Country Diagnostic: Brazil

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Contents

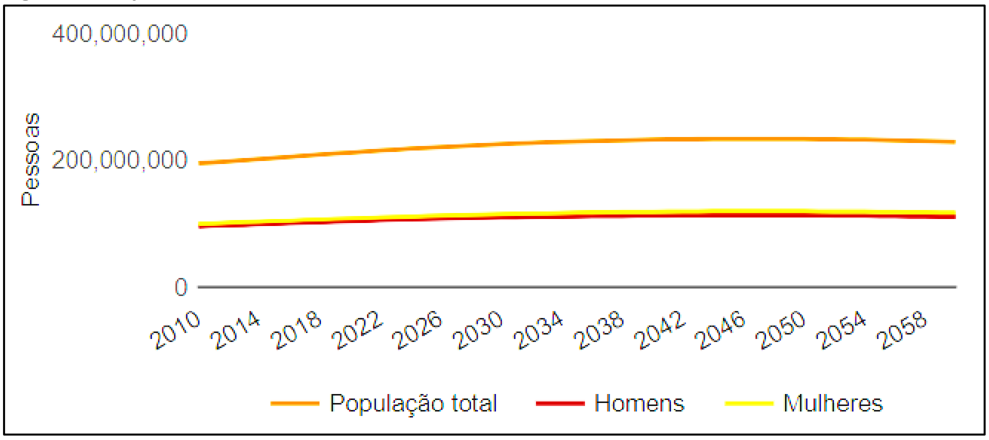
Abbreviations

ANAC	National Civil Aviation Agency
ANTP	National Association of Public Transportation
ANTT	National Land Transportation Agency
IDB	Inter-American Development Bank
CAMEX	Chamber of Foreign Trade
CDFMM	Carine Fund Board of Trustees
NDC	Nationally Determined Contribution
CONAC	Civil Aviation Council
CONAERO	National Commission of Airport Authorities
CONAMA	National Environmental Council
CONAPORTOS	National Commission of Port Authorities
CONTRAN	National Transit Council
CPRM	Geological Survey of Brazil
DNIT	National Department of Transportation Infrastructure
GHG	Greenhouse Gases
IPI	Tax on industrialized products
IPVA	Motor Vehicle Property Tax
MDIC	Ministry of Industry, Foreign Trade and Services
MMA	Ministry of Environment
MME	Ministry of Mines and Energy
NDC	Nationally Determined Contribution
UNFCCC	United Nations Framework Convention on Climate Change
SIMOB	Urban Mobility Information System
PT	Public Transportation
TI	Individual motorized transport
NMT	Non-Motorized Transport

1. Country Brief

Brazil has an area of 8,511,965 square km, making it the largest country in South America and the fifth largest in the world. In terms of population, the Brazilian Institute of Geography and Statistics (IBGE, 2020) estimated that in 2019 there were 210 million inhabitants, and projected that by 2030 there will be 224 million inhabitants. Below is the population growth projection from 2010 to 2058 (orange) along with the growth of men (yellow) and women (red).

Figure 1: Population Growth



Source: Brazilian Institute of Geography and Statistics. 2020

In economic terms, Brazil is the ninth largest economy in the world with a GDP of 2.01 trillion dollars at 2018 prices, which makes it the largest in Ibero-America, as well as accounting for 40% of the entire GDP of the region (Ministry of Foreign Affairs, European Union and Cooperation, 2020). The behavior of the Brazilian economy in recent years shows enormous potential for development after it overcame, in 2017, the greatest internal crisis experienced since the democratization occurred between 2014-2016, where GDP declines of 3.5 % per year were recorded. It was until 2018 when quarterly advances of 0.5 %, 0 %, 0.5 % and 0.1 %, respectively, were recorded, showing a slow recovery (Ministry of Foreign Affairs, European Union and Cooperation, 2020). In foreign trade, exports of the primary sector, soybean, oil, natural gas and metalliferous minerals stand out. Imports were mainly petroleum refined products, electronic and communication equipment and automobiles[1].

On the other hand, its internal political structure consists of a federal republic formed by 26 states and the Federal District. There is a separation of executive, legislative and judicial powers, and a presidentialist system of government currently headed by the president (Ministry of Foreign Affairs, European Union and Cooperation, 2020). As for major cities (See **Error! Reference source not found.**), the list is headed by Sao Paulo, Rio de Janeiro and the political capital Brasilia. Next to them it can be observed that in the country there are more than 10 cities with more than 1 million inhabitants.

1 General Directorate of Communication, Public Diplomacy and Networks. COUNTRY DATA SHEET: Brazil, Federative Republic of Brazil. July 2020.

Table 1: Population by City

#	City	Population	#	City	Population
1	Sao Paulo	12,325,232	8	Curitiba	1,948,626
2	Rio de Janeiro	6,747,815	9	Recite	1,653,461
3	Salvador	2,886,698	10	Porto Alegre	1,488,252
4	Brasilia	3,055,149	11	Belém	1,499,641
5	Fortress	2,686,612	12	Goiania	1,536,097
6	Belo Horizonte	2,521,564	13	Sao Luis Marceio	1,108,975
7	Manaus	2,219,580	14	Maceió	1,025,360

Source: Brazilian Institute of Geography and Statistics. 2020

2. Policy Framework

In Brazil, Law No. 12,187 of December 29, 2009 institutes the National Climate Change Policy (PNMC). This Law establishes principles, objectives, guidelines and instruments of the PNMC, considering adaptation, mitigation to the adverse effects of climate change, emissions, source, greenhouse gases, impact on climate change, vulnerability to climate variability and extreme events. The resulting actions, carried out under the responsibility of political entities and public administration bodies, will observe the principles of precaution, prevention, citizen participation, sustainable development and common but differentiated responsibilities, the latter at the international level.

The PNMC guidelines aim to comply with the commitments assumed by Brazil in the United Nations Framework Convention on Climate Change. The Kyoto Protocol and other documents on climate change to which it will become a signatory, calls to mitigate climate change by adopting adaptation measures to reduce the adverse effects of climate change and the vulnerability of environmental, social and economic systems by using integrated strategies to mitigate and adapt to climate change as well as encourage and support the participation of federal, state, district and municipal governments and also the productive sector, the academic sphere and organized civil society.

The main instruments of the PNMC are:

- The National Climate Change Plan;
- The National Climate Change Fund;
- The Action Plans for the Prevention and Control of Deforestation;
- Brazil's National Communication to the United Nations Framework Convention on Climate Change;
- The resolutions of the Interministerial Commission on Global Climate Change;
- Fiscal and tax measures designed to encourage the reduction of emissions and the elimination of greenhouse gases;
- Specific lines of credit and financing, the development of lines of research;
- Specific allocations for actions against climate change in the Union's budget;
- Financial and economic mechanisms to mitigate climate change and adapt to the effects of climate change;
- Financial and economic mechanisms to mitigate and adapt to climate change.

The institutional instruments for PNMC activities include:

- The Interministerial Committee on Climate Change;
- The Interministerial Commission on Global Climate Change;
- The Brazilian Forum on Climate Change;
- The Brazilian Research Network on Global Climate Change;
- The Coordinating Commission for Meteorology, Climatology and Hydrology Activities.

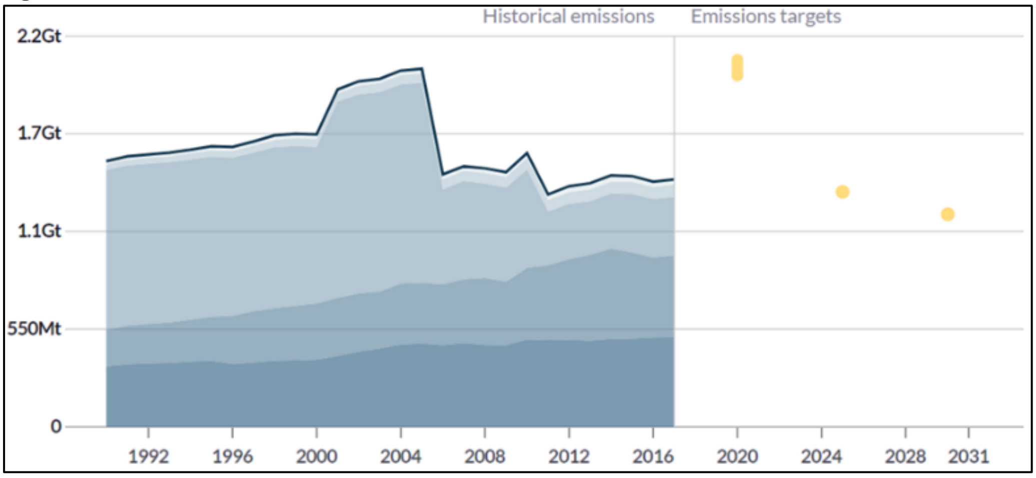
The National Policy also establishes that official financial institutions will provide specific lines of credit and financing to develop actions and activities that comply with the objectives of this Law and that aim to induce the behavior of private agents to observe and execute the PNMC, within the scope of their actions and social responsibilities.

Main regulatory framework in Brazil for the Climate Change Agenda:

- Law No. 12.187: National Policy on Climate Change (PNMC), dated 12/29/2009,
- Decree No. 7.390: Regulates the PNMC, dated 09/12/2010,
- National Climate Change Plan, by December 2020.

The following graph shows GHG emissions over the last 30 years and projections up to 2030.

Figure 2: GHG Emissions Brazil



Source : ClimateWatch. 2019

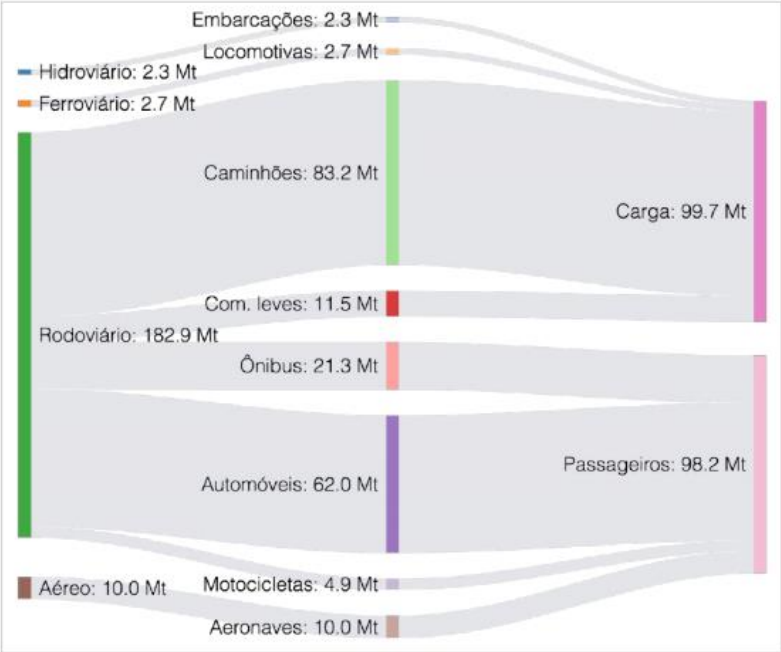
For the last historical year (2017) it is shown that agriculture is the activity that generates the most emissions with 506 Mt, followed by energy with 459 Mt and forestry with 329.

Annual estimates of greenhouse gas emissions in Brazil in 2020, according to the Ministry of Science, Technology, Innovations and Communications, show that the energy sector presented a 7.0 % reduction in emissions compared to 2015 due to the economic recession, which led to a decrease in industrial activity and consumption of fossil fuels in road transport. In addition, 2016 saw an increase in rainfall patterns that led to an increase in the domestic supply of energy from hydroelectric sources given the seasonal effects of the weather. This was also accompanied by the expansion of wind power and a drop in thermal generation using fossil fuels.

In 2019, emissions from transportation (196.5 million tons CO_{2e}) remained stable compared to 2018. These emissions are generated by the use of fuels in freight or passenger vehicles. Trucks and automobiles are the two main sources of emissions in transportation, responsible for 40% and 31%, respectively, of the GHGs emitted in this activity in 2019 (SEEG, 2020). Transportation emissions peaked in 2014 and has since shown considerably lower carbon levels. This is largely due to the country's economic slowdown in recent years, with a recession in 2015 and 2016 and growth that has been at less than 1.5 % per year since then. In addition to the crisis, this subsector has reduced a portion of its emissions due to the increased use of biofuels (biodiesel and ethanol), which are considered carbon neutral. 2019 was the year that saw the highest consumption of biodiesel and ethanol, which prevented a higher record of emissions in transport (SEEG, 2020).

Taking 2016 as a reference, the most used modes of transport in the country and which emit significant amounts of CO_2, are road (183 Mt), air (10 Mt), rail (3 Mt) and waterway (2 Mt). In addition, there is a balance between emissions from freight transport (99.7 Mt) and passenger transport (98.2 Mt) (Lopes Espíndola, 2020).

Figure 3: GHG Transportation Emissions in Brazil 2016



Source: (Lopes Espíndola, 2020).

In its NDC (Nationally Determined Contribution, 2015) Brazil commits to mitigate, adapt and implement measures with the purpose of achieving the ultimate goal of the convention foreseen in the Paris Agreement. The fundamental objective of the NDC is to reduce greenhouse gas emissions by 37% , reaching lower level than 2005, by 2030, in order to help limit the global average temperature growth to 2°C above pre-industrial levels, and to promote the country's long-term sustainable development.

