy used for paper production is available). The assumptions made to establish these specific consumptions and the BAT level are detailed in the annex, which should be used to analyse these results.

A major opportunity for reducing specific consumption is to produce more paper from recycled sources. Increasing the share of production from recovered fibre could considerably reduce energy use. To this end, improving recycling channels can help increase collection of paper products for recycling. Governments could also implement landfill and waste collection fees that encourage greater recycling of household and commercial paper waste.[29]

Looking at global trends, the share of recovered fibre in total fibre furnish (the mix of fibres used in paper production) increased by more than ten percentage points during 2000-17.

[29] It is important to note that structural effects – such as shifts in product mixes or regions of production – can also influence energy use, and data quality issues make it difficult to draw firm conclusions about energy intensity trends.

Higher on-site waste heat recovery and cogeneration can also improve energy efficiency. The speed and scale of deploying these technologies can be raised through collaborative efforts by industry, public sector and research partners to share best practices on state-of-the-art technologies and develop plant-level action plans.

Furthermore, ensuring efficient equipment operation and maintenance will help guarantee optimal energy performance. This can be reinforced by implementing energy management systems.

8.4 Households

Summary

- Households account for 10% of total final energy consumption and 25% of electricity consumption in Brazil. The average household floor area remains quite low compared to major advanced economies, while the number of people per household is closest to that of China, in between the levels seen in most other emerging and advanced economies.
- The use of biomass in cooking has risen since 2015, due to the economic crisis, which led households to turn away from LPG (liquefied petroleum gas) back to less costly but less efficient biomass. Today cooking accounts for 54% of total final residential consumption in households.
- Due to the relatively low ownership levels of washing machines and air conditioners, ownership and electricity consumption are likely to grow, particularly as GDP rises. Energy efficiency can help secure access to vital services (cooling and clean clothes) while mitigating the impact on the electricity system, on customer bills and on the environment.
- In Brazil and other countries, the average efficiency of air conditioners purchased is well below the best performing, typically available model. This indicates that there is significant potential to shift to more efficient models applying available technologies. Policies and programmes can help overcome barriers such as the higher upfront cost and longer payback times of more efficient models.
- To better measure the efficiency performance of air conditioners, many countries are moving to a seasonal energy efficiency ratio. Moving to a seasonal ratio could help more accurately compare air conditioners based on actual performance throughout the cooling season, strengthening the effectiveness of MEPS in driving the market towards the most energy efficient models.
- Brazil has years of experience with MEPS and labels, and has the opportunity to continue to use these to further improve residential efficiency. Similarly, existing standards and labelling programmes for buildings could be strengthened. Among other benefits, strengthened buildings standards and labelling can drive down the demand for active cooling in buildings, mitigating the overall increase in energy consumption from air conditioners.

This section analyses energy consumption in households.[30] It explores how much energy households use and from which sources, which end-uses are responsible for the most energy use, appliance ownership levels, and factors such as household size and floor area that affect energy consumption.

Brazil has a range of energy efficiency policies covering energy use in households, including minimum energy performance standards, appliance labelling, and incentive programmes. This analysis provides insights into trends and opportunities to further advance energy savings by exploring how much energy households use, which appliances are responsible for the largest share of consumption, and how appliance ownership has evolved over time. It does not incorporate the most recent "Equipment Ownership and Usage Survey" of household appliances recently released by Procel for reasons of timing; however, that research will undoubtedly enrich the understanding of household appliance ownership and use going forward.

Air conditioners receive special attention, as air conditioning ownership is expected to increase over the coming years. Energy efficiency will play an important role in enabling access to cooling while mitigating the impact of increased air conditioning ownership on the electricity system and the environment.

Energy efficiency in the residential sector is important due to its positive impact on the energy sector as well as the broader benefits that energy efficiency delivers. These include lower household energy bills, reduced indoor and outdoor air pollution, access to fundamental services like cooling in hot climates, and public savings through reduced subsidies for energy.

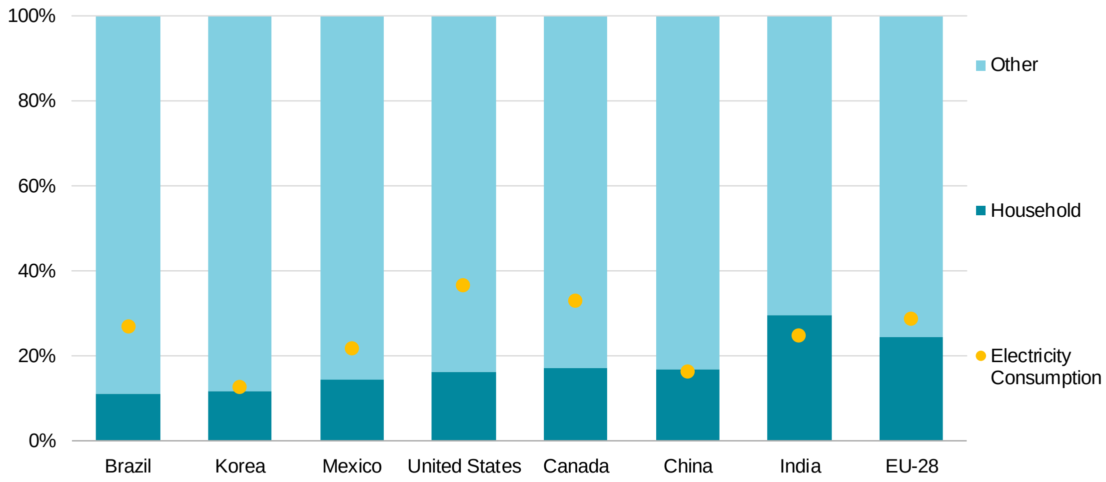
8.4.1 Energy efficiency in households: the global context

Globally, energy consumption has been rising in residential buildings over the past several years. Structural changes such as increased ownership and use of devices and increased per-capita residential floor area across economies have consistently matched or outpaced efficiency gains since 2014.

The residential sector in Brazil accounted for nearly 10% of total final energy consumption in 2017 and 25% of electricity consumption, as illustrated in Figure 70. In most countries, households account for a higher share of electricity consumption than total final energy consumption, due to the role of electric appliances and lighting in delivering household energy services.

[30] Households in this case are defined as "occupied dwellings," with each dwelling representing a housing unit.

Figure 70 – Residential energy consumption as a share of total final energy consumption, 2017



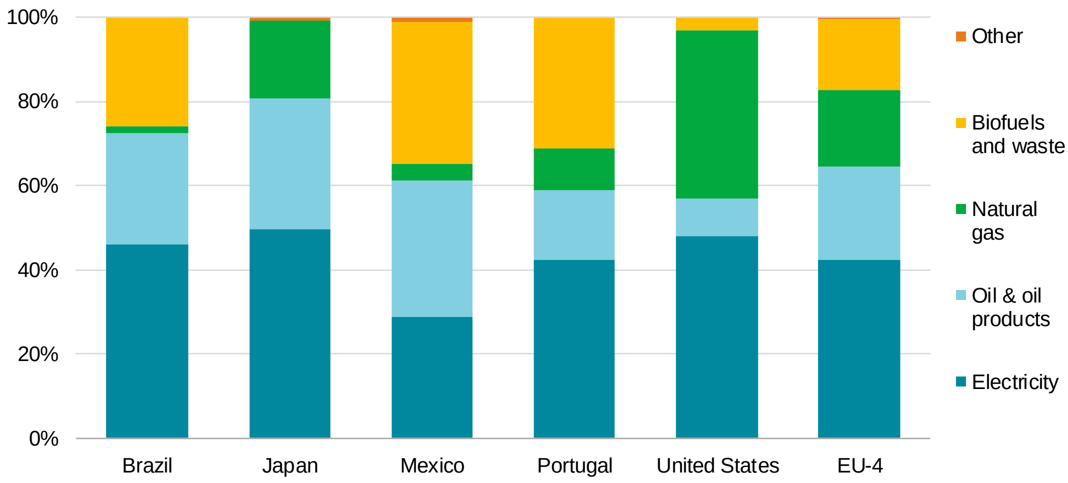
Source: IEA (2019b), World Energy Balances

The fuels that deliver energy to households differ significantly from one country to another, depending on available resources and dominant cooking, heating and cooling technologies.

In Brazil, electric appliances account for nearly half of energy consumption in households as illustrated in Figure 71. In 2017, electricity accounted for 46% of consumption, while oil and oil products (mainly LPG) and biofuels and waste (firewood) each accounted for about 26% of domestic energy consumption. Natural gas accounted for only 2%.

While the share of electricity consumption is comparable to that of other countries, the per capita electricity consumption is still low. This is in part because of low levels of appliance ownership. The use of firewood for cooking and heating, which has a low conversion efficiency, further increases the relative share of biomass in total final household energy consumption. This is similar to the dynamic in Portugal, where biomass is also common for cooking and heating.