The Transportation and Urban Mobility Sector Plan for Climate Change Mitigation and Adaptation (PSTM) seeks to contribute to the mitigation of GHG emissions in the sector, through initiatives that lead to the expansion of freight transportation infrastructure and greater use of more energy-efficient modes and, in the urban mobility sector, greater use of efficient public passenger transportation systems, contributing to the fulfillment of the commitments voluntarily assumed by Brazil.

The NDC dedicates a paragraph to the transportation sector to state that the government will further promote efficiency measures and improve public transportation infrastructure in urban areas. These include increasing the share of sustainable biofuels in the Brazilian energy mix to approximately 18% by 2030, through three key measures:

- increased consumption
- increased ethanol supply
- increased share of biodiesel in the diesel mix.

Energy Policies

Brazil has a share of 27% of biofuels in the transportation sector in 2019. The biodiesel content is 4.7% and the bio-ethanol share 22%. Several public policies were implemented over the years, specifically made for biofuels, such as the National Alcohol Program (PROALCOOL), in the 1970s, the National Program for the Production and Use of Biodiesel (PNPB) in 2005 and more recently the National Biofuels Program (Renovabio) in 2017 (EPE, 2016) (EPE, 2018). In addition, the country has mandates to add biofuels to petroleum derivatives and sectoral financing lines (BNDES, 2020), (BRASIL, 2016), (MAPA, 2020). Another important point was the adoption of flex fuel technology in 2003 by automakers, which allowed the use of up to 100 % hydrated ethanol in vehicles.

The Ministry of Mines and Energy (MME) formulates energy-related public policy. With the Brazilian Technologies and Emissions Program (in partnership of the Ministry of Environment (MMA), the National Agency of Petroleum, Natural Gas and Biofuels (ANP), Ibama, Petróleo Brasileiro S.A. (Petrobras) and the Brazilian Association of Automotive Engineering (AEA)), promotes scientific studies on the influence of fuels and vehicle technologies on automotive emissions. The entity focuses on biofuels instead of electromobility. (PROMOB-e, 2018).

The MME also coordinates the RenovaBio program, a state policy that generates a joint strategy to recognize the role of all types of biofuels in the Brazilian energy mix. The program aims at both energy security and GHG mitigation and has an indirect interface with electrification. (PROMOB-e, 2018). According to Renovabio rules, producers and importers of biofuels will be able to calculate energy and environmental efficiency through the tool called RenovaCalc in order to certify their production.

In order to meet the goals established in the National Energy Plan 2030 (PNE 2030), the National Energy Efficiency Plan (PNEF) was developed. The lines of action related to the topic of electromobility intend to study incentives (subsidies or tariff benefits) for the entry of individual electric vehicles, and studies of issues related to regulation in the electricity sector (PROMOB-e, 2018).

In addition, the National Electric Energy Agency (Aneel), in 2016 and 2017, launched public consultations with the objective of obtaining subsidies for improvements in the tariff structure and assessing the impacts associated with electric vehicle charging. Another of Aneel's recent initiatives that stimulates the electrification of vehicles, is the adoption of differentiated tariffs ("white tariff") according to the time of day and day of the week, having higher tariffs at times when energy demand is normally higher (PROMOB-e, 2018).

In September 2017, the government launched the national plan "ROTA 2030" aimed at the automotive sector that seeks to; achieve energy efficiency, improve vehicle safety, promote investments in research and development, and generate tax discounts for electric cars in order to boost the sale of these vehicles (Bellido, De la Cruz, Hidalgo, Oré, & Taype, 2018). The energy policy on transportation for 2030 tends to favor the use of biodiesel and ethanol in flex-fuel technology. This policy, included in Brazil's Ten-Year Energy Plans, estimates residual electric mode in the next 10 years, because the results of electric buses are good from the environmental point of view but bad from the financial point of view, therefore, studies recommend the use of flex-fuel and biodiesel technology in the short and medium term. (CAF, 2019).

Transportation Policies

The National Transportation Policy (PNT) is the highest level document for the country's Transportation Sector, where the principles, objectives, fundamental guidelines and instruments for planning and implementation are established. The PNT is divided into two documents, presenting in its State Book the fundamental principles, objectives and guidelines governed by the Federal Constitution, and in the Government Strategies Booklet, the strategic actions to implement the policy in line with the guidelines of the government and the country. The PNT aims to induce sustainable socioeconomic development and promote national and international integration through the provision of infrastructure and transportation services, providing greater competitiveness and reducing inequalities in the country.

In 2018, the formulation of new bases for the National Transportation Policy was premised on the participation of government sectors and society, and sought to reach other national policies, in the planning, social, economic, environmental, integration and defense segments. Institutionally, discussions and incentives for electric mobility have been developed since the beginning of this century. These advances have promoted clean or sustainable technologies, resulting in a set of policies with electric vehicles, which are shown in the table below.

Table 2: EV Policies

Instrumento	Nombre del programa, proyecto o política pública
Incentivos para producción local	(1986-): Programa de control de la contaminación del aire para vehículos de motor (PROCONVE) (2008-): Programa de etiquetado de vehículos (2011-): Programa climático BNDES Fundo (2013-2017): Innovate Auto (2016): Resolución CAMEX n° 34. de abril de 2016 (2018) Ley N ° 13.755, de 10 de diciembre de 2018 - instituye el Programa Rota 2030 - Movilidad y Logística
Apoyo para desarrollo científico y tecnológico	(2002): Programa Brasileño de Sistemas de Pilas de Combustible (FINEP) (2003-2016): Proyectos de Investigación (CNPq) relacionados con vehículos eléctricos (2005-2007): Fortalecimiento del Centro de Desarrollo de Energía y Vehículos (FINEP) (2008-2018): Proyectos de I + D de Aneel relacionados con los vehículos eléctricos (2010-2016): FInanciamiento del CT - Fondo Sectorial Energia (FINEP) (2011-2015): Convocatoria de Sibratec (2011-2013): Programa de Apoyo a la Inversión del BNDES (2011-): Fondo Tecnológico (FUNTEC) (2012-): estándares ABNT relacionados con vehículos eléctricos (2018) Ley N ° 13.755, de 10 de diciembre de 2018 - instituye el Programa Rota 2030 - Movilidad y Logística
Soporte de infraestructura recargar	(2013-): Inova Energía - La línea de financiación incluyó proyectos piloto para sistemas de carga de vehículos eléctricos (2016): Consulta Pública de Aneel sobre la necesidad de regular aspectos relacionados con el suministro de energía eléctrica a los VE (2018): Reglamento de la Aneel para la prestación del servicio de recarga de energía eléctrica para vehículos eléctricos (2018) Ley N ° 13.755, de 10 de diciembre de 2018 - instituye el Programa Rota 2030 - Movilidad y Logística (2018) Lanzamiento de la consulta pública n° 19/2018 de aportaciones a la convocatoria del Proyecto Estratégico de I + D n° 22/2018: "Desarrollo de Soluciones Eficientes de Movilidad Eléctrica".
Incentivos para consumo	(2015): Resolución CAMEX n° 97 - reducción del impuesto a la importación de VE (2016): Resolución CAMEX de reducción del impuesto a la importación de VE por transporte de mercancías (2018) Ley N ° 13.755, de 10 de diciembre de 2018 - instituye el Programa Rota 2030 - Movilidad y Logística Estatal / Municipal (2014—): Exenciones estatales IPVA de vehículos eléctricos (RS, MA, PI, CE, RN, PE, SE) y tarifas diferenciadas (MS, SP, RJ) (2015): Exención de rotación en Sao Paulo

Source: PROMOB-e. 2019

It is clear that Brazil has a robust regulatory framework with public policies that favor electric mobility, however, there is no clear course that promotes the sector. In the last 5 years, mainly in 2015, 2016 and 2017, the government has tried to solve this difficulty through a series of interesting changes and implementations that seek to orientalize the previous policies. Mainly the following measures stand out (Promobe, 2019):

- CAMEX Resolution 97 of October 26, 2015: the import tax rate for automobiles with electric propulsion engine powered by accumulators or fuel cells with a range of at least 80 km was reduced to 0. For hybrids, it reduced the rate from 35% to between 2 and 7% depending on the capacity and efficiency of the engine.
- Normative Resolution No. 819, dated June 19, 2018: The first regulation on the recharging of electric vehicles is found. It is established that the recharging service is a competitive activity and distict from commercialization or supply, so it does not make sense to set rates for this service.
- Rota 2030 Program: Mobility and logistics, via Law No. 13,755, of December 10, 2018. It sets a course for the automotive sector in the 2020-2030 horizon in pursuit of greater energy efficiency of vehicles and vehicle-oriented development. In compliance with the program, a group called G17 was created to discuss electric mobility
- Decree No. 9,442 of July 4, 2018. This decree reduced the rates of the Indistrualized Products Tax (IPI) to vehicles with hybrid and electric motors. The rate decreased from 25% to a range between 7% and 20%. The more efficient the vehicle, the lower the percentage.

There are 21 bills pending in the Chamber of Deputies on electric mobility that seek greater incentives for electric vehicles (Promobe, 2019). Finally, it is important to note that the aforementioned decrees also contribute to the manufacture and marketing of cabs. In addition, initiatives to promote electromobility in the industry have been highlighted, such as the Taxi Pilot Program in Rio de Janeiro, which took place in 2013. It was a program carried out with Japanese capital through the multinational Nissan, which sought to promote the brand and its clean technologies. Their efforts consisted in launching about 60 Nissan Leaf vehicles on loan under a loan contract to circulate constantly in Rio de Janeiro (Promobe, 2019).

Technology opportunities and constraints

Parallel to transportation policies, Brazil has been making giant strides in terms of component production through agreements and national technological advances. However, certain barriers have also been encountered that have slowed the spread of clean technologies. These opportunities and barriers are shown below:

Powertrain:

Oportunidades	Barreras
• Industria local con capacidad productiva en las tecnologías de *tren motriz* / capacidad de los proveedores locales para responder a las demandas específicas de los fabricantes de automóviles • Uso de capacidades y habilidades tecnológicas existentes para el desarrollo local de *tren motriz* híbrido de etanol / *combustible flex*, así como programas gubernamentales interesados en mantener y consolidar el sector de biocombustibles en el país (conciliación de intereses)	• Los fabricantes de automóviles locales no están muy abiertos a establecer asociaciones con la cadena de producción local. • Industria local dependiente de la importación de tecnologías complementarias

Source: PROMOB-e. 2019.

Batteries:

Oportunidades	Barreras
Baterías de bajo voltaje • Existencia de capacidades locales en baterías de bajo voltaje aplicadas al sector automotriz • Base de conocimiento para la producción de baterías industriales y estacionarias, que también se puede aplicar a la producción de baterías para tracción eléctrica y viceversa. • • Transición internacional que tiene como objetivo que todos los vehículos convencionales dejen de usar baterías de 12v y comiencen a usar baterías de 48V.	• Opinión dominante entre los actores de que Brasil seguirá dependiendo de la importación de componentes de baterías elementales Poco vínculo entre las TIC y el sector productivo Alta concentración de la industria en empresas extranjeras, colocando altas barreras de entrada tanto en términos de conocimiento científico-tecnológico como en términos de capital necesario para instalar plantas de producción local.

Source: PROMOB-e. 2019.

Infrastructure:

Oportunidades	Riesgos y barreras
• VE ligeros aprovechando la infraestructura de carga para vehículos pesados • Posibilidad de que los mismos actores que suministran electróforos públicos brinden soluciones individuales y domésticas • Posicionamiento con infraestructura de vanguardia • Posibilidad de liderazgo latinoamericano en provisión de infraestructura	• Importar dependencia de controladores electrónicos y *tapones* y sus protocolos de recarga • Obsolescencia de los patrones de acceso de los usuarios a los electróforos

Source: PROMOB-e. 2019.

Other Regulations

In order to comply with the objectives of the Framework Convention on Climate Change in Sao Paulo, a Climate Change policy was created and enacted by law 14,933/09 under the name of Climate Law. This law promoted the use of renewable energies and the substitution of fossil fuels for fuels with lower greenhouse gas emissions through the following articles:

- Article 5: established a 30% emissions reduction target for 2012 with a base year of 2006. It also required that new targets be redefined two years before the end of the committed periods.

- Articles 30, 37 and 38: this section of the law required that public bids and administrative contracts in São Paulo must contain environmental and sustainability criteria. This was in line with the fact that public transport service in the city was tendered by the government to private companies, so all transport contracts were conditioned to meet minimum sustainability criteria.

In addition, contracts and any authorization related to public transportation in the city had to reduce the use of fossil fuels with a goal of at least 10% each year since 2009. It also established that by 2018 renewable non-fossil fuels were to be used in all buses in the municipal public transport system.

Expectations in terms of sustainable transport were high on paper, but at the time of implementation the companies were not obliged to meet them as tenders that progressively reduced emissions were not ready in time. As a sign of this was that by 2017, little more than 1% of the municipal buses complied with the legal requirement. Of the 14,000 buses in the fleet, only 201 trolleybuses powered by electricity met the standards of Article 60 of the Climate Change Policy. (Diario do Transporte, 2017). In short, despite several deadlines and rigid targets, delays and lack of incentives did not allow progress to be made.

Faced with this, in January 2018, Article 60 of Law 14,933/09 was rewritten under the name of Law 16,802/18, with the objective of reducing emissions from the entire fleet of buses in São Paulo. Its purpose is to require operators of the Urban Passenger Transport System of the Municipality of Sao Paulo to progressively reduce emissions of carbon dioxide and toxic pollutants. The new law has as goasto reduce GHG emisisons within 10 years by 50% and within 20 years by 100%. The new law also created a "Steering Committee of the Fleet Replacement Monitoring Program for Cleaner Alternatives", whose function is to encourage, monitor and oversee the adoption of plans, programs and actions that allow compliance with the Follow-up Program Fleet Replacement with Cleaner Alternatives (Sao Paulo,2018).