Figure 71 – Total final energy consumption in households by fuel, 2017



**EU-4 includes France, Germany, Italy and the United Kingdom*

Source: IEA (2019e), World Energy Statistics

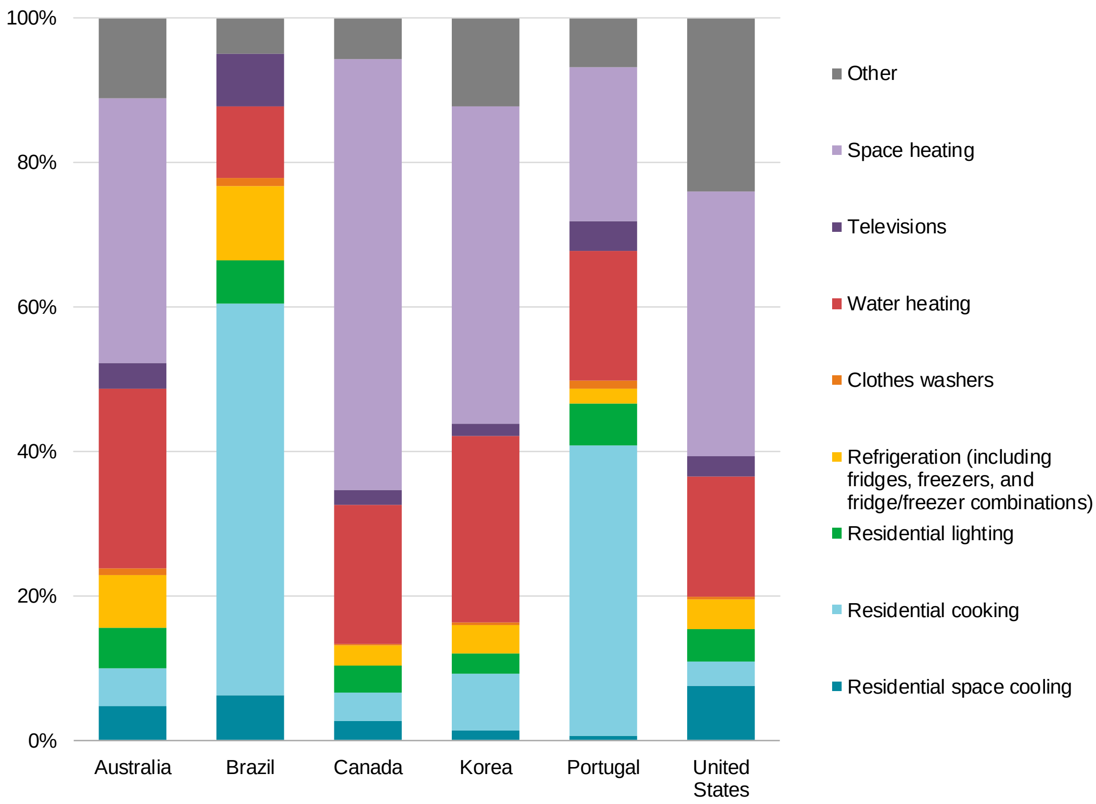
While the use of biomass for cooking in Brazil declined for several decades under government programmes aimed at replacing biomass with LPG, it is now increasing. Factors driving this are the increasing cost of LPG, combined with the economic downturn in 2015 and the availability of biomass, which is often harvested from back yards at no cost.

As Figure 72 illustrates, cooking in Brazil accounts for 54% of total final energy consumption in households. Refrigeration and water heating were each responsible for 10% of total final energy consumption, and space cooling accounted for 6% of final consumption.

Continued monitoring of energy consumption by appliance is important to track progress in advancing the Sustainable Development Goals (SDGs). The data provide insights into access to essential energy services, such as cooling and clean cooking, challenges such as indoor air pollution, and effects of appliance ownership and use on the energy system. For instance, as biomass for cooking in Brazil increases, so does indoor air pollution. And while air conditioner ownership is low, a significant increase is expected in the next decade. This will expand access to cooling, which is an essential service, while also creating a challenge to mitigate emissions of refrigerants and increased demand on the electricity system, including at peak times.

It is also worth noting the high share of energy dedicated to water heating. Brazil continues to have a significant share of electric showers, despite decreasing ownership over the past few years. This creates an opportunity to improve energy efficiency, including through promotion of solar heating systems.

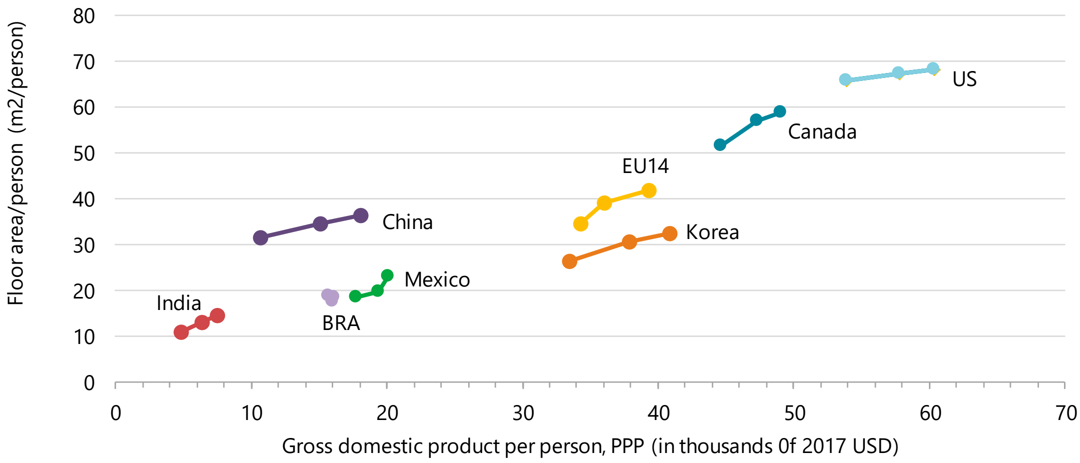
Figure 72 – Total final residential consumption by end-use



Source: IEA (2019e), World Energy Statistics

In Brazil, there has been a slight increase in estimated floor area per person between 2010 and 2018, as illustrated in Figure 73. The increase is less pronounced than in other countries. A likely explanation is that, despite a rise in GDP 2010 to 2015, an economic downturn pushed GDP back down from 2015 to 2018. An increase in floor area per person correlates to increased energy consumption for some household end uses, such as lighting, space heating and cooling.

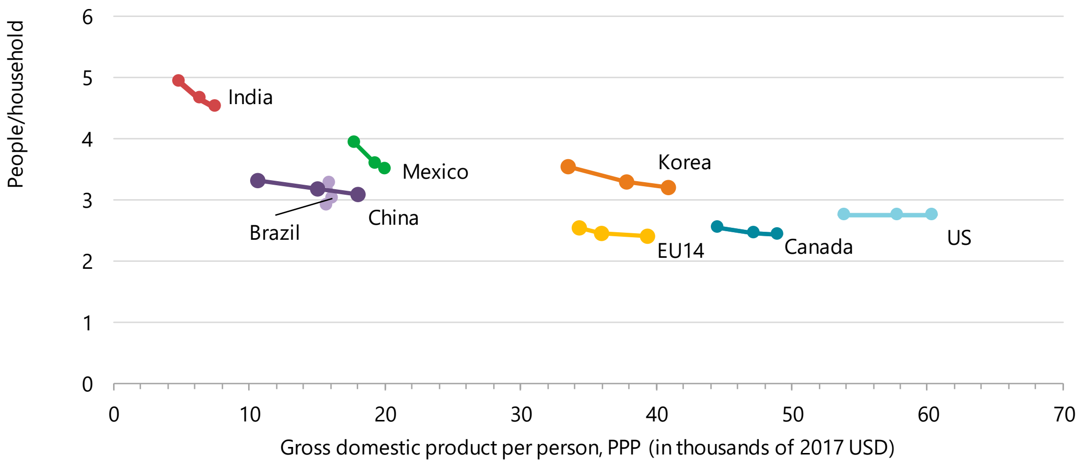
Figure 73 – Floor area/person, 2010, 2015 and 2018



Source: Adapted from IEA (2019f), Energy Efficiency Market Report 2019 and IEA (2019g) Energy Technology Perspectives (buildings model)

There were fewer people per household in Brazil – as in other countries - in 2018 when compared to 2010, as illustrated in Figure 74. The number of people per household can affect energy consumption in different ways. Fewer people per household can lead to reduced energy consumption per household of certain end-uses, such as clothes washing, dishwashing, and heating and hot water consumption.

Figure 74 – People per household, 2010, 2015 and 2018



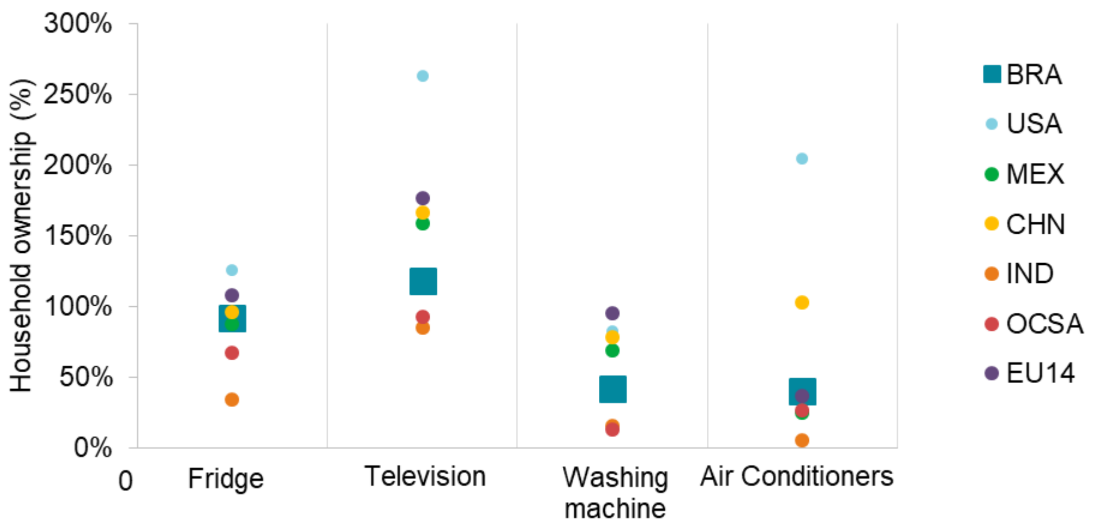
Source: Adapted from IEA (2019f), Energy Efficiency Market Report 2019 and IEA (2019g) Energy Technology Perspectives (buildings model)

8.4.2 Energy consumption of leading household appliances

Figure 75 presents ownership levels of the main energy consuming appliances in Brazil and other major emerging and advanced economies. In Brazil, ownership levels of fridges and televisions are relatively high – near 100%. At the same time, relatively few households own a washing machine or air conditioner. As GDP and household wealth grow, ownership levels of these appliances can be expected to grow, raising the importance of energy efficiency.