At the same time, in Brazil, electromobility initiatives have been highlighted in light vehicles that seek to encourage their commercialization. The following are different programs and initiatives developed in more than 10 cities.

Table 3: E-Mobility Activities per City

Actor	Institución	Origen del capital	lugar de actividades en Brasil	Principales programas / acciones / iniciativas
Automóviles (paseo, comercial y flota)	Nissan	Japón	Río de Janeiro (sede comercial) y Resende (RJ) (planta productiva de vehículos de combustión VE	Programa Piloto de Taxi en Río de Janeiro, iniciado en 2013, como la principal acción de marca en marcha en el país. Cerca de 50 vehículos fueron cedidos en un contrato de préstamo, con el objetivo de promover la marca y la tecnología eléctrica en la ciudad de Río de Janeiro. Desarrollo de tecnología de prototipos *tren motriz* Residencia en a pilas de combustible utilizando tecnología SOFC, que permite la uso de etanol como fuente de energía para la tracción de vehículos Nueva generación de Nissan Leaf planeada para su comercialización en Brasil en 2019
	BMW	Alemania	São Paulo (sede comercial), Araquari (SC) (planta productiva vehículos de combustión interna)	Actuaciones en dos frentes de trabajo: la venta de vehículos a particulares y empresas, así como el establecimiento de alianzas para la instalación de infraestructura de recarga en concesionarias de vehículos y establecimientos comerciales, con miras a la promoción y publicidad. sus coches eléctricos. Las motivaciones se refieren a la alineación a la estrategia global de la marca, orientada a la difusión de sus modelos, así como así como la expectativa de diseño e implementación de políticas públicas para vehículos eléctricos en Brasil.
	Fíat	Italia	Betim (MG)	Desarrollo de tecnologías de hibridación de vehículos, como tecnologías micro y híbridas suaves, ejemplificadas por el generador de arranque por correa y los productos del sistema start-stop (dos patentes están registradas en Brasil). En Brasil, hay discusión, estudios y desarrollo de estas tecnologías, pero ninguna aplicación práctica. En la década del 2000 se desarrollaron prototipos de autos Palio electrificados con Itaipu, con el propósito de realizar proyectos demostrativos.
	Vado	Estados Unidos	São Bernardo do Campo (SP) y Camaçari (BA) empresas productivas de vehículos de combustión interna	Importación y comercialización de VHs en Brasil, como Ford Fusion.
	Renault	Francia	São José dos Pinhais (PR) tomó de vehículos de combustión interno	prestados y vendió sus modelos eléctricos a empresas, con una planta de producción VE se utiliza para acciones más pequeñas, proyectos de asociación y pequeñas flotas dirigidas a un público específico. Renault tiene para la realización de pruebas y estudios tecnológicos. Hasta 2018, no comercializar vehículos eléctricos a los consumidores brasileños en general, aunque ya ha señalado un cambio en esta estrategia. Participó activamente en la clasificación y regulación de cuadriciclos con el modelo Twizzy, lo que permitió otras homologaciones en el país.
Automóviles (paseo, comercial y flota)	Toyota	Japón	São Bernardo do Campo (SP) e Indaiatuba (SP) con planta de producción de vehículos de combustión interno	Tiene como meta la hibridación global total de sus modelos para el 2050. Para el caso brasileño, importa uno de sus modelos híbridos, el Prius, pero tiene conversaciones avanzadas para la producción de un modelo híbrido en Brasil. En el primer semestre de 2018, realizó pruebas con el Prius Flex, el primer automóvil híbrido que puede alimentarse con etanol en lugar de gasolina y combinarse con el motor eléctrico. Es una tecnología desarrollada en asociación con Toyota Brasil y Japón, que se puede aplicar a otros modelos de vehículos de la empresa.
	GM (Chevrolet)	Estados Unido	São Caetano do Sul (SP) y Gravataí (RS) con una planta de producción de vehículos de combustión interno	La empresa confirmó la venta de su modelo eléctrico, Bolt, de 2019 en Brasil a particulares y empresas. Realizó experiencias y evaluaciones locales con VOLT durante los años 2010.
	BYD	China	Campinas (SP) con planta de montaje de autobuses eléctricos	La primera acción de la empresa tuvo lugar en Brasil en 2014 - y aún está vigente -, con la importación de vehículos eléctricos listos para la venta en el país. BYD tiene tres modelos de vehículos eléctricos a batería en el país: dos autos (un hatchback y un sedán) y un vehículo utilitario. La mayor acción de la empresa fue la instalación de una fábrica en Brasil para la producción del chasis del autobús eléctrico, que entró en operación en 2017 en Campinas, pero no se descarta la posibilidad de ensamblar autos eléctricos en los próximos años en el país.

Source: PROMOB-e. 2019.

In Brazil, several studies have been carried out on electromobility, however, there has not been significant progress in the inclusion of electromobility. The following is a summary of the main measures and policies presented in recent years on the subject:

Policy	Main components
CAMEX Resolution N°97 of 2016	Reduction of import tax on EVs
Aneel Regulations 2018	Provision of electric energy recharging services for electric vehicles.
Public consultation N° 19/2018	Contributions to the call for Strategic Project N°22/2018 "Development of Efficient Electric Mobility Solutions".
Law No. 13,755 of December 10, 2018.	Establishes the Rota 2030 State/Municipal Mobility and Logistics Program.

3. Macro-Economic Frame

Brazil, one of the largest markets for the sale and manufacture of automobiles, has also been a leader in clean transportation with the federal "Proálcool" initiative launched in the 1970s to promote the use of sugarcane ethanol as fuel. From 1990 to 2011, the cultivated area increased by 45 % and ethanol production increased by an average of 1.5 billion tons per year, generating 1.2 million direct and indirect jobs. Therefore, electric vehicles are expected to face a strong resistance form biofuels (ethanol) in Brazil. (Geraldo Costa, 2019).

On the other hand, Brazil is a major oil producer (in 2017 it ranked 11th in the world). But, being a major producer should not necessarily be a barrier for electric vehicles, as Norway, for example, is a major oil producer and is a world leader in electric vehicle penetration. However, given the strength and economic and energy importance of the oil industry for the country, as well as the Brazilian government's policy incentives to increase oil production, it is foreseeable that EVs will face a barrier from the domestic oil sector in Brazil (Geraldo Costa, 2019).

The Brazilian automotive industry is among the ten most important in the world. Consequently, it will have to make significant investments if it decides to produce electric vehicles for the mass market (Geraldo Costa, 2019). Under the government policy INOVAR auto, which promotes the local manufacture of efficient vehicles, "super credits" are provided to electric vehicle producers, helping them to achieve their consumption goals (Bellido, De la Cruz, Hidalgo, Oré, & Taype, 2018). On the other hand, if it is decides to produce batteries for electric vehicles, there will have to be large financial investments and the raw material will have to be imported (Geraldo Costa, 2019).

In October 2015, the first incentives for the purchase of electric vehicles were adopted. These vehicles were mandated to have a 0 % import tariff rate and there is currently an initiative to reduce to 0 % the Industrialized Products Tax for hybrid, electric, and ethanol vehicles manufactured in the country. At the state and local level, electric vehicles are exempt from paying the annual owner's tax in the states of Pernambuco, Maranhão, Ceará, Piauí, Rio Grande do Norte, Rio Grande do Sul and Sergipe, and reduced taxes in Rio de Janeiro, Mato Grosso do Sul and São Paulo. In 2014, the city of São Paulo enacted a law exempting electric and hybrid vehicles from the "Rodizio Veicular," a program that reduces the circulation of vehicles (Bellido, De la Cruz, Hidalgo, Oré, & Taype, 2018).

4. Transportation Sector

4.1. Relevant Actors

- **Ministry of Infrastructure**

  This ministry is in charge of formulating guidelines for the development of the transit sector in the country. The areas of competence of this ministry are (gob.br, 2020):
    - National policy for rail, road, river, airport and air transportation.
    - National traffic policy
    - Planning of the implementation of transportation investment programs

- **Ministry of the Environment (MMA)**

  The objective of the ministry is to formulate environmental public policies that encourage sustainable development. Its areas of competence are (Ministério do Meio Ambiente, s.f.):
    - National environmental policy
    - Policy for the preservation, conservation and sustainable use of ecosystems, biodiversity and forests.
    - Strategies for improving environmental quality and the sustainable use of natural resources
    - Environmental and productive integration policies
    - Environmental policies and programs for the Amazon
    - Strategies for the promotion of environmental policies
    - Economic-ecological zoning

- **Ministry of Mines and Energy (MME)**

  It has four secretary sections that propose the guidelines in their areas of activity (gob.br, 2020):
    - Secretary of petroleum, natural gas and biofuels: proposes guidelines for bidding in areas for the exploitation and production of these components.
    - Geology, mining and mineral processing secretary: conducts studies and proposes sustainable actions for mining and mineral processing.
    - Secretary of electric energy: seeks access to this resource through society.
    - Energy planning and development secretary: analyzes the granting of concessions, authorizations and permits for electric power services.

- **Ministry of Economy**

  This ministry integrates functions of the Ministries of Finance, Planning, Development and Management, Industry, Foreign Trade and Services, and Labor. Among its many tasks is the formulation of guidelines for public projects with multilateral organizations and government agencies. (gob.br, 2020)

- **National Department of Transportation Infrastructure (DNIT)**

  It is linked to the Ministry of Transportation and is responsible for the maintenance, expansion, construction, supervision and elaboration of studies related to the road, rail and water systems. (LinkFang, 2020).

- **State governments**

  They are in charge of maintaining interstate highways, and in return municipal highways are maintained by the corresponding municipalities (CAF Development Bank of Latin America, 2020).

- **National Land Transportation Agency (ANTT)**

  Its main objective is to regulate, supervise and inspect transportation activities carried out by third parties, preserving the public interest. (gob.br, n.d.).

4.2. Urban Mobility in Brazil

Urban mobility in the country is considered one of the main challenges today. Cities such as Brasília were designed for automobile commuting, which creates traffic jams and high environmental pollution, common factors in large cities.

In a study conducted by the Urban Mobility Information System (SIMOB) and the National Association of Public Transportation (ANTP); 67 billion trips were made in 2018 , which corresponds to about 223 million trips per day. The majority of trips were by foot and bicycle (Non-Motorized Transport (NMT)) (28.0 billion), followed by individual motorized transport, which includes cars and motorcycles (20.3 billion) and public transport (PT) (18.8 billion). This number of trips corresponds to an average mobility of 1.65 trips per inhabitant per day. (SIMOB/ANTP, 2020)

Public Transportation in Brazil is mainly composed of the following modes of transportation: Buses and Urban Railways (Subway, Train and Light Rail Transit). However, only 12 cities have urban rail services: São Paulo, Rio de Janeiro, Recife, Natal, Porto Alegre, Fortaleza, Brasília, Salvador, Maceió, João Pessoa, Belo Horizonte and Teresina. Thus, buses are the most representative mode of public transportation in the country. (PROMOBE, 2019).

The 15 cities prioritized for the purposes of this diagnosis had a total of 24 million registered vehicles (NOV, 2020), of which; 16 million cars, 423,000 trucks, 101,000 minibuses, 3 million motorcycles, and 141,000 buses.

Table 4: Vehicle Registration Statistics of 15 Largest Cities

UF	MUNICIPIO	AUTOMOVEL	CAMINHAO	CAMINHONETE	CAMIONETA	CICLOMOTOR	MICRO-ONIBUS	MOTOCICLETA	MOTONETA	ONIBUS	UTILITARIO
BA	SALVADOR	610461	18206	69349	48744	1253	4212	140921	11593	8948	15156
DF	BRASILIA	1328622	24767	132643	91584	1250	6171	198792	20912	13305	31528
ES	VITORIA	125519	4305	17659	12509	209	1052	23122	4282	912	5723
GO	GOIANIA	632078	25347	102831	44388	6360	2176	242252	55916	7118	15488
MG	BELO HORIZONTE	1576738	36293	204144	124222	1114	6628	236968	20506	9420	31137
PE	RECIFE	401518	19530	41904	36434	6588	2465	150782	8077	4023	13002
PI	TERESINA	217793	12047	39490	11521	5136	1207	181374	26359	4133	5873
PR	CURITIBA	1086316	38459	114261	81345	1013	3970	152078	27686	6893	26750
RJ	NITEROI	188493	2827	12533	14336	449	1255	34473	6067	2438	5949
RJ	RIO DE JANEIRO	2074776	43227	133486	158251	9201	18127	319647	50910	17278	41670
RS	PORTO ALEGRE	610617	15969	46449	55536	609	2294	97712	11341	5209	17446
SC	FLORIANOPOLIS	230367	3872	20711	24232	118	915	50326	10307	1977	11119
SP	CAMPINAS	618367	20392	64717	38194	404	3897	119751	15365	5748	10389
SP	GUARULHOS	469284	20801	43946	31806	228	4179	91139	11503	4117	5417
SP	SAO PAULO	5868736	135850	518441	483619	4179	39869	1011478	176305	47508	150735
TOTAL		16039685	421892	1562564	1256721	38111	98417	3050815	457129	139027	387382

Source: DENATRAN

On the other hand, according to data from NTU (National Association of Urban Transport Companies) in 2018, urban buses represented 86 % of the share of total public transport, serving 3,313 Brazilian municipalities, with a fleet of 107,000 buses, and a total of 40 million passengers transported per day.