Air conditioners pose a particular challenge in Brazil and across major emerging economies. While household ownership levels are relatively low at 40%, experience in China has shown how quickly ownership can rise as GDP and incomes grow. This can have a profound effect on electricity demand, and particularly peak demand during the hot seasons and hottest times of day.

Figure 75 – Ratio of appliance ownership per household, 2017



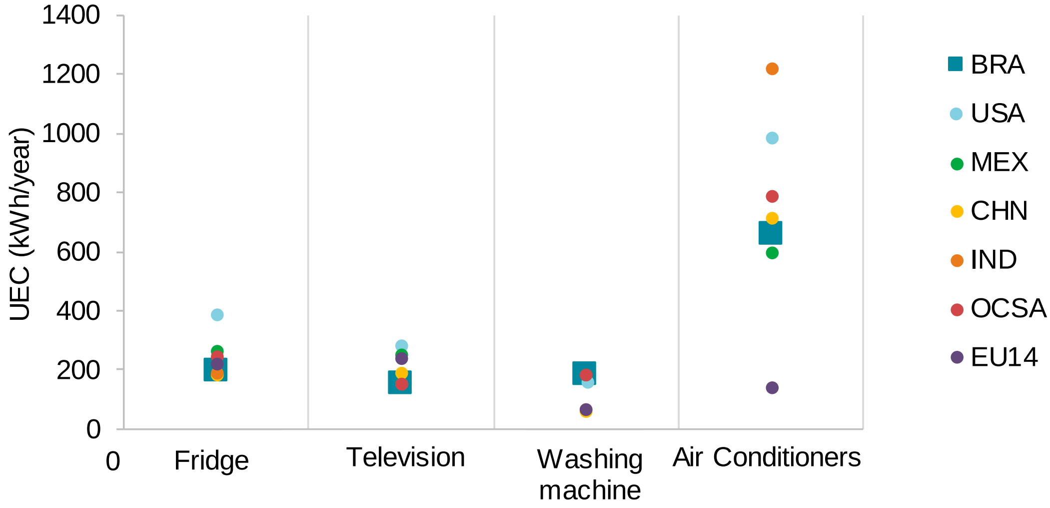
Note: Fridge includes refrigerators as well as refrigerator and freezer combinations. It does not include freezers.

Source: Adapted from IEA (2019g) Energy Technology Perspectives (buildings model) and EPE

The unit energy consumption of appliances per year is one measure that can help gauge the average efficiency of new appliances on the market. However, other factors such as frequency and duration of use, appliance design, and other behavioural factors such as whether washing machines run at partial or full loads, also strongly influence the average annual energy consumption per appliance.

As Figure 76 illustrates, energy consumption in Brazil is low for the average model of refrigerator and television, while washing machine consumption is high. For washing machines, the larger household size for those owning a machine, and the prevalence of less efficient top-loaded machines are likely to play a role in explaining this larger energy consumption. That is, the higher consumption is not necessarily all due to the underlying efficiency level of the machines.

Figure 76 – Electric energy consumption (kWh/year) per unit of equipment, 2017

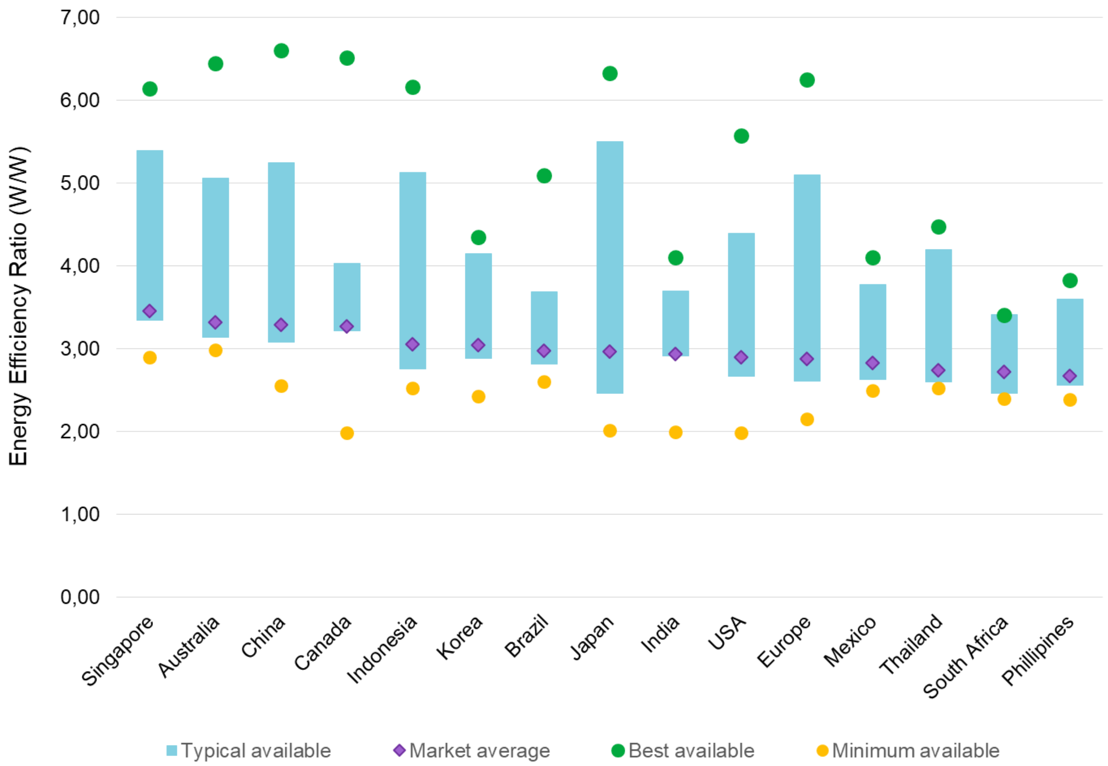


Source: Adapted from IEA (2019g) Energy Technology Perspectives (buildings model) and EPE

Note: UEC refers to Unit Energy Consumption

Air conditioner ownership in Brazil is expected to increase substantially over the next few years. This will have a significant impact on the electricity system and on emissions of gases with high-global warming potential. Energy efficiency can play a critical role in mitigating these impacts. However, currently the average air conditioner in the market, including in Brazil, has a much lower efficiency than the typically available model. And even the best typically available model is well below the best available technology available on the market globally (Figure 77).

Figure 77 – Range of available efficiencies for residential air conditioners (EER)

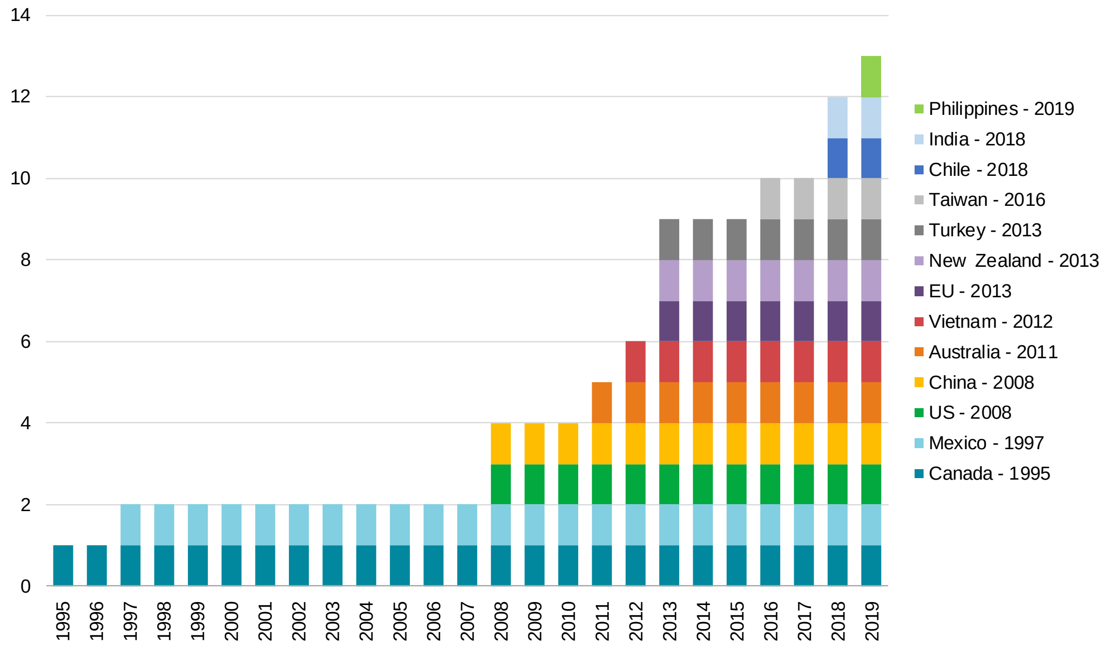


Source: IEA (2019h), Kigali Tracker

Policy has a critical role to play in shifting the market towards more efficient and – from a lifecycle cost perspective – often more economic – models of air conditioners. Brazil has in place minimum energy performance standards, set in terms of an energy efficiency rating (EER). This rating compares performance of air conditioners based on a fixed indoor and outdoor temperature, meant to simulate the conditions under which the air conditioner is operating at full capacity.

Several countries have begun introducing minimum energy performance standards and energy labelling that are framed in terms of a seasonal metric, either a seasonal energy efficiency ratio (SEER) or cooling seasonal performance factor (CSPF). A seasonal metric accounts for seasonal variations and variable operating conditions, which allow for a more representative measurement of air conditioner energy consumption. Importantly, this allows more efficient products, such as those using inverter technology, to reflect higher level of efficiency attained under real life operating conditions.

Figure 78 – Countries with minimum energy performance standards SEER or CSPF



Source: IEA (2019a), Policies Database

While it is still difficult to compare seasonal metrics to each other due to differences in test conditions, the move to a seasonal metric can significantly strengthen the effectiveness of the minimum performance standards and labelling. This is because a seasonal metric more accurately reflects the operational performance of air conditioners under varying outdoor conditions and partial loads. This empowers the consumer to understand how much electricity an air conditioner can be expected to consume over the course of the year. In contrast, an EER will only give the consumer information on how much electricity would be consumed at full capacity.

8.5 Transport

Summary

- Across all modes of transport, Brazil is consistent with other countries in terms of energy intensity, i.e. rail is the least intensive mode and aviation and larger cars the most.
- Brazil's transport sector is unique in its high share of ethanol consumption. It has over half of the global fleet of flex fuel vehicles. New flex fuel vehicle sales increased to 94% of new car sales in 2017, indicating that this trend is set to continue.
- Brazil is increasing its share of new car sales, in line with other emerging economies. In 2017, it accounted for 2.6% of global new car sales, with India at 4.2% and China at 30.7% (IEA, 2019i). It is the largest vehicle market in South America.
- Brazil's light duty vehicle (LDV) fuel economy is improving over time and benefits from the use of smaller vehicles. In comparison with advanced economies, the fuel consumption for similar types of cars (size and power) is higher in Brazil. This is a pattern seen with other emerging economies.
- Understanding the impact of advanced technologies and the role of fuel economy standards could be key to unlocking further fuel energy efficiency opportunities.
- Brazil's future transport energy demand needs may increase by over a third by 2040 under current policies (IEA, 2018b). Energy efficiency could help reduce this demand. This would facilitate further benefits in terms of: reduced reliance on fuel imports, increased opportunities for fuel exports and reductions in transport emissions.

This section provides perspectives on the energy efficiency of the transport sector in Brazil in a global context. It focuses primarily on the fuel economy of new light duty vehicles[31], measured in litres of gasoline equivalent (LGE) per km travelled. It also considers the relevance of structural differences in the LDV market, and, in particular, the high share of flex-fuel[32] vehicles in Brazil. Lastly, it provides insights on the options

[31] Information on vehicle classifications is provided on the following pages

[32] Flex-fuel vehicles are adapted to high biofuel blend levels or unblended biofuel use.

for improving fuel efficiency, taking into consideration the high share of flex-fuel vehicles in the market and the low-carbon profile of electricity generation.

It is important in any discussion on energy efficiency in transport to have in mind the complexity and scope of the sector. While this section focuses on fuel economy and comparison of vehicle designs and technologies, there are much broader considerations that must be taken into account to develop comprehensive efficiency-oriented transport policies. Examples include infrastructure planning (such as road design, traffic management, sidewalks and bike lanes) as well as public transportation networks.

A common approach to addressing energy efficiency in transport from a systems perspective is to frame the discussion around a broad conceptual hierarchy: **avoid, shift, improve**. That is, there are urban planning measures that can **avoid** the need for travel, reduce distances, and avoid extra trips where one trip can be organised to accomplish multiple errands. Investing in public transit and increasing the monetary or time costs of private car travel can drive a **shift** towards less intensive modes of transport. In an urban context, this typically means walking, cycling and mass transit. Finally, for captive trips where neither of the above approaches is viable (such as for commute trips from distant suburbs, or for intercontinental travel) more advanced fuels and technologies can be introduced to **improve** the efficiency within each mode.

While this section focuses on the “improve” portion of the formula, it is essential to combine the findings summarised here with a broader discussion that includes consideration of the strategies of “avoid” and “shift.”

8.5.1 Structure of Brazil’s transport sector in the global context

Globally, transport accounted for 29% of total final energy consumption in 2017. Road transport accounted for 74% of all transport demand. Worldwide sales of new light-duty vehicles totalled nearly 97 million in 2017, including 26 million commercial vehicles and 71 million passenger cars. Passenger car sales have been growing over the past decade. There were 4 million more sales in 2017 than 2015 – and 25 million more than in 2005.

From 2015-2018, energy efficiency has not been able to compensate for demand growth within the passenger transport sector. A shift to more intensive transport modes, an appetite for larger cars, and lower vehicle occupancy have all contributed to higher energy consumption (IEA, 2019f). The growing global appetite for sport utility vehicles

(SUVs), for example, means that SUVs were the second-largest contributor to the increase in global CO_2 emissions since 2010 after the power sector.[33]

Vehicle classifications

Light duty vehicles (LDVs) and heavy duty vehicles (HDVs) are classified based on a combination of vehicle size and weight.

LDVs include the following vehicles falling below 3.5 tonnes gross vehicle weight (GVW):

- Two wheelers
- Three and four wheelers (both passenger and freight)
- Passenger cars
- Passenger light trucks
- Minibuses
- Light commercial vehicles (LCVs)

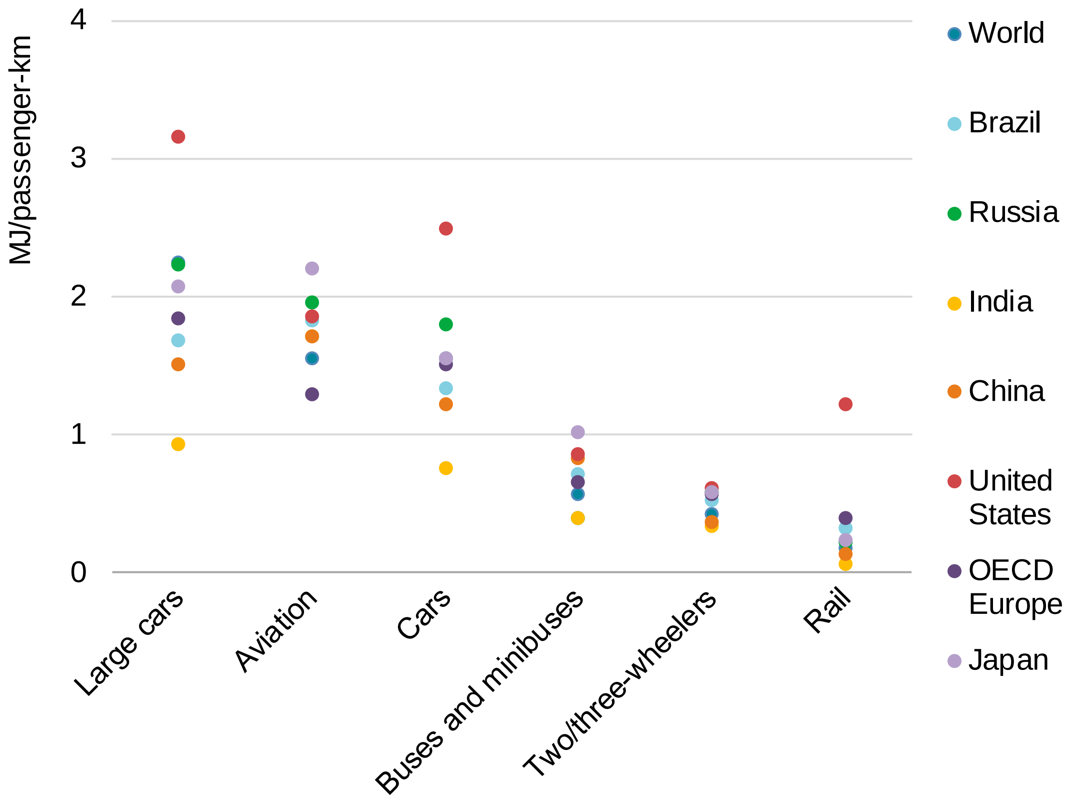
HDVs include the following vehicles falling above 3.5 tonnes GVW:

- Buses
- Bus Rapid Transit (BRT)
- Medium trucks (MFTs), between 3.5-15 tonnes GVW
- Heavy trucks (HFTs), over 15 tonnes GVW

In Brazil, as in other countries, there is a significant difference between the efficiency of passenger and freight service provision depending on the transport mode. On average, large cars tend to be the least efficient, followed by aviation and smaller cars (though there is a high degree of overlap among these modes, depending on the vehicle technologies, occupancy rates, and other trip characteristics). Two and three-wheelers (motor bikes and “trikes”) are more efficient than cars. Public transport, including buses, minibuses and rail can all perform far better than any of the private motorized modes (and air travel), provided that they are well utilised. Rail is generally the most efficient mode of motorised passenger transport, and ranks second to maritime in terms of lowest energy use per tonne-kilometre transport in most regions of the world.