Sindipeças reports that as of 2017, the average age of the bus fleet was 10 years (Diário Do Transporte, 2018). In the six-year period (2014 to 2019), the aging of the fleet in circulation increased by 1 year and 2 months. Since 2015, the average age of the fleet has been increasing. The possibilities of reversing this phenomenon depend on the increase in the growth rate of new vehicle sales versus the scrapping rate of the existing fleet and/or public policies that require the retirement of very old vehicles, i.e., a fleet renewal program.

Vehicle Production

Vehicle production (cars, light commercial vehicles, trucks and buses) in Brazil is shown below (AMFAVEA, 2020).

Table 5: Annual vehicle production 2001-2019

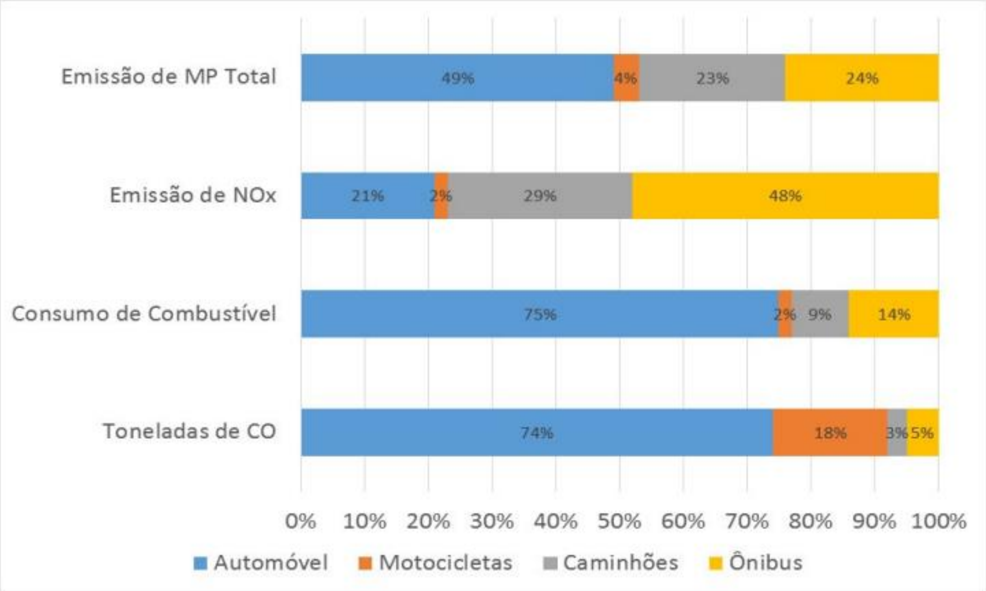
Ano *Year*	Automóveis *Cars*	Comerciais leves *Light commercials*	Caminhões *Trucks*	Ônibus *Buses*	Total *Total*
2001	1.516.182	199.813	77.431	23.690	1.817.116
2002	1.525.491	174.655	68.558	22.826	1.791.530
2003	1.561.780	160.061	78.960	26.990	1.827.791
2004	1.954.604	226.527	107.338	28.758	2.317.227
2005	2.122.101	255.068	117.693	35.387	2.530.249
2006	2.204.390	266.826	106.601	34.512	2.612.329
2007	2.481.949	321.922	137.229	39.011	2.980.111
2008	2.634.010	370.852	167.406	44.111	3.216.379
2009	2.655.704	369.609	123.633	34.536	3.183.482
2010	2.924.208	484.839	191.613	45.880	3.646.540
2011	2.630.893	530.330	229.083	56.023	3.446.329
2012	2.766.978	488.872	136.264	41.556	3.433.670
2013	2.955.788	547.749	190.962	45.026	3.739.525
2014	2.509.295	487.682	143.660	37.222	3.177.859
2015	2.016.500	332.445	77.686	25.659	2.452.290
2016	1.800.040	307.583	64.539	23.550	2.195.712
2017	2.308.797	330.616	89.449	25.280	2.754.142
2018	2.388.337	358.981	115.697	31.889	2.894.904
2019	2.448.600	355.351	117.692	29.803	2.951.446

Source: (AMFAVEA, 2020)

According to the Annual Vehicle Production (2000-2019) by fuel type it is evident that there has been a shift from gasoline, to flex fuel for the case of cars and light commercials vehicles, while trucks and buses have been characterized by the use of Diesel for the last 19 years (AMFAVEA, 2020). Based on data from RENAVAN, ANFAVEA reported that the majority of vehicles in Brazil in 2020 operate with the flex fuel model (85.2 %) and that only 10.8 % are diesel and 3 % gasoline. Electric cars represent only 1% of the total number of vehicles.

It is estimated that almost half of the total emissions of particulate matter (PM) come from trucks and buses, reaching 77 % for NO_x emissions (epe, 2018).

Figure 4: Emissions by Vehicle Category



Source: (epe, 2018)

Financing

In Brazil, the financing of mobility projects is almost always done through development banks, such as BNDES (Banco Nacional de Desenvolvimento) and Caixa. The Banco Nacional de Fomento - BNDES - offers a line of financing especially for mobility projects (BNDES Finem - Urban Mobility). (The German Chamber Network, 2018).

In parallel, the Rota 2030 Program, which promotes, electric mobility and biofuels in Brazil, offers tax incentives of up to R$1.5 billion per year when automotive companies invest at least R$5 billion in biofuels research in Brazil. In addition, the federal IPI (tax on industrialized products) for electric and hybrid vehicles is reduced from 25% to 7% to 20%. (The German Chamber Network, 2018).

Taxi Services

In 2017, a survey conducted by the Brazilian Institute of Geography and Statistics (IBGE) revealed that, in 113 municipalities in the country, cabs are the only means of public transport (MACHINE, 2019). For the case of the municipality of São Paulo, in 2015 there was a fleet of approximately 34,000 cabs. These cabs are divided into: private individuals (30,438 cabs in which the owners are represented by the Taxi Drivers Union-SINDITAXIS) and legal entities (3,491 cabs divided into 58 companies represented by ADETAX and SINETAX). (ADETAX, 2015).

Institutionally, there are three subcategories of cabs in São Paulo: common cab, special cab and luxury cab. The first is characterized by being white and has a fleet of 33,193 cars, the special (624 cars) is white and red, and differs from the previous one because drivers take a training and orientation course. Finally, the luxury cab is black (157 vehicles), has all the characteristics of the special cab but the driver has knowledge of languages and works in fine clothing, therefore, this type of cab works in hotels and tourist places. The average age of the fleet for 2015 was 3 years. (ADETAX, 2015).

The Brazilian Chamber of Deputies approved in March 2018 the law 13,640/2018 that regulates transportation apps such as Uber, Cabify or 99, whose drivers will be required a series of conditions to be able to offer their service.

5. e-Mobility

Key players

In Brazil, current standards, regulations and programs have been raised to serve as a basis for identifying initiatives for the development of new standards to support the implementation of electric mobility. (PROMOBE, 2020). The following are the main regulations around electromobility, established by the following actors:

- Ministry of Industry, Foreign Trade and Services (MDIC) and presidency of the republic with Decree No. 9,442/2018: Establishes reduction of Industrialized Products Tax (IPI) for hybrid and electric vehicles.
- State governments: MA, PI, CE, RN, PE, SE, RS, SP, RJ and MS: Exemption and differentiated rate of the Motor Vehicle Property Tax (IPVA).
- Municipalities of SP and São Bernardo do Campo: Exemption and differentiated rate of IPVA in cities
- SP City Hall and SPTrans with Edital No. 001/2015: Requirements in the elaboration of public notices for the concession of the Collective Public Transport System.
- Curitiba City Hall with Municipal Law no. 14,826/2016: Policy to incentivize the use of electric or hydrogen vehicles.
- National Traffic Department (Denatran) with Portaria nº 279/2010: Homologation of vehicles - new classification
- Chamber of Foreign Trade (Camex) with Resolution No. 86/2014, Resolution No. 97/2015 and Resolution No. 27/2016: import taxes.
- ANEEL with Regulatory Resolution No. 819/2018: recharging infrastructure.
- Chamber of Deputies with Bill No. 3,895/2012 and Bill No. 65/2014: recharging infrastructure.
- Federal Senate with Bill n° 5,590/2019: recharge infrastructure.

Role of electric utilities in the country

One of the key players in driving electric mobility in public transport are the electric power companies, as they are responsible for supplying the energy needed to charge the buses. According to estimates by the SPTrans team, the energy consumption of the entire system fleet is negligible compared to the national energy production, which is mainly from renewable sources. Thus, SPTrans and Eletropaulo, which was acquired by the Italian company Enel in June 2018, are conducting joint studies to determine the actions needed to ensure the availability of energy in households (PROMOBE, 2019).

Public charging network

There are about 16 different plugs and connectors for charging electric vehicles. However, in Brazil there is no standardization in their adoption, being the most used plugs: (1) Type 2 (used in about 80 % of power plants), (2) CCS Combo 2, (3) J-1772, (4) CHADEMO, and (5) Muro. In addition, about 80 % of the electric and hybrid vehicle models available in the Brazilian market have Type 2 and CCS Combo 2 connectors, which are from Chinese manufacturers (BYD, Jac and Chery). (PROMOBE, 2019).

In terms of infrastructure, Plug Share, a site that is responsible for mapping international charging infrastructure, estimates that there are about 150 public / private charging points installed in Brazil, which are concentrated in the south and south-eastern axes of the country.

Actors involved in the promotion of EVs

Three automakers stand out (PROMOBE, 2019):

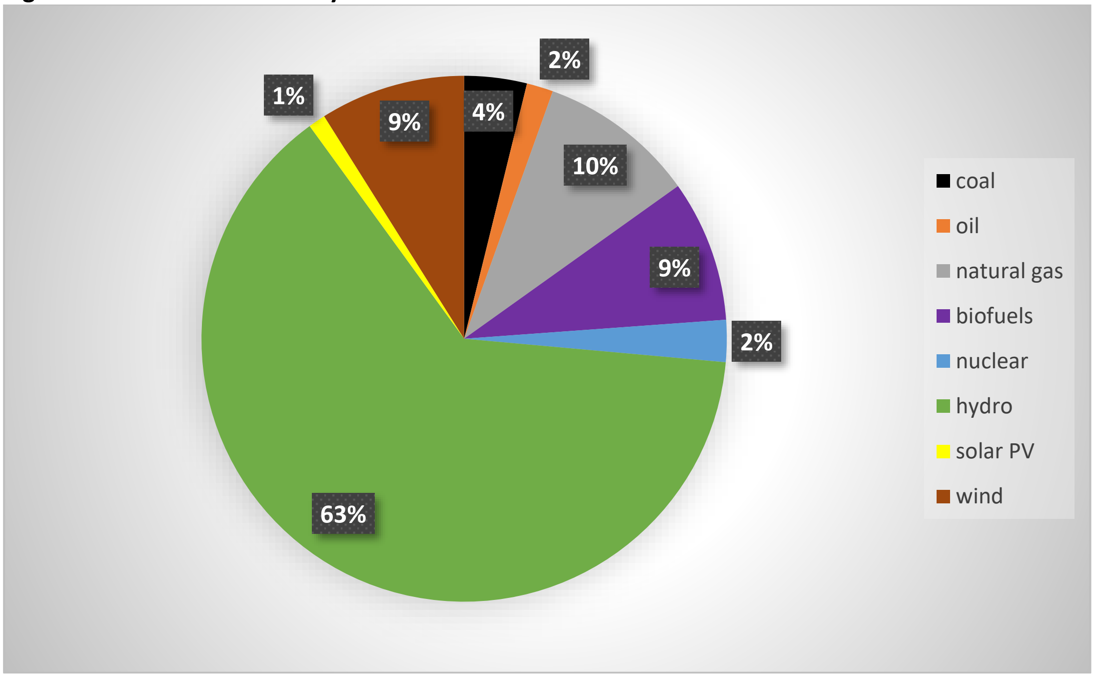
- Eletra: is a Brazilian company that develops and integrates electric traction systems for low-emission buses. Its main expertise is electric traction systems for trolleybuses. The company has also developed a series of hybrid buses, which operate with an electric motor and two energy sources: a diesel-electric generator set and a battery bank. Eletra also developed a battery-electric bus with domestic technology in partnership with Japanese companies Mitsubishi Heavy Industries and Mitsubishi Corporation. The batteries used are lithium-ion.
- Volvo: since 2009, Volvo has started to manufacture hybrid buses of the Diesel series. In 2016, it introduced two new hybrid bus models. The first was the articulated hybrid, as part of the Smart City Concept project in Curitiba, which has the participation of the governments of Curitiba and Sweden. The second model is a plug-in hybrid bus, which allows external recharging of the battery.
- Build Your Dreams (BYD): In 2014, BYD set up an electric bus factory in Campinas, São Paulo. In 2018 it had the capacity to produce 720 electric buses per year in three shifts.

6. Energy Sector

6.1. Electricity Generation

In 2019 82% of electricity was generated by renewable and 18% by fossil sources (see figure below).