[33] IEA Commentary, *Growing preference for SUVs challenges emissions reductions in passenger car Market*. 1 October 2019. https://www.iea.org/commentaries/growing-preference-for-suvs-challenges-emissions-reductions-in-passenger-car-market

Figure 79 – Energy intensity of passenger transport by mode



Source: IEA (2019j), Mobility Model

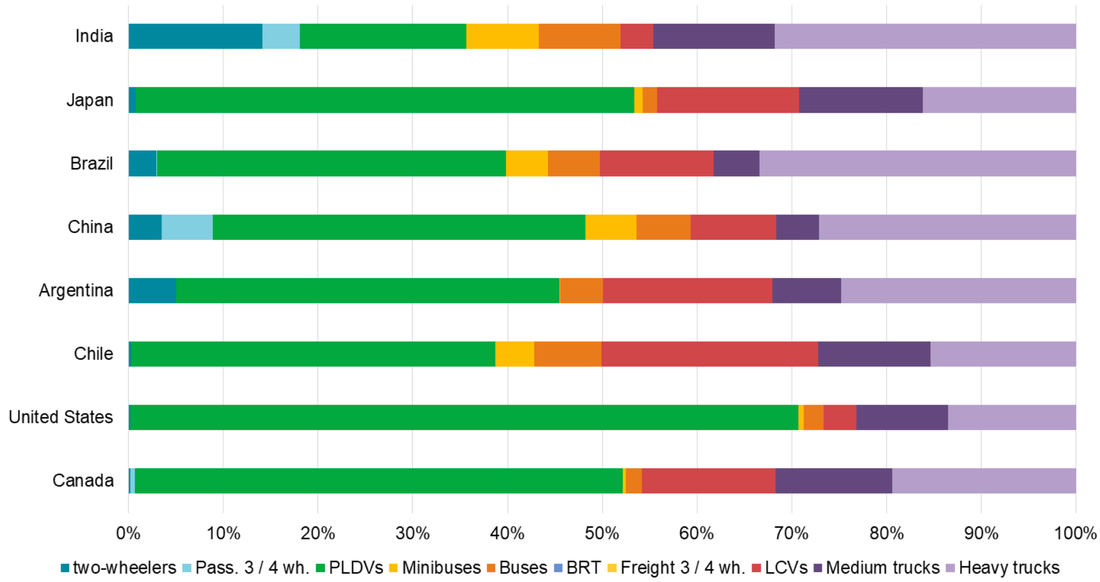
As their share of new cars worldwide grows, emerging economies are increasingly driving changes in global average fuel consumption for road transport. In 2005, emerging economies accounted for 20% of the global car market; today, they account for nearly 50%, largely driven by growth in China and India.

About 2.2 million light-duty vehicles (LDVs) were sold in Brazil in 2017 (IHS Markit, 2018) accounting for 2.6% of global sales[34] (iGFEI). Vehicle sales have declined sharply since 2014 due to economic difficulties. In 2012 LDV sales were 3.6 million, nearly two-thirds higher than 2017. However, in 2017 sales rebounded somewhat, increasing 9.5% from 2016. Brazil remains the largest vehicle market in South America. In 2017, its LDV stock was 36.6 million, equivalent to 0.18 LDVs per capita, similar to other countries in South America (IEA, 2018).

In Brazil, LDVs accounted for 54% of fuel consumption in in 2017, while HDVs accounted for 46% of fuel consumption.

[34] IEA elaboration and enhancement for broader coverage of IHS Markit database.

Figure 80 – Road transport, final consumption by mode

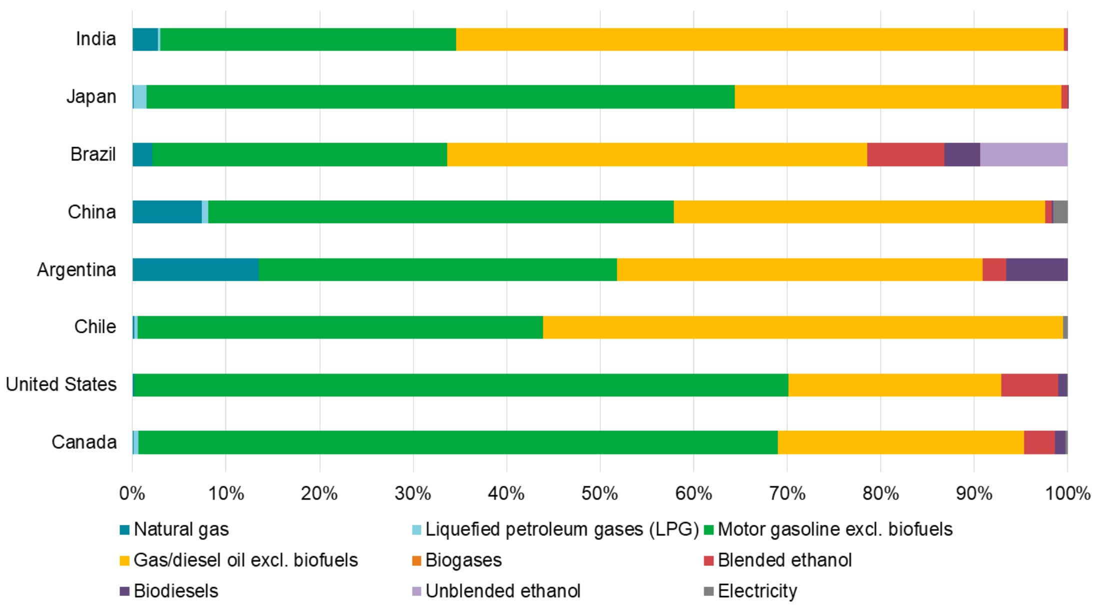


Source: IEA (2019k), Global Electric Vehicle Outlook

Gasoline and diesel continue to dominate the fuel mix for road transport globally. In 2017 in Brazil, gasoline accounted for 32% of road transport fuel consumption, while diesel accounted for 45% of road transport fuel consumption.

Brazil has the highest share of ethanol consumption in the world in overall fuel consumption in road transport. In 2017, the share was 18%, when blended and unblended ethanol are taken together.

Figure 81 – Final consumption by fuel, all road transport, 2017



Source: IEA (2019b), World Energy Balances

Light Duty Vehicles

In this section, Light Duty Vehicles are defined as having a gross weight of less than 3.5 tonnes. They are further divided into six market segments. While there is no standard accepted definition of market categories, the following table illustrates the boundaries of each category:

Market Segment	**Selected examples of vehicle models**
City car	Volkswagen Polo, Renault Clio, Chevrolet Onix, Kia Rio
Medium car	Volkswagen Golf, Honda Civic, Toyota Corolla, Volkswagen Lavida
Van/light-commercial vehicle	Ford Transit, Renault Master, Fiat Doblo, Tata Ace, Isuzu Elf
Small SUV/pick-up truck	Toyota RAV4, Honda CR-V, Great Wall Haval H6, Nissan Rogue
Large car	Toyota Camry, Honda Accord, Audi A4, Hyundai Elantra
Large SUV/pick-up truck	Ford F-150, Toyota Hilux, BMW X5, Isuzu D-Max, Audi Q7

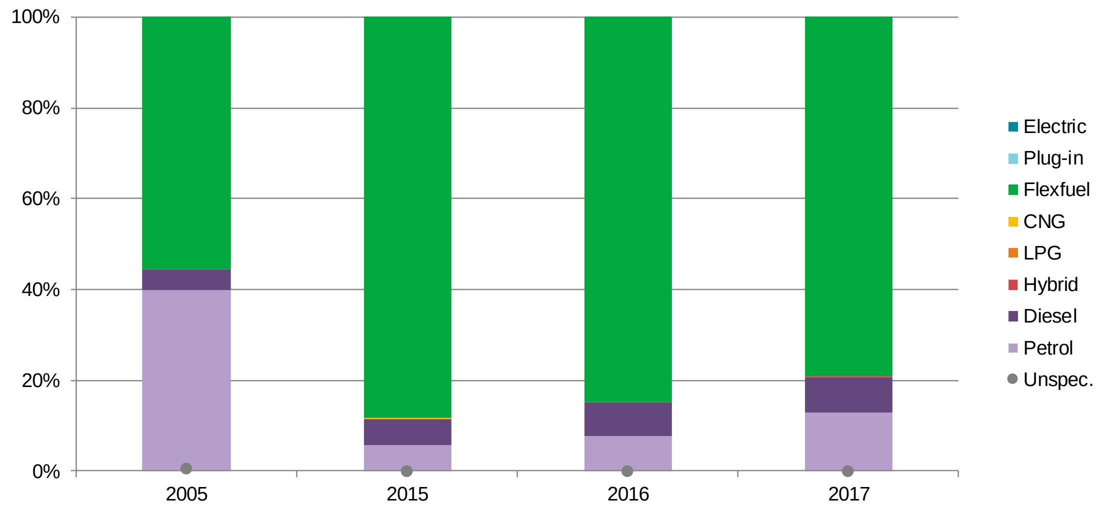
Source: IEA (2018d), Fuel Economy in Major Car Markets 2005-2017

Brazil is unique in the high share of flex fuel vehicles that can run on high ethanol blend levels (currently 27% by volume) or unblended ethanol. Between 2005 and 2017, the share of flex fuel vehicles increased from 52% to 94% of new car sales. No country comes close to this level of flex fuel vehicle sales. In total there are over 28 million flex fuel vehicles in Brazil (EPE, 2018), in comparison with around 21 million in the United States (DOE, 2019) . While not an efficiency measure, the high proportion of ethanol has a positive effect of lowering greenhouse gas and other harmful emissions from fuel combustion compared to gasoline and diesel.[35]

In addition, the production of ethanol is of strategic importance to Brazil as a core component of the output from its sugar industry. The ability of sugar mills to vary production between sugar and ethanol (within technical limits) based on the relative profitability of each is essential to the financial health of the sector.