Figure 5: Power Generation by Source in 2019



Source: IEA

6.2. Grid Factor

The carbon emission factor of the grid is calculated based on national data. The latest available grid factor is used. The actual grid factor is taken and not the grid factor used by UNFCCC methodologies based primarily on the Combined Margin (CM). The UNFCCC approach using the CM is not applied as former was designed primarily for renewable energy projects trying to capture what type of electricity would be displaced from more GHG intensive means[2]. It is a tool designed for energy supply and not energy demand projects. The CM does not reflect actual GHG emissions of the electric grid and in some cases can be far off actual emissions due (i) non-inclusion of low-cost/must-run (LCMR) resources defined as power plants with low marginal generation costs or dispatched independently of the daily or seasonal load of the grid including primarily hydro, geothermal, wind, low-cost biomass, nuclear and solar generation and (ii) the non-inclusion of CDM projects in the CM. Especially the non-inclusion of LCMR resources result in misleading results.

Following values are used for the grid factor of Brazil (all year 2018, IEA database):

- Total electricity generation: 601,371 GWh
- Electricity losses: 97,973 GWh
- GHG emissions from electricity generation: 59,885,300 tCO_{2e}

The carbon factor of the electricity grid of Brazil is therefore: **0.119 $kgCO_2$/kWh**[3].

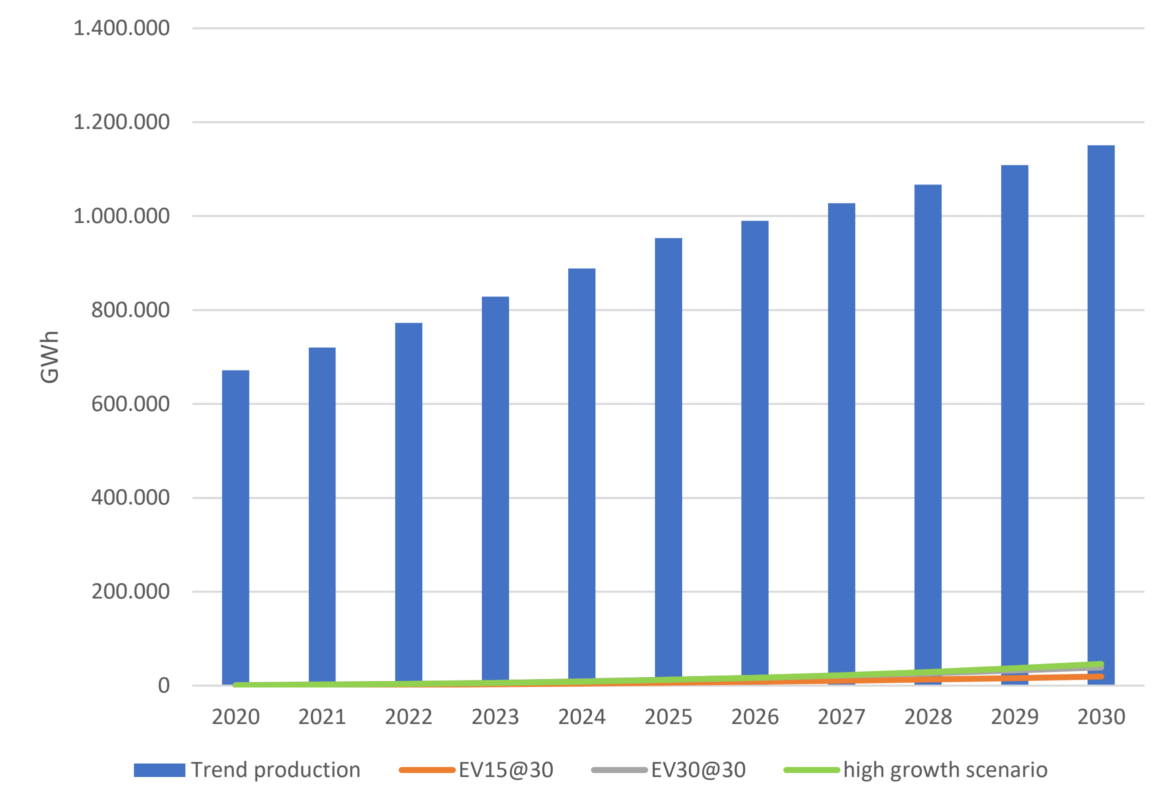
[2] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v6.pdf

[3] GHG emissions / net production

6.3. Electricity Sector and EVs

The following figure shows the projected electricity demand from EVs based on the three scenarios and the projected electricity generation of Brazil.

Figure 6: EV Electricity Demand versus Projected Electricity Consumption Brazil 2020-2030



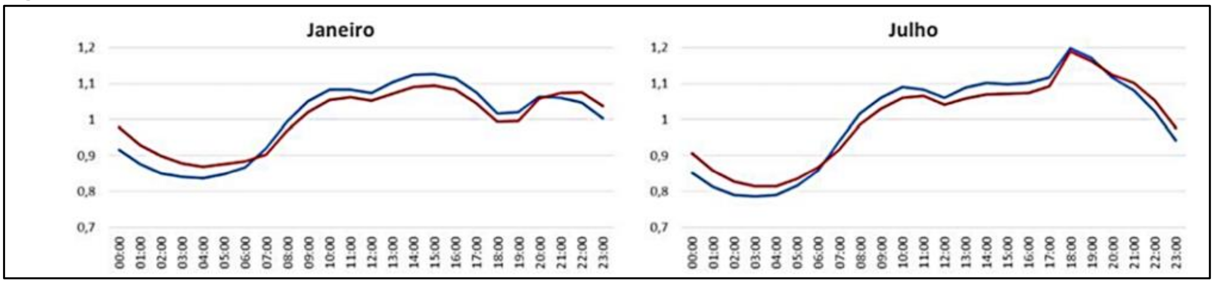
Source: Grutter Consulting based on EV scenarios and generation based on epe

The 2030 electricity demand of EVs represents 2% of projected electricity generation for the EV15@30, 3% for the EV30@30, and 4% for the highest growth scenario. The demand increase is very gradual and thus leaves enough time to the country to plan a small production expansion required.

Running 100% EVs not only stresses the grid in terms of electricity production but also in terms of power demand. EV charging can have a sizeable impact on the loads applied to the grid at certain times and locations. The rise in the number of EVs can be accommodated fairly easily by power generation facilities as long as the vehicles are charged off peak. Faster charging during peak demand, however, can have a significant impact[4]. The extent on which EVs will impact the electricity networks will depend highly on technologies and charging modes used with the bulk of charging expected to occur in low-voltage distribution grids in residential or commercial areas (IEA, 2017). The management of the grid is considered critical rather than absolute capacities. Problems which can occur are increased peak loads and charging hotspots resulting in local network overloading. EV charging can have a sizeable impact on the loads applied to the grid at certain times and locations. The following figure shows the typical demand curve in Brazil.

[4] Peak demand from a single EV using a top-of-the-range fast charger can be 80 times higher than the expected peak demand of a single typical household. See (McKinsey, 2018)

Figure 7: Demand Curve Brazil



Source: epe

The system has during summer months a peak between 1 and 4PM and in winter an evening peak at 6PM.

Electric buses can avoid using these peaks for charging. This is true for overnight charged buses as well as intermediate or opportunity fast charged buses. Intermediate fast-charged buses are charged 1-2x per day during off-peak transport hours which also coincide with low demand times of the power sector and opportunity charged buses can easily be equipped with large-enough battery sets to run 2-3 hours without charging.

Taxi fast charging could basically be done outside the peak as well and fast chargers could apply significant differential pricing to avoid peak charging. Passenger cars and LCVs are basically charged overnight which minimises the need for incremental electricity generation capacity and investment in distribution infrastructure upgrades. Plugging EVs to the grid too early i.e. before 8PM may however result in this additional demand coinciding with the evening peak electricity demand resulting in a higher risk of overloading of the power distribution network ultimately requiring additional generation capacity and network upgrades. Especially LCVs and passenger cars, but also taxis could be prone to be charged too early as people return home and plug-in their vehicle. This will require smart management involving e.g. controlled charging and using Demand Side Management (DSM) instruments.

7. Emissions in the Transportation Sector

7.1. Introduction

2020 some 98 million vehicles were operating in Brazil. The country has the vehicle emission standard equivalent to Euro 2 for light vehicles since 1997, and Euro 4 since 2009. Euro 5 has been introduced from 2013-2015[5]. Euro VI standards are expected to be introduced 2022. Diesel fuel sold in the country has 500 ppm sulfur with cities also selling 100ppm sulfur diesel.

7.2. Road Transport Emissions

The following table shows registered vehicles of Brazil in 2020.

Table 6: Vehicles Registered Brazil 2020

Vehicle category	Gasoline	Diesel	total
Passenger car	61,192,392	0	61,192,392
Taxi	369,371		369,371
Motorcycle	23,788,071		23,788,071
small bus		419,519	419,519
standard urban bus		197,804	197,804
coach		461,542	461,542
LCV	1,651,958	6,607,832	8,259,790
Truck < 7.5t		574,653	574,653
Truck 7.5-16t		574,653	574,653
Truck 16-32t		574,653	574,653
Truck >32t		1,149,305	1,149,305

Source: Ministério da Infraestrutura, DENATRAN - Departamento Nacional de Trânsito, RENAVAM-Registro Nacional de Veículos Automotores; Taxi number based on share of taxis as total cars in Sao Paulo (0.6%)

For 2019 emissions the average emission factor used for modelling purposes is Euro 4/IV. The following table summarizes core assumptions on mileage and fuel consumption used for calculations[6].

Table 7: Main Parameters Used for Emission Calculations 2019

Vehicle Category	Fuel Used	Specific fuel consumption (g/km)	Annual mileage (km)
Passenger car	Gasoline	66	9,500
Taxi	Gasoline	66	50,000
Motorcycles	Gasoline	36	5,000
small bus	Diesel	148	60,000
standard urban bus	Diesel	371	60,000
Coach	Diesel	247	60,000
LCV	Gasoline	70	12,000
	Diesel	80	30,000
Truck < 7.5t	Diesel	101	30,000
Truck 7.5-16t	Diesel	155	30,000
Truck 16-32t	Diesel	210	30,000
Truck >32t	Diesel	251	30,000

Source: Passenger car size: small gasoline and large/SUV diesel; Fuel consumption values from (EEA, 2020) Tier 2 approach for vehicles > Euro 1/I; vehicle mileage calibrated with fuel usage

[5] Brazil: Light-duty: Emissions | Transport Policy

[6] Fuel consumption is the base for calculation of GHG emissions using for tank-to-wheel (TTW) calculations the fuel consumed, Net Calorific Value and the CO_2 Emissions factor and for well-to-wheel (WTW) calculations an upstream mark-up for fuel extraction, refinery and transport plus the GHG emissions caused by Black Carbon.

The following table shows estimated 2019 road transport emissions for Brazil. The model has been calibrated with actual fuel consumed by Brazil in 2019 with a difference between top-down actual and the modelled bottom-up consumption of less than 1%.

Table 8: Estimated 2019 Road Transport Emissions

Vehicle category	NO_x	$PM_{2.5}$	CO_2 TTW	CO_2 WTW	Energy in TJ
Passenger car	35,461	639	117,788,241	140,254,333	1,699,686
Taxi	1,014	18	3,367,873	4,010,237	48,598
Motorcycles	23,074	416	13,145,245	15,736,507	189,686
small bus	128,171	1,007	12,184,410	15,666,445	164,432
standard urban bus	64,326	548	14,043,266	17,643,328	206,747
Coach	125,170	980	21,794,459	27,468,897	294,122
LCV	166,002	8,130	54,790,940	73,573,812	743,401
Truck < 7.5t	28,273	183	5,547,981	6,947,366	74,872
Truck 7.5-16t	45,685	278	8,514,228	10,659,852	114,902
Truck 16-32t	66,028	412	11,535,406	14,466,667	155,673
Truck >32t	158,949	924	27,575,090	34,541,088	372,133
Total	**842,153**	**13,535**	**290,287,138**	**360,968,534**	**4,064,253**

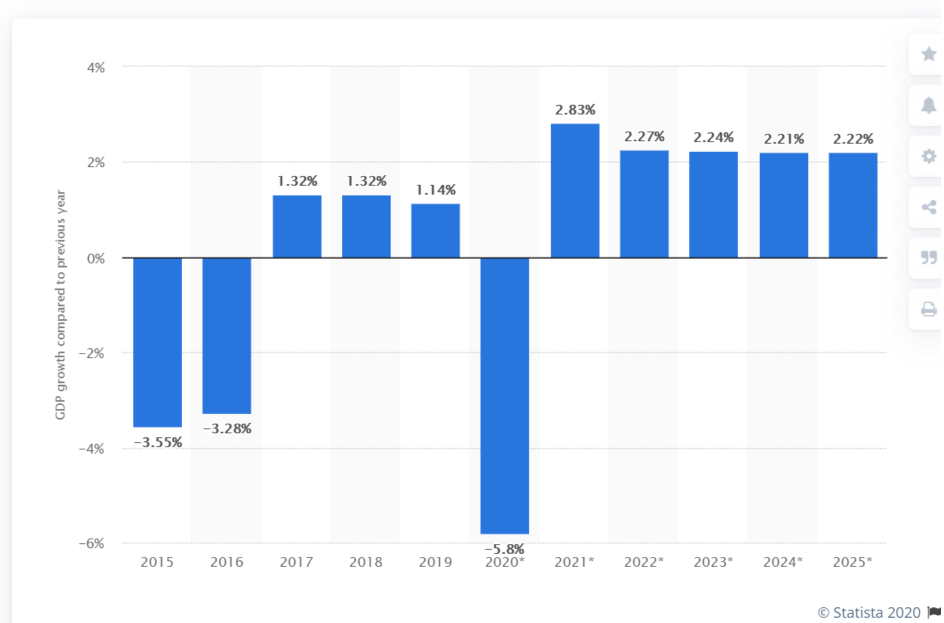
Source: Grutter Consulting; for details of modelling data see Annex 1

Road transport GHG emissions of Brazil TTW in 2019 were 290 million tCO_{2e}. WTW GHG emissions of 361 million tCO_{2e} reflect the GHG emissions caused directly and indirectly by the road transportation sector of Brazil. Taking into account a share of 22% of ethanol in gasoline and close to 5% of biodiesel in diesel and assuming 0-combustion emissions the TTW emissions of Brazil are 253 MtCO2e in 2019. Commercial vehicles (taxis, buses, LCVs) represent around 1/3rd of emissions.