[35] Key to securing the sustainability of biofuels is ensuring proper governance frameworks to ensure biofuels are sourced sustainably.

Figure 82 – Sales by LDV powertrain in Brazil



Source: IHS Markit, 2018 - IEA elaboration and enhancement for broader coverage of IHS Markit database

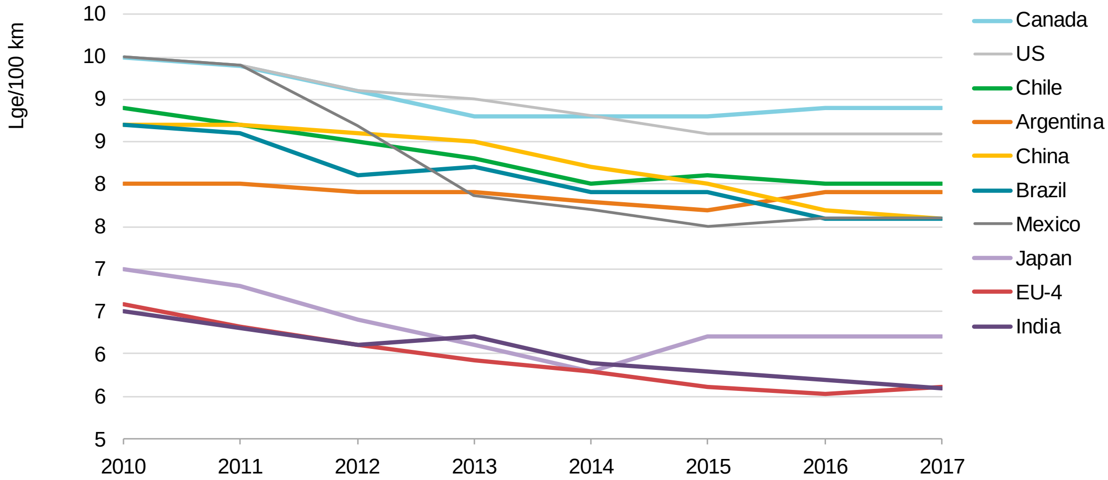
Several countries are expected to substantially increase levels of ethanol production and consumption in the coming years – notably China and India. As in Brazil, drivers for this increase include agricultural policy, energy security, and reducing emissions of CO_2 and other harmful air pollutants (notably particulate matter). China has set the goal to achieve the use of 10% ethanol (E10) in transport nationwide[36], while India's 2018 biofuels policy advocates 20% ethanol blending by 2030.

8.5.2 Fuel economy of the vehicle fleet

Brazil's average LDV fuel economy of 7.6 lge/100 km is slightly higher than the global average of 7.3, and of the average among emerging economies (7.4), as demonstrated in Figure 83. It is the same as China and Mexico.

[36] Through implementation of the Expansion of Ethanol Production and Promotion for Transportation Fuel plan.

Figure 83 – Average fuel economy improvement of LDVs



Source: IEA (2019i), Global Fuel Economy Initiative

Several factors affect vehicle adoption and fuel economy:

Fuel prices have a clear influence on the structure of the vehicle fleet. Advanced economies with fuel prices below USD 1/L have substantially lower average fuel economy due to a preference for bigger, more powerful vehicles. Canada and the United States fall in this category. Advanced economies with fuel prices above USD 1/L tend to have greater fuel economy. Europe and Japan fall in this category. Emerging economies tend to have fuel economy between 6.5 to 8.5 Lge/100km, with India as an outlier due to its high share of small, light vehicles. Brazil has a similar gasoline price and average fuel consumption to several other countries: China, Mexico, Argentina, South Africa, Peru, Chile and Australia.(IEA, 2019i) For example, gasoline costs per litre were US cents/litre 96 for China, US cents/litre 102 for Brazil and US cents/litre 110 for Argentina in November 2016. Globally, costs ranged from US cents/litre 0.8 in Venezuela to US cents/litre 200 in Eritrea (GIZ, 2016)

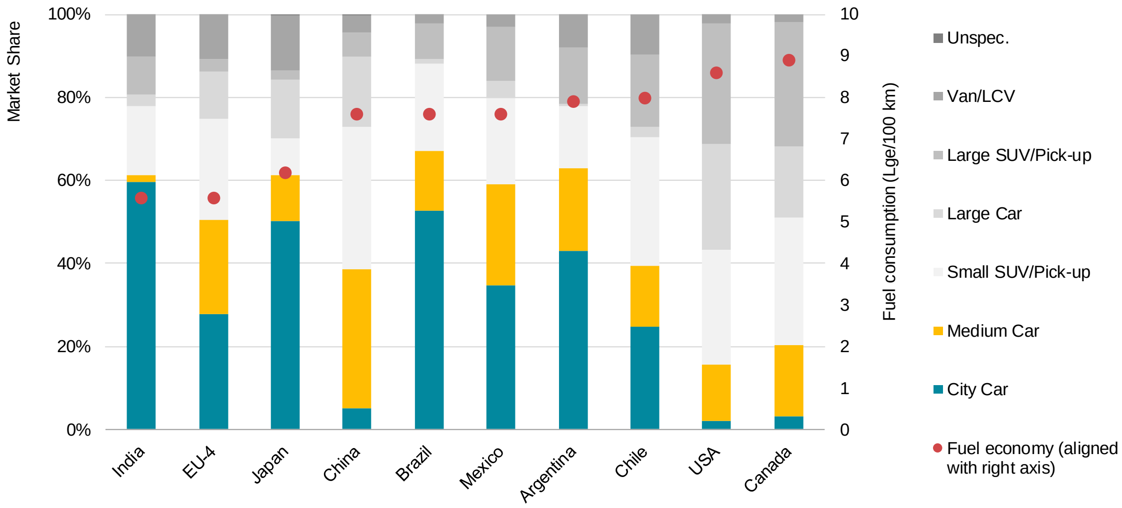
Design, size, weight and engine power combine to determine the fuel economy of a vehicle. Whether the fleet of LDVs in a country is made up of larger, heavier, more powerful vehicles, or smaller, lighter, less powerful ones will have a direct impact on average fuel economy. However, it is important to consider each of these factors separately. Sports cars, for instance, will be smaller in size, but have a more powerful engine, lowering their fuel economy compared to a similar-sized car with a smaller engine.

Powertrain and fuel also have a strong influence on fuel economy. All things being equal, gasoline engines have the lowest fuel economy, followed by diesel, hybrid electric (HEV), plug-in hybrid electric (PHEV), and battery electric (BEV) vehicles.

8.5.2.1 Design, size and engine power

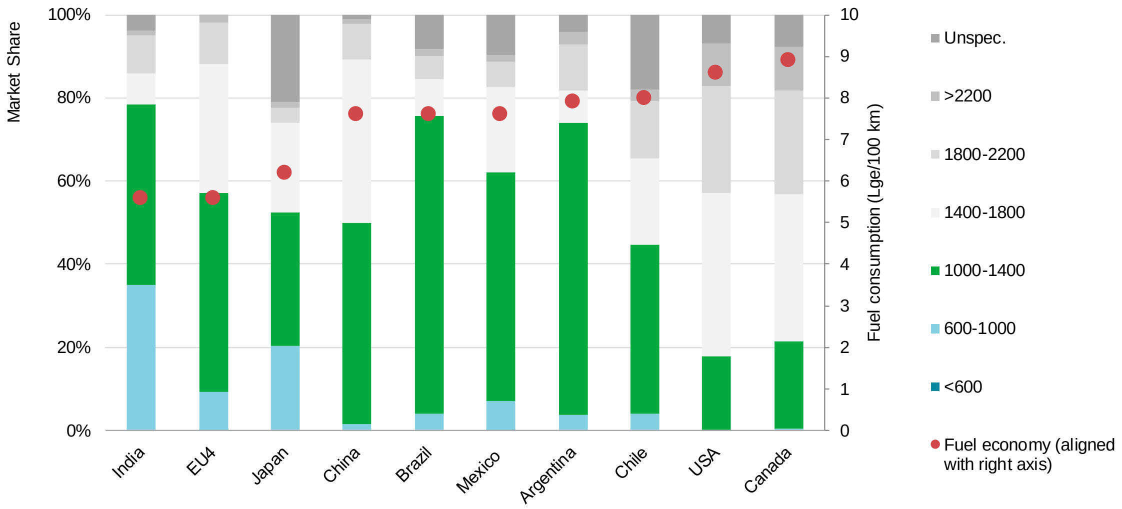
Most of Brazil's LDV fleet consists of relatively small and light vehicles. This has a positive influence on average fuel economy across the fleet. As illustrated below, this translates into a vehicle fleet composed of small car models that are light in size, have a small vehicle footprint, and small engine size.