7.3. Projected 2030 Transport Emissions

For 2030 projections an elasticity or growth factor per vehicle category was determined. The following graph shows the projected medium-term GDP growth rate in real terms of Brazil including the recent COVID-19 impact followed by a table showing data relevant for calculation of the projected vehicle numbers in the country.

Figure 8: Medium Term Real GDP Growth Rate



Source: Statista

Table 9: Parameters for Projection of Vehicle Numbers and Emissions

Parameter	Value	Source/Explanation
CAGR population growth 2020-2030	0.6%	IBGE projections
CAGR GDP real growth 2020-2030	1.7%	Statista CAGR 2020 to 2025 with assumed constant values 2025 to 2030
CAGR GDP per capita growth 2020-2030	1.1%	Calculated from GDP and population growth rate
CAGR freight transport growth rate	1.7%	Freight intensity of 0.98[7] based on income per capita 2030 (PPP) of 9,800 USD using 2019 data from the World Bank and the real GDP growth rate
CAGR public transport	0.6%	In line with population growth (more trips but declining mode shares)
CAGR passenger transport	1.6%	Based on Gomperz function with α of -2.2 and β of -0.00013 with a saturation level of 590 vehicles per 1,000 population[8]

Vehicle growth rates per vehicle category are used to model vehicle numbers for 2030. The average emission level assumed for 2030 is Euro 4/IV. The mileage of vehicles is kept constant. The following table shows projected 2030 road transport emissions of Brazil.

Table 10: Projected 2030 Road Transport Emissions

Vehicle category	NO_x	$PM_{2.5}$	CO_2 TTW	CO_2 WTW	Energy in TJ
Passenger car	41,537	749	137,969,621	164,284,967	1,990,904
Taxi	1,188	21	3,944,911	4,697,336	56,925
Motorcycles	27,028	488	15,397,501	18,432,739	222,186
small bus	135,916	1,068	12,920,674	16,613,117	174,368
standard urban bus	68,213	581	14,891,854	18,709,456	200,970
coach	132,734	1,040	23,111,427	29,128,753	311,895
LCV	195,826	9,590	64,634,756	86,792,186	876,961
Truck < 7.5t	33,352	216	6,544,739	8,195,539	88,323
Truck 7.5-16t	53,893	327	10,043,907	12,575,016	135,545
Truck 16-32t	77,890	486	13,607,873	17,065,769	183,642
Truck >32t	187,506	1,090	32,529,269	40,746,788	438,991
Total	**955,083**	**15,656**	**335,596,531**	**417,241,667**	**4,680,711**

Source: Grutter Consulting; for details of modelling data see Annex 1

TTW emission from the transport sector are expected to grow under a BAU scenario by around 16% reaching 336 million tCO_2 by 2030 (417 million tCO_{2e} with a WTW approach; 291 assuming a constant biofuel ratio).

[7] Freight intensity rates based on groupings realized by (OECD, 2017), table 2-4
[8] Saturation level based on Japanese pattern (Tian, 2014); parameters calculated by Grutter Consulting

8. EV Scenarios

3 different EV scenarios have been constructed which are contrasted with the BAU scenario:

- EV30@30: The EV30@30 scenario of IEA has as target that 30% of all vehicles sold in 2030 are electric. The scenario is built on newly purchased vehicles (and not the stock of vehicles) in line with IEA scenarios (IEA, 2019). In addition to the IEA also motorcycles and trucks <7.5t are included with the same EV penetration rates.
- EV15@30: The moderate EV scenario is based on the "EV new policies scenario" which has as target for 2030 15% instead of 30% EV share. The same approach is used as for EV30@30.
- EV “high growth” scenario focusing on the potential for commercial vehicles targeted by the e-mobility fund with an EV target of 100% of new registered vehicles for these categories by 2030. In all other vehicle categories the EV30@30 scenario has been chosen.

No Brazilian scenario was realized as no specific 2030 targets for EVs have been identified. Newly registered vehicles are the sum of additional (due to vehicle growth) and replacement vehicles. The following table shows the average lifespan of vehicles and the average annual replacement rate of the fleet as used for projections.

Table 11: Assumed Average Lifespan and Replacement Rate per Vehicle Category Brazil

Vehicle category	lifespan in years	% replaced per annum
Passenger car	20	5%
Taxi	10	10%
Motorcycles	8	13%
small bus	15	7%
standard urban bus	15	7%
Coach	15	7%
LCV	20	5%
Truck < 7.5t	20	5%
Truck 7.5-16t	20	5%
Truck 16-32t	20	5%
Truck >32t	20	5%

Source: authors assumption

EV 15@30 and 30@30 Scenarios

The following table shows the modelled share of EVs as total of new registered vehicles from 2019 to 2030.

Table 12: EV Rates of Newly registered Vehicles

Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EV15@30	3%	3%	4%	5%	7%	9%	10%	11%	12%	14%	15%
EV30@30	5%	6%	8%	11%	14%	18%	20%	22%	24%	27%	30%

Source: Grutter Consulting based on IEA scenarios

EV High Growth Scenario

The share of newly registered EVs for the selected vehicle categories in the high growth scenario is shown below.

Table 13: Share of EVs of Newly Registered Vehicles "High Growth Scenario"

Vehicle Category	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Taxis	0%	4%	4%	8%	14%	22%	32%	45%	61%	79%	100%
Urban Buses	0%	11%	4%	8%	14%	22%	32%	45%	61%	79%	100%
Small buses	0%	8%	4%	8%	14%	22%	32%	45%	61%	79%	100%
LCVs	0%	3%	4%	8%	14%	22%	32%	45%	61%	79%	100%

Source: For urban buses, taxis and LCVs the target is that 100% of new registered buses/taxis/LCVs in 2030 are electric; This takes into consideration that EVs in this segment should be cost-competitive by 2030. No early replacement of vehicles is made i.e. conventional vehicles could still be used until ending their lifespan. The growth curve towards 2030 is based on a power curve with the function y=0.0024*n^2.52 based on the curve of Norway for the last 10 years. Initial experiences are built and cost structures go down. Barriers are removed and financial equivalence will be achieved. The vehicle penetration rates increases then (for new vehicles)

For other vehicle categories no specific scenario is made but the value from EV30@30 is taken.

Scenario Results

The following table shows the results in terms of GHG reduction against the BAU scenario of no EVs as well as the additional electricity consumption due to EVs with the different scenarios. Scenarios do not include electric trucks > 7.5t as no massive penetration of such trucks can be expected.

Table 14: Scenario Results

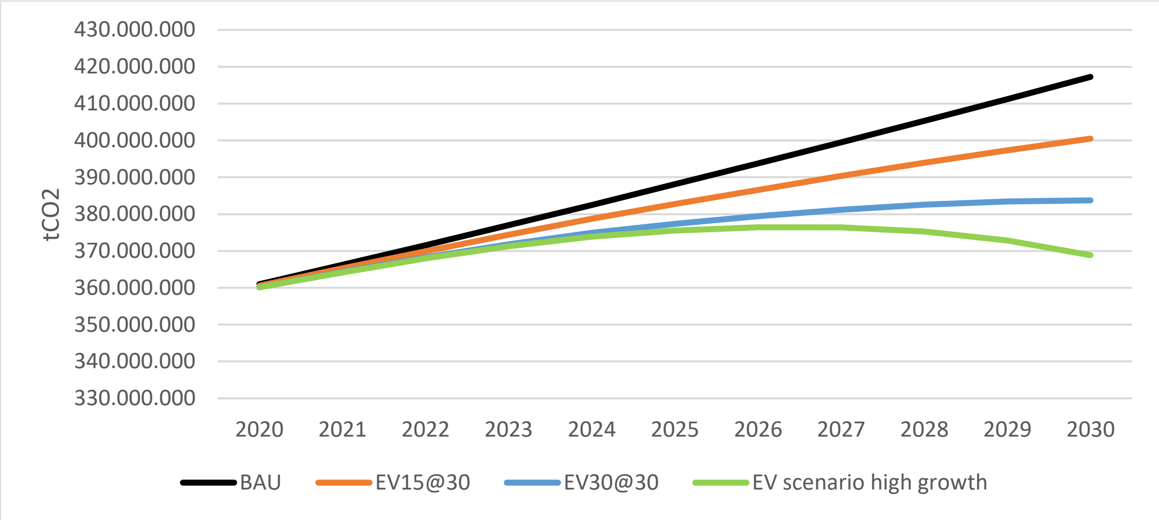
Impact	Scenario	By 2025	By 2030
GHG reduction WTW in tCO_{2e} per annum	IEA 15@30	5,380,000	16,800,000
	IEA30@30	10,760,000	33,500,000
	"High growth" scenario	12,550,000	48,300,000
Electricity demand of EVs in GWh per annum	IEA 15@30	6,240	19,000
	IEA30@30	12,480	39,000
	"High growth" scenario	12,190	46,000

Source: Grutter Consulting, see Annex for further details

The growth of electricity demand is discussed in chapter 6.

The most ambitious scenario (EV high growth scenario) would result in a 12% reduction of GHGs relative to the baseline. Only the high growth scenario result in a trend change in this period with GHG emissions in 2030 being comparable to current emissions. The figure below shows however the slow reaction of GHG emission reductions of the sector due to long permanence of vehicles once purchased. The introduction of EVs takes a long time to reduce in absolute terms GHG emissions of the transport sector as vehicle growth still occurs and as vehicle replacement rates are relatively low i.e. it takes time to achieve a large stock and therefore large impact of EVs. This highlights the importance of early actions. Waiting 5-10 years more until the market has evolved without support will result in a 5-10-year time lag of GHG reductions and thus non-attainment of climate targets.

Figure 9: Projected GHG Transport Emissions Brazil BAU and with EV Scenarios (WTW)



Source: Grutter Consulting

The following tables shows the potential GHG reduction which is possible to achieve for the targeted vehicle sectors.

Table 15: Projected GHG Reductions for Taxis "High Growth Scenario"

Taxis High Potential	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all taxis	369,371	375,258	381,240	387,317	393,491	399,763	406,136	412,610	419,187	425,869	432,657
Replacement taxis	36,358	36,937	37,526	38,124	38,732	39,349	39,976	40,614	41,261	41,919	42,587
Additional new taxis	5,795	5,888	5,982	6,077	6,174	6,272	6,372	6,474	6,577	6,682	6,788
EV taxi fleet new	0	1,614	1,664	3,490	6,222	10,007	14,993	21,326	29,153	38,624	49,375
EV taxi fleet stock	0	1,614	3,278	6,768	12,990	22,997	37,991	59,316	88,469	127,092	176,468
EV taxi as % of stock	0%	0%	1%	2%	3%	6%	9%	14%	21%	30%	41%
GHG reduction WTW in tons	0	15,969	32,430	66,959	128,513	227,520	375,854	586,836	875,252	1,257,370	1,745,857
Electricity demand GWh	0.0	13.1	26.6	54.8	105.2	186.3	307.7	480.5	716.6	1029.4	1429.4

Source: Grutter Consulting

Table 16: Projected GHG Reductions for Small Buses "High Growth Scenario"

Small Bus Potential scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	419,519	421,988	424,471	426,968	429,481	432,008	434,550	437,107	439,679	442,267	444,869
Replacement vehicles	27,804	27,968	28,133	28,298	28,465	28,632	28,801	28,970	29,140	29,312	29,484
Additional new vehicles	2,454	2,469	2,483	2,498	2,512	2,527	2,542	2,557	2,572	2,587	2,602
EV vehicle fleet new	0	2,517	1,171	2,432	4,292	6,835	10,139	14,278	19,326	25,351	32,087
EV vehicle fleet stock	0	2,517	3,688	6,119	10,411	17,246	27,385	41,664	60,989	86,340	118,427
EV fleet as % of stock	0%	1%	1%	1%	2%	4%	6%	10%	14%	20%	27%
GHG reduction WTW in tons	0	71,698	105,053	174,324	296,593	491,309	780,147	1,186,911	1,737,458	2,459,648	3,373,738
Electricity demand GWh	0.0	84.6	123.9	205.6	349.8	579.5	920.1	1399.9	2049.2	2901.0	3979.1

Source: Grutter Consulting

Table 17: Projected GHG Reductions for Urban Buses "High Growth Scenario"

Urban bus high growth	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	197,804	198,968	200,139	201,316	202,501	203,693	204,891	206,097	207,310	208,530	209,757
Replacement vehicles	13,110	13,187	13,265	13,343	13,421	13,500	13,580	13,659	13,740	13,821	13,902
Additional new vehicles	1,157	1,164	1,171	1,178	1,185	1,192	1,199	1,206	1,213	1,220	1,227
EV vehicle fleet new	0	1,524	552	1,147	2,024	3,223	4,781	6,732	9,112	11,953	15,129
EV vehicle fleet stock	0	1,524	2,076	3,222	5,246	8,468	13,249	19,981	29,093	41,046	56,175
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	6%	10%	14%	20%	27%
GHG reduction WTW in tons	0	125,018	170,319	264,400	430,458	694,910	1,087,193	1,639,636	2,387,358	3,368,195	4,609,658
Electricity demand GWh	0.0	91.4	124.5	193.3	314.7	508.1	794.9	1198.9	1745.6	2462.8	3370.5

Source: Grutter Consulting

Table 18: Projected GHG Reductions for LCVs "High Growth Scenario"

LCV high growth	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	8,259,790	8,397,398	8,537,299	8,679,530	8,824,131	8,971,141	9,120,600	9,272,550	9,427,030	9,584,085	9,743,755
Replacement vehicles	406,222	412,990	419,870	426,865	433,977	441,207	448,557	456,030	463,627	471,352	479,204
Additional new vehicles	135,353	137,608	139,901	142,231	144,601	147,010	149,459	151,949	154,481	157,054	159,671
EV vehicle fleet new	0	16,751	21,408	44,935	80,164	129,030	193,451	275,351	376,675	499,403	638,875
EV vehicle fleet stock	0	16,751	38,159	83,094	163,258	292,287	485,739	761,090	1,137,765	1,637,168	2,276,043
EV fleet as % of stock	0%	0%	0%	1%	2%	3%	5%	8%	12%	17%	23%
GHG reduction WTW in tons	0	46,653	106,273	231,420	454,678	814,031	1,352,799	2,119,661	3,168,714	4,559,570	6,338,859
Electricity demand GWh	0.0	40.2	91.6	199.4	391.8	701.5	1165.8	1826.6	2730.6	3929.2	5462.5

Source: Grutter Consulting

The following table shows key figures for the potential EV scenario in terms of number of electric vehicles, the GHG impact and the vehicle investment volume.