Figure 84 – Market share per vehicle segment and fuel economy



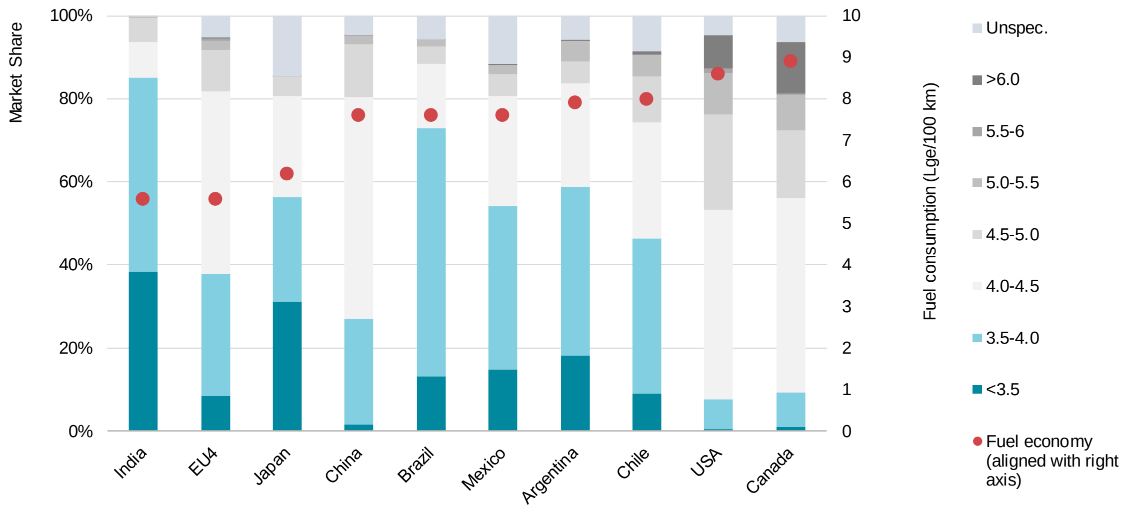
Source: IEA (2019i), Global Fuel Economy Initiative

Figure 85 – Sales by empty weight (average kerb weight, kg) and fuel economy



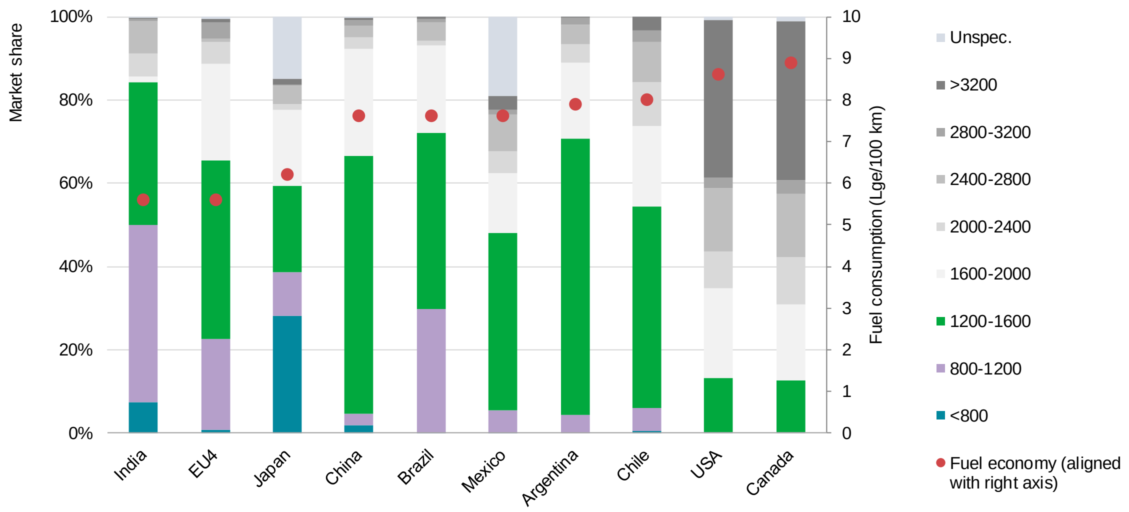
Source: IEA (2019i), Global Fuel Economy Initiative

Figure 86 – Vehicle footprint (m2) and fuel economy



Source: IEA (2019i), Global Fuel Economy Initiative

Figure 87 – Engine size (cm3) and fuel economy



Source: IEA (2019i), Global Fuel Economy Initiative

Fuel efficiency incentives in Brazil

Brazil has relied primarily on fiscal incentives to drive energy efficiency improvements in the automotive sector. Two policies have stimulated improvements in energy efficiency, under a broader objective of technological innovation and improved industrial competitiveness: the Inovar-Auto programme and, following its retirement, the Rota 2030 programme.

The Brazilian government introduced the "Inovar-Auto" programme in 2012. Under the programme, manufacturers and importers that met minimum fuel efficiency targets benefitted from a tax reduction of up to 30%. This effectively offset the 30% tax rate that was established before the introduction of the fuel efficiency target (TransportPolicy, 2016 in IEA, 2017a). The Inovar-Auto programme ended in 2017.

The Rota 2030 programme was introduced in January 2018 (Law nº 13,755), and follows a strategic line similar to “Inovar-Auto.” However, the main focus is to encourage research and development projects throughout the value chain, which extends beyond car manufacturers and importers to include auto parts manufacturers and strategic vehicle production systems.

Rota 2030 introduces minimum energy efficiency targets, alongside mandatory vehicle labelling and certain equipment safety and technology requirements. For energy efficiency, the programme includes a target of a 11% reduction in vehicle consumption from 2017 levels for cars and light commercial vehicles.

The programme further introduces financial penalties for non-compliance. On the other hand, companies that exceed the efficiency requirements by a certain margin and that implement a full list of safety equipment and technologies may qualify for fiscal incentives.

The mandatory vehicle labelling under Rota 2030 replaces the voluntary labelling programme for fuel economy introduced in 2007 (ICCT, 2014).

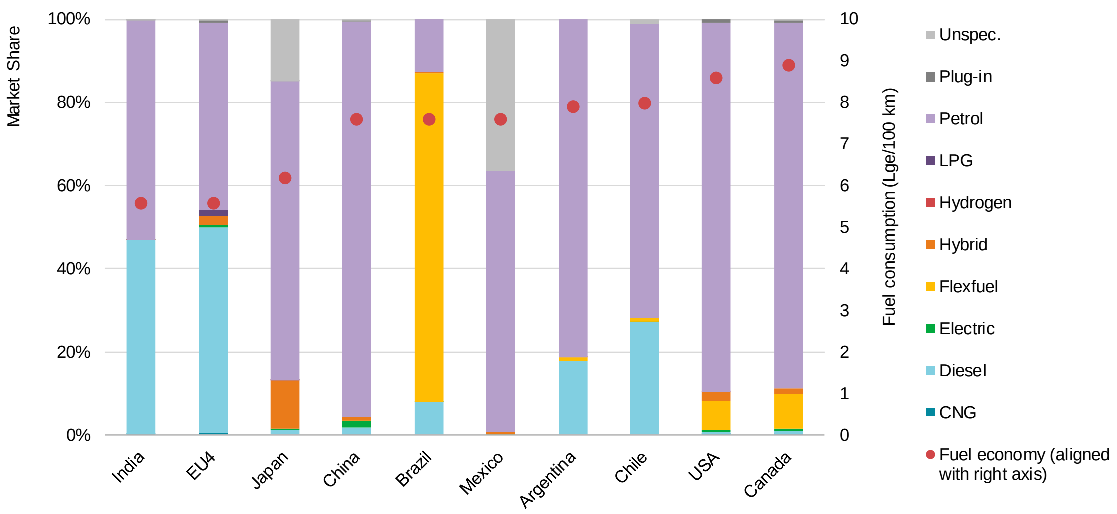
It is also worth noting that Brazil’s latest biofuels policy, RenovaBio, while focused on promoting the national biofuels industry, calls for improvements in the life cycle energy efficiency of biofuels. The programme will also establish “decarbonisation” credits (Créditos de Descarbonização) to track compliance with carbon emission reductions, as well as certificates reflecting the energy efficiency and carbon intensity of biofuels.

8.5.2.2 Powertrain and fuel

Powertrain technologies and associated fuels have a strong influence on LDV fuel economy. In most countries, internal combustion engines and gasoline dominate, as illustrated in Figure 88. Diesel plays a prominent role in Europe, India, and to a lesser extent, Chile, Argentina and Brazil. Most markets have limited shares of hybrid, plug-in electric and LPG cars, with only a nominal (less than 1%) share of fuel cell electric vehicles.

Brazil has the largest market share of flex-fuel powertrains of any country in the world, accounting for 94% of its new vehicle sales in 2017. By comparison, about 10% of LDV sales in 2017 were for flex-fuel powertrains in the United States and Canada. The only other countries with a market share above 1% were Chile and Argentina. Globally, cars with flex-fuel powertrains accounted for about 4% of LDV sales in 2017 (IEA, 2019i).

Figure 88 – New LDV market share by vehicle powertrain technology and fuel consumption[37]



Source: IEA (2019j), Mobility Model

Note: EU4 refers to Italy, France, Germany and the United Kingdom.