Table 19: Key Figures Commercial Vehicles EV "High Growth Scenario"

Parameter	Taxis	Small Buses	Urban Buses	LCVs	Total
EV stock year 2025 (share)	23,000	17,000	8,500	292,000	340,999
EV Stock year 2030 (share)	176,000	118,000	56,000	2,276,000	2,627,113
GHG impact year 2025 tCO_2	228,000	491,000	695,000	814,000	2,227,769
GHG impact year 2030 tCO_2	1,746,000	3,374,000	4,610,000	6,339,000	16,068,112
$PM_{2.5}$ reduction year 2030 (tons)	9	284	156	2,240	2,689
NO_x reduction year 2030 (tons)	484	36,182	18,268	45,743	100,677
Savings emission costs in 2030 (MUSD)	72 MUSD	253 MUSD	246 MUSD	793 MUSD	1,365 MUSD
Emissions savings excl. GHG in 230 MUSD	3 MUSD	118 MUSD	62 MUSD	540 MUSD	722 MUSD
Vehicle CAPEX 2025 cumulative in MUSD	1,364 MUSD	1,321 MUSD	1,953 MUSD	6,690 MUSD	11,328 MUSD
Vehicle CAPEX 2030 cumulative in MUSD	3,919 MUSD	7,566 MUSD	11,090 MUSD	47,677 MUSD	70,252 MUSD

Note: Constant real USD of 2020; vehicle values based on 2020 average values and annual reduction rate for each vehicle category based on market trends; see Annex for further details
Source: Grutter Consulting

By implementing this strategy Brazil would have around 2.6 million commercial EVs by 2030 reducing more than 16 million tons of CO_2 per annum. The impact is distributed between taxis, urban buses and LCVs. The estimated cumulative vehicle investment required by 2025 is around 11 billion USD and 70 billion USD by 2030. This excludes the investment required for chargers, grid upgrades or other investments e.g. in depot facilities. This is not the incremental investment for EVs relative to the BAU investment for fossil vehicles but the total required vehicle investment i.e. also in absence of an EV strategy a large part of this investment will take place, but in fossil units and not in EVs.

9. Enabling Aspects and Barriers

Factors which potentially foster e-mobility in Brazil are:

- **Integration of the electricity sector with the automotive sector:** Electric and plug-in hybrid vehicles, have been considered an opportunity for the electric sector. It would be a complementary solution for this sector in the intermittency of electricity generation from non-dispatchable sources (such as wind and solar), because of the ability to store energy in their batteries. Some even believe that the future of mobility will be integrated into the future of the electricity sector. However, there is still no technical consensus on this integration, given its complexity (epe, 2018)

- **Technological innovation in the automotive sector:** Innovations in the sector focus on four concepts: electrification, automation, connectivity and safety. The investment plans announced by automakers in electric vehicles and more efficient technologies total US $168 billion, over different horizons, and these annualized values represented 35 % of the investment of the companies surveyed. Moreover, automotive revenues could grow by more than 30% by 2030. Moreover, there may be additional incentive for automakers to try to launch new hybrid and electric models and expand the focus on these businesses (epe, 2018).

- **Smart cities:** They are those that provide a better quality of life to their inhabitants. They make use of infrastructure, services and information and communication with urban planning and management to respond to the social and economic needs of society. Therefore, policies in favor of advances in urban mobility, efficient energy use, energy demand management, better use of waste and biogas are in line with this concept (epe, 2018).

- **Batteries: raw materials, manufacturing and final destination:** Lithium-ion batteries have lithium as their main component. In the process of extracting and separating it, there is a high demand for water and the use of chemicals. In the National Mining Plan 2030, both lithium and rare earths are considered strategic minerals. Currently, lithium-ion batteries are not produced in Brazil. As electromobility develops in the country, this industry can be made possible in the country by prioritizing the construction of industrial plants efficient in the use of natural resources and with the capacity to recycle batteries. It is important to adopt the reverse logistics model for batteries. In Brazil, the National Solid Waste Policy (PNRS) can bring benefits to the industry in the reuse of materials and minimize the pollution of natural resources. Studies indicate that, depending on the secondary use, the useful life of the battery can be extended up to 20 years. (epe, 2018).

Factor which are currently barriers to widespread deployment of e-mobility in Brazil include:

- **Vehicle price and consumer preference:** The high purchase prices of hybrid and electric vehicles become a challenge for their diffusion. The models sold in 2016 were priced between R$115 to 250 thousand, however, the market share of vehicles in the price range above R$80 thousand in Brazil is around 6%. In addition, the preference in this price range is for larger and more luxurious vehicles (epe, 2018).

- **Adaptation of infrastructure:** For the diffusion of electric and plug-in hybrid vehicles to occur, an adequate electric charging infrastructure is necessary. These adaptations require significant infrastructure investments.

- **Biofuel policy:** Brazil focuses its efforts on the promotion of biofuels, although biofuels tend to have very significant upstream emissions and environmental degradation. This presents a barrier towards a shift to a more sustainable transportation technology.

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Annex

Vehicle Data

				97,561,753

Vehicle category	gasoline	diesel	CNG	total
Passenger car	61,192,392	0	0	61,192,392
Taxi	369,371			369,371
Motorcycle	23,788,071			23,788,071
small bus		419,519		419,519
standard urban bus		197,804		197,804
coach		461,542		461,542
LCV	1,651,958	6,607,832		8,259,790
Truck < 7.5t		574,653		574,653
Truck 7.5-16t		574,653		574,653
Truck 16-32t		574,653		574,653
Truck >32t		1,149,305		1,149,305

Source: Ministério da Infraestrutura, DENATRAN - Departamento Nacional de Trânsito, RENAVAM-Registro Nacional de Veículos Automotores; Taxi number based on share of taxis as total cars in Sao Paulo (0.6%)

Year of data	2020
Country	Brazil
GDP growth rate	1.7%

take from country values

Carbon grid factor	0.119

take from country values

Growth rate freight transport	1.7%

See below

Bus, coach growth	1%

decreasing mode share and population increase result in 0% growth

Passenger car, MC, taxi growth	1.6%

Income Group USD/Capita	Freight Intensity
< 5,000	1.18
5,000-25,000	**0.98**
25,000-50,000	0.87
> 50,000	0.82

Parameters Gompertz for medium income country

α	-2.2
β	-0.00013
vehicl pop 2030	71676860
CAGR	1.6%

Based on OECD pattern, see source above

GDP per capita 2019	8717
GDP per capital 2030	9844

Projected population 2(	224
Population 2019	210
CAGR	0.6%

Emissions

All data in tons per annum

2020

Vehicle category	NO_x	$PM_{2.5}$	CO_2 TTW	CO_2 WTW	Energy in TJ
Passenger car	35,461	639	117,788,241	140,254,333	1,699,686
Taxi	1,014	18	3,367,873	4,010,237	48,598
Motorcycles	23,074	416	13,145,245	15,736,507	189,686
small bus	128,171	1,007	12,184,410	15,666,445	164,432
standard urban bus	64,326	548	14,043,266	17,643,328	206,747
coach	125,170	980	21,794,459	27,468,897	294,122
LCV	166,002	8,130	54,790,940	73,573,812	743,401
Truck < 7.5t	28,273	183	5,547,981	6,947,366	74,872
Truck 7.5-16t	45,685	278	8,514,228	10,659,852	114,902
Truck 16-32t	66,028	412	11,535,406	14,466,667	155,673
Truck >32t	158,949	924	27,575,090	34,541,088	372,133
Total	**842,153**	**13,535**	**290,287,138**	**360,968,534**	**4,064,253**
with biofuel share			**252,612,515**		

2030

Vehicle category	NO_x	$PM_{2.5}$	CO_2 TTW	CO_2 WTW	Energy in MJ
Passenger car	41,537	749	137,969,621	164,284,967	1,990,904
Taxi	1,188	21	3,944,911	4,697,336	56,925
Motorcycles	27,028	488	15,397,501	18,432,739	222,186
small bus	135,916	1,068	12,920,674	16,613,117	174,368
standard urban bus	68,213	581	14,891,854	18,709,456	200,970
coach	132,734	1,040	23,111,427	29,128,753	311,895
LCV	195,826	9,590	64,634,756	86,792,186	876,961
Truck < 7.5t	33,352	216	6,544,739	8,195,539	88,323
Truck 7.5-16t	53,893	327	10,043,907	12,575,016	135,545
Truck 16-32t	77,890	486	13,607,873	17,065,769	183,642
Truck >32t	187,506	1,090	32,529,269	40,746,788	438,991
Total	**955,083**	**15,656**	**335,596,531**	**417,241,667**	**4,680,711**
with biofuel share			**291,075,398**		

Emission costs	2020	2030
Pollutants	3,364	4,807
GHG	14,439	16,690
Total	**17,802**	**21,496**

in MUSD of 2019

Fuel Usage	2020	2030	2019 fuel sales	
Gasoline	60,910	72,094	60,750	100.3%
Diesel	56,894	66,779	57,296	99.3%
CNG	0	0		

in million liters for diesel and gasoline and tons for CNG

statista/IEA

EV Scenarios

Rate of EVs of newly registered vehicles

Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
S1 EV 15@30	3%	3%	4%	5%	7%	9%	10%	11%	12%	14%	15%
S2 EV30@30	5%	6%	8%	11%	14%	18%	20%	22%	24%	27%	30%

High Potential Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Taxis	0%	4%	4%	8%	14%	22%	32%	45%	61%	79%	100%
Urban Buses	0%	11%	4%	8%	14%	22%	32%	45%	61%	79%	100%
Small buses	0%	8%	4%	8%	14%	22%	32%	45%	61%	79%	100%
LCVs	0%	3%	4%	8%	14%	22%	32%	45%	61%	79%	100%

This scenario is only made for the vehicle categories of the program i.e. urban buses, small buses, taxis and LCVs

For urban buses, taxis and LCVs the target is 100% of new registered buses/taxis/LCVs in 2030 are electric; This takes into consideration that Evs in this segment should be cost-competitive by 2030. No early replacement of vehicles is made i.e. conventional vehicles could still be used till ending their lifespan.