There is some evidence that ethanol blend levels will have a positive impact on efficiency and particulate matter.[38] It is difficult, however, to isolate the relative efficiency of flex fuel powertrains and their gasoline (in the case of ethanol) or diesel (in the case of biodiesel) counterparts. In Brazil, defining the average fuel economy is further

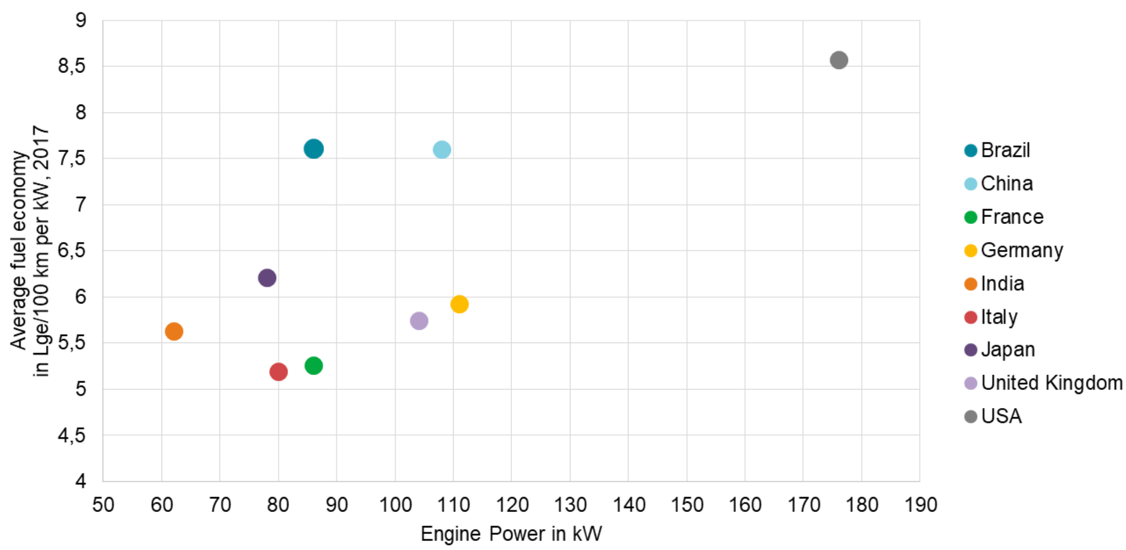
[37] Note there are slight differences between this and ANFAVEA data.

[38] See, e.g., Szikora (2018), Frankl (2017) and IEA (2019l).

complicated by the fact that the blends consumed in LDVs will vary depending on the relative price of ethanol compared to gasoline.

Brazil and many other emerging economies benefit in terms of fuel economy due to large portion of relatively small, light cars in the overall mix of LDVs. At the same time, as Figure 89 shows, these vehicles are not as fuel efficient as cars with similar engine power in advanced economies. In other words, cars with similar-sized engines, which would be expected to have similar fuel economy, in fact are often much less efficient in emerging economies. This indicates that there is potential for technological advancements in engine design to further improve the fuel economy. Technologies to consider include turbocharging, variable valve actuation and new transmission technologies.

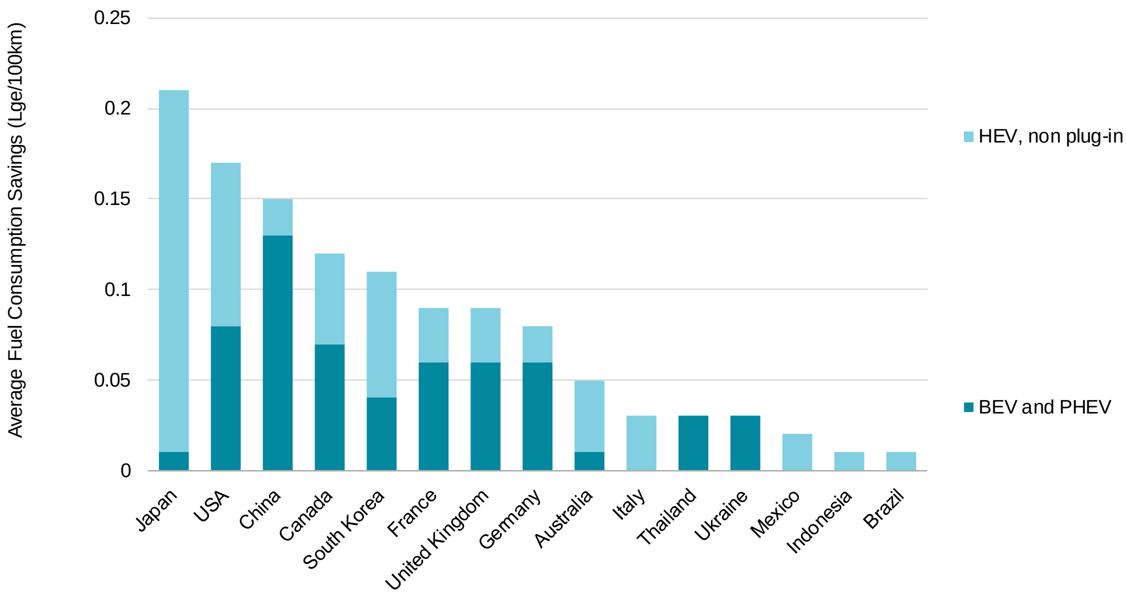
Figure 89 – Fuel economy and engine power, 2017



Source: IEA (2019i), Global Fuel Economy Initiative

Brazil is still in the early days of hybrid and electric vehicle adoption. Figure 90 presents the contribution of hybrid and plug in vehicles to average fuel economy savings. That is, how much did fuel economy improve as a result of the uptake of hybrid and plug in vehicles? The largest contribution among countries included are in Japan (primarily from hybrid vehicles), followed by China (primarily plug in vehicles).

Figure 90 – Electrified vehicles contribution to average fuel economy, 2017



Source: *IEA (2018d), Fuel Economy in Major Car Markets*

Well-to-wheel (WTW) greenhouse gas emissions in biofuels

For biofuels, a number of factors must be taken into account to assess WTW greenhouse gas emissions. The relevant factors will vary according to the characteristics of each fuel production pathway (location, feedstock, logistics).

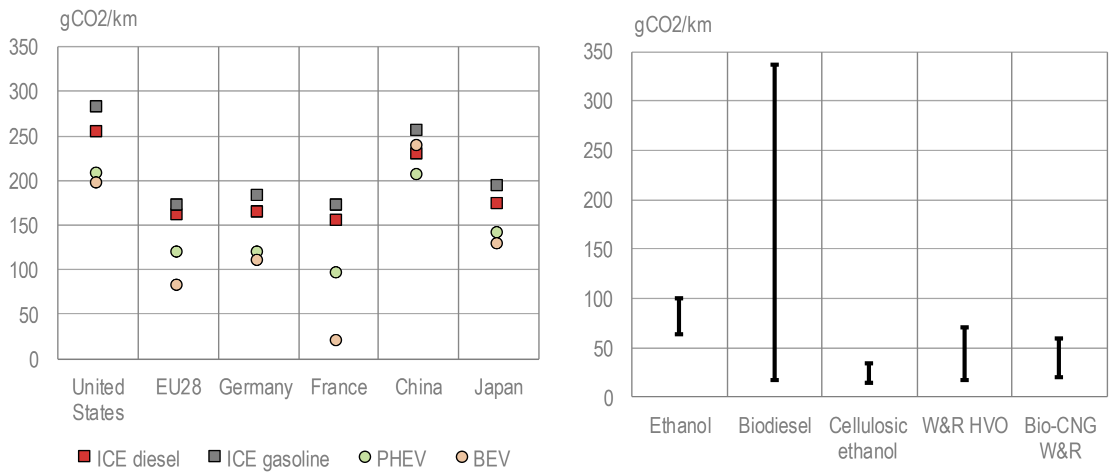
When considered on a WTW basis, CO_2 emissions per kilometre travelled from various biofuels compare favourably with those from fossil gasoline, diesel and electric cars in countries and regions analysed by the IEA.

One exception can be conventional biodiesel where the inclusion of modelled emissions from land use change results in upper-end estimates of WTW CO_2 emissions higher than fossil fuels with certain feedstocks, although biodiesel production pathways can also result in lower emissions (IEA, 2017b). In Brazil, at least 80% of biodiesel is produced from family cooperatives, which can involve the achievement of some environmental and social requirements and the award of a certificate – "Selo Social de Combustivel" (Social Fuel Seal). A share of the biodiesel produced in Brazil is from tallow (animal fat) and therefore very low carbon.

Brazil will introduce RenovaBio, its flagship biofuels policy in 2020. It is the core policy to increase the share of sustainable biofuels in Brazil's energy mix. RenovaBio will help Brazil to raise demand for biofuels (e.g. ethanol, biodiesel, biojet fuel and biomethane) and make their production more profitable.

In Brazil the uptake of electric and hybrid vehicles is still low. As Figure 91 demonstrates in terms of future adoption of electric vehicles, it is important to note that the CO2 emission reductions offered vary depending on the structure of the vehicle fleet and carbon intensity of the fuel mix. So countries with lower carbon electricity sources (renewables and nuclear) will have lower WTW CO_2 emissions. While vehicles with smaller batteries will have lower in-use energy requirements.

Figure 91 – On-road well-to-wheel greenhouse gas emissions from electric cars for selected countries and regions (left) and Reference WTW CO2 emissions from selected biofuels (right)



Source: IEA (2017b), Renewables Market Report 2017

Notes: PHEV assumes 30% electric driving; W&R = waste and residue feedstocks; bio-CNG = compressed biomethane; conventional fuel etanol and biodiesel values take account of modelled land-use change (LUC) and ILUC values; biodiesel range is for fatty acid methyl ester (FAME) based on sunflower, soybean and W&R feedtocks.

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