The growth curve towards 2030 is based on a power curve with the function y=0.0024*n^2.52 based on the curve of Norway for the last 10 years). Initial experiences are built and cost structures go down. Barriers are removed and financial equivalence will be achieved. The vehicle penetration rates increases then (for new vehicles)

Passenger cars S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all cars	61,192,392	62,167,813	63,158,781	64,165,546	65,188,359	66,227,476	67,283,156	68,355,664	69,445,269	70,552,241	71,676,860
Replacement cars	3,011,614	3,059,620	3,108,391	3,157,939	3,208,277	3,259,418	3,311,374	3,364,158	3,417,783	3,472,263	3,527,612
Additional new cars	960,116	975,420	990,969	1,006,765	1,022,813	1,039,117	1,055,680	1,072,508	1,089,604	1,106,973	1,124,618
EV car fleet new	100,159	130,989	171,308	224,038	292,999	383,186	431,994	487,020	549,054	618,990	697,835
EV car fleet stock	100,159	231,148	402,456	626,494	919,493	1,302,678	1,734,673	2,221,692	2,770,747	3,389,737	4,087,572
EV fleet as % of stock	0%	0%	1%	1%	1%	2%	3%	3%	4%	5%	6%
GHG reduction WTW in tons	209,192	482,775	840,568	1,308,494	1,920,450	2,720,770	3,623,032	4,640,221	5,786,974	7,079,795	8,537,290
Electricity demand GWh	171.3	395.3	688.2	1071.3	1572.3	2227.6	2966.3	3799.1	4738.0	5796.5	6989.7

Passenger cars S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all cars	61,192,392	62,167,813	63,158,781	64,165,546	65,188,359	66,227,476	67,283,156	68,355,664	69,445,269	70,552,241	71,676,860
Replacement cars	3,011,614	3,059,620	3,108,391	3,157,939	3,208,277	3,259,418	3,311,374	3,364,158	3,417,783	3,472,263	3,527,612
Additional new cars	960,116	975,420	990,969	1,006,765	1,022,813	1,039,117	1,055,680	1,072,508	1,089,604	1,106,973	1,124,618
EV car fleet new	200,318	261,978	342,616	448,076	585,997	766,372	863,989	974,040	1,098,108	1,237,981	1,395,669
EV car fleet stock	200,318	462,296	804,912	1,252,988	1,838,985	2,605,357	3,469,345	4,443,385	5,541,493	6,779,474	8,175,143
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	5%	7%	8%	10%	11%
GHG reduction WTW in tons	418,384	965,550	1,681,137	2,616,987	3,840,899	5,441,541	7,246,065	9,280,441	11,573,947	14,159,590	17,074,581
Electricity demand GWh	342.5	790.5	1376.4	2142.6	3144.7	4455.2	5932.6	7598.2	9476.0	11592.9	13979.5

Taxis S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all taxis	369,371	375,258	381,240	387,317	393,491	399,763	406,136	412,610	419,187	425,869	432,657
Replacement taxis	36,358	36,937	37,526	38,124	38,732	39,349	39,976	40,614	41,261	41,919	42,587
Additional new taxis	5,795	5,888	5,982	6,077	6,174	6,272	6,372	6,474	6,577	6,682	6,788
EV taxi fleet new	1,063	1,390	1,818	2,378	3,110	4,067	4,585	5,169	5,827	6,570	7,406
EV taxi fleet stock	1,063	2,453	4,271	6,649	9,759	13,826	18,411	23,579	29,407	35,976	43,382
EV taxi as % of stock	0%	1%	1%	2%	2%	3%	5%	6%	7%	8%	10%
GHG reduction WTW in tons	10,517	24,271	42,258	65,782	96,547	136,782	182,142	233,279	290,930	355,925	429,198
Electricity demand GWh	8.6	19.9	34.6	53.9	79.0	112.0	149.1	191.0	238.2	291.4	351.4

Taxis S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all taxis	369,371	375,258	381,240	387,317	393,491	399,763	406,136	412,610	419,187	425,869	432,657
Replacement taxis	36,358	36,937	37,526	38,124	38,732	39,349	39,976	40,614	41,261	41,919	42,587
Additional new taxis	5,795	5,888	5,982	6,077	6,174	6,272	6,372	6,474	6,577	6,682	6,788
EV taxi fleet new	2,126	2,780	3,636	4,756	6,219	8,134	9,170	10,338	11,655	13,139	14,813
EV taxi fleet stock	2,126	4,906	8,543	13,298	19,518	27,651	36,821	47,159	58,813	71,952	86,765
EV taxi as % of stock	1%	1%	2%	3%	5%	7%	9%	11%	14%	17%	20%
GHG reduction WTW in tons	21,034	48,541	84,516	131,565	193,095	273,564	364,284	466,559	581,861	711,850	858,396
Electricity demand GWh	17.2	39.7	69.2	107.7	158.1	224.0	298.3	382.0	476.4	582.8	702.8

Taxis High Potential	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all taxis	369,371	375,258	381,240	387,317	393,491	399,763	406,136	412,610	419,187	425,869	432,657
Replacement taxis	36,358	36,937	37,526	38,124	38,732	39,349	39,976	40,614	41,261	41,919	42,587
Additional new taxis	5,795	5,888	5,982	6,077	6,174	6,272	6,372	6,474	6,577	6,682	6,788
EV taxi fleet new	0	1,614	1,664	3,490	6,222	10,007	14,993	21,326	29,153	38,624	49,375
EV taxi fleet stock	0	1,614	3,278	6,768	12,990	22,997	37,991	59,316	88,469	127,092	176,468
EV taxi as % of stock	0%	0%	1%	2%	3%	6%	9%	14%	21%	30%	41%
GHG reduction WTW in tons	0	15,969	32,430	66,959	128,513	227,520	375,854	586,836	875,252	1,257,370	1,745,857
Electricity demand GWh	0.0	13.1	26.6	54.8	105.2	186.3	307.7	480.5	716.6	1029.4	1429.4

Motorcycle S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all MC	23,788,071	24,167,258	24,552,489	24,943,862	25,341,472	25,745,421	26,155,808	26,572,738	26,996,313	27,426,640	27,863,827
Replacement MC	2,926,854	2,973,509	3,020,907	3,069,061	3,117,983	3,167,684	3,218,178	3,269,476	3,321,592	3,374,539	3,428,330
Additional new MC	373,238	379,187	385,231	391,372	397,611	403,949	410,388	416,929	423,575	430,327	437,187
EV MC fleet new	83,222	108,838	142,339	186,152	243,451	318,387	358,942	404,663	456,207	514,316	579,828
EV MC fleet stock	83,222	192,060	334,399	520,551	764,002	1,082,389	1,441,332	1,845,994	2,302,201	2,816,517	3,396,344
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	6%	7%	9%	10%	12%
GHG reduction WTW in tons	53,816	124,197	216,242	336,619	494,049	699,937	932,050	1,193,729	1,488,739	1,821,326	2,196,277
Electricity demand GWh	10.4	24.0	41.8	65.1	95.5	135.3	180.2	230.7	287.8	352.1	424.5

Motorcycle S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all MC	23,788,071	24,167,258	24,552,489	24,943,862	25,341,472	25,745,421	26,155,808	26,572,738	26,996,313	27,426,640	27,863,827
Replacement MC	2,926,854	2,973,509	3,020,907	3,069,061	3,117,983	3,167,684	3,218,178	3,269,476	3,321,592	3,374,539	3,428,330
Additional new MC	373,238	379,187	385,231	391,372	397,611	403,949	410,388	416,929	423,575	430,327	437,187
EV MC fleet new	166,443	217,676	284,678	372,304	486,902	636,775	717,884	809,325	912,413	1,028,632	1,159,655
EV MC fleet stock	166,443	384,119	668,798	1,041,102	1,528,004	2,164,779	2,882,663	3,691,988	4,604,401	5,633,034	6,792,689
EV fleet as % of stock	1%	2%	3%	4%	6%	8%	11%	14%	17%	21%	24%
GHG reduction WTW in tons	107,632	248,394	432,484	673,238	988,098	1,399,874	1,864,100	2,387,458	2,977,478	3,642,652	4,392,554
Electricity demand GWh	20.8	48.0	83.6	130.1	191.0	270.6	360.3	461.5	575.6	704.1	849.1

Small Bus S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	419,519	421,988	424,471	426,968	429,481	432,008	434,550	437,107	439,679	442,267	444,869
Replacement vehicles	27,804	27,968	28,133	28,298	28,465	28,632	28,801	28,970	29,140	29,312	29,484
Additional new vehicles	2,454	2,469	2,483	2,498	2,512	2,527	2,542	2,557	2,572	2,587	2,602
EV vehicle fleet new	763	988	1,279	1,657	2,145	2,778	3,100	3,461	3,863	4,312	4,813
EV vehicle fleet stock	763	1,751	3,031	4,687	6,832	9,610	12,710	16,171	20,034	24,346	29,159
EV fleet as % of stock	0%	0%	1%	1%	2%	2%	3%	4%	5%	6%	7%
GHG reduction WTW in tons	21,738	49,886	86,333	133,527	194,637	273,767	362,092	460,682	570,731	693,568	830,681
Electricity demand GWh	25.6	58.8	101.8	157.5	229.6	322.9	427.1	543.4	673.1	818.0	979.7

Small Bus S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	419,519	421,988	424,471	426,968	429,481	432,008	434,550	437,107	439,679	442,267	444,869
Replacement vehicles	27,804	27,968	28,133	28,298	28,465	28,632	28,801	28,970	29,140	29,312	29,484
Additional new vehicles	2,454	2,469	2,483	2,498	2,512	2,527	2,542	2,557	2,572	2,587	2,602
EV vehicle fleet new	1,526	1,976	2,559	3,313	4,290	5,555	6,201	6,922	7,726	8,624	9,626
EV vehicle fleet stock	1,526	3,502	6,061	9,374	13,665	19,220	25,421	32,342	40,068	48,692	58,318
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	6%	7%	9%	11%	13%
GHG reduction WTW in tons	43,476	99,771	172,666	267,055	389,275	547,533	724,184	921,365	1,141,461	1,387,136	1,661,363
Electricity demand GWh	51.3	117.7	203.7	315.0	459.1	645.8	854.1	1086.7	1346.3	1636.1	1959.5

Small Bus Potential scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	419,519	421,988	424,471	426,968	429,481	432,008	434,550	437,107	439,679	442,267	444,869
Replacement vehicles	27,804	27,968	28,133	28,298	28,465	28,632	28,801	28,970	29,140	29,312	29,484
Additional new vehicles	2,454	2,469	2,483	2,498	2,512	2,527	2,542	2,557	2,572	2,587	2,602
EV vehicle fleet new	0	2,517	1,171	2,432	4,292	6,835	10,139	14,278	19,326	25,351	32,087
EV vehicle fleet stock	0	2,517	3,688	6,119	10,411	17,246	27,385	41,664	60,989	86,340	118,427
EV fleet as % of stock	0%	1%	1%	1%	2%	4%	6%	10%	14%	20%	27%
GHG reduction WTW in tons	0	71,698	105,053	174,324	296,593	491,309	780,147	1,186,911	1,737,458	2,459,648	3,373,738
Electricity demand GWh	0.0	84.6	123.9	205.6	349.8	579.5	920.1	1399.9	2049.2	2901.0	3979.1

Urban bus standard S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	197,804	198,968	200,139	201,316	202,501	203,693	204,891	206,097	207,310	208,530	209,757
Replacement vehicles	13,110	13,187	13,265	13,343	13,421	13,500	13,580	13,659	13,740	13,821	13,902
Additional new vehicles	1,157	1,164	1,171	1,178	1,185	1,192	1,199	1,206	1,213	1,220	1,227
EV vehicle fleet new	360	466	603	781	1,011	1,310	1,462	1,632	1,821	2,033	2,269
EV vehicle fleet stock	360	826	1,429	2,210	3,221	4,531	5,993	7,625	9,446	11,479	13,749
EV fleet as % of stock	0%	0%	1%	1%	2%	2%	3%	4%	5%	6%	7%
GHG reduction WTW in tons	29,523	67,752	117,252	181,349	264,345	371,814	491,773	625,672	775,133	941,964	1,128,184
Electricity demand GWh	21.6	49.5	85.7	132.6	193.3	271.9	359.6	457.5	566.8	688.8	824.9

Urban bus standard S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	197,804	198,968	200,139	201,316	202,501	203,693	204,891	206,097	207,310	208,530	209,757
Replacement vehicles	13,110	13,187	13,265	13,343	13,421	13,500	13,580	13,659	13,740	13,821	13,902
Additional new vehicles	1,157	1,164	1,171	1,178	1,185	1,192	1,199	1,206	1,213	1,220	1,227
EV vehicle fleet new	720	932	1,206	1,562	2,023	2,619	2,924	3,264	3,643	4,066	4,539
EV vehicle fleet stock	720	1,651	2,858	4,420	6,443	9,062	11,986	15,249	18,892	22,958	27,497
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	6%	7%	9%	11%	13%
GHG reduction WTW in tons	59,046	135,503	234,505	362,698	528,691	743,628	983,545	1,251,345	1,550,267	1,883,928	2,256,367
Electricity demand GWh	43.2	99.1	171.5	265.2	386.6	543.7	719.2	915.0	1133.5	1377.5	1649.8

Urban bus high growth	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	197,804	198,968	200,139	201,316	202,501	203,693	204,891	206,097	207,310	208,530	209,757
Replacement vehicles	13,110	13,187	13,265	13,343	13,421	13,500	13,580	13,659	13,740	13,821	13,902
Additional new vehicles	1,157	1,164	1,171	1,178	1,185	1,192	1,199	1,206	1,213	1,220	1,227
EV vehicle fleet new	0	1,524	552	1,147	2,024	3,223	4,781	6,732	9,112	11,953	15,129
EV vehicle fleet stock	0	1,524	2,076	3,222	5,246	8,468	13,249	19,981	29,093	41,046	56,175
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	6%	10%	14%	20%	27%
GHG reduction WTW in tons	0	125,018	170,319	264,400	430,458	694,910	1,087,193	1,639,636	2,387,358	3,368,195	4,609,658
Electricity demand GWh	0.0	91.4	124.5	193.3	314.7	508.1	794.9	1198.9	1745.6	2462.8	3370.5

Coach S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	461,542	464,258	466,990	469,738	472,502	475,282	478,079	480,892	483,722	486,568	489,431
Replacement vehicles	30,589	30,769	30,951	31,133	31,316	31,500	31,685	31,872	32,059	32,248	32,438
Additional new vehicles	2,700	2,716	2,732	2,748	2,764	2,780	2,797	2,813	2,830	2,846	2,863
EV vehicle fleet new	839	1,087	1,408	1,823	2,360	3,056	3,411	3,807	4,250	4,744	5,295
EV vehicle fleet stock	839	1,927	3,334	5,157	7,517	10,573	13,984	17,791	22,041	26,785	32,080
EV fleet as % of stock	0%	0%	1%	1%	2%	2%	3%	4%	5%	6%	7%
GHG reduction WTW in tons	43,971	100,907	174,631	270,095	393,706	553,766	732,428	931,853	1,154,455	1,402,927	1,680,275
Electricity demand GWh	50.4	115.6	200.0	309.4	451.0	634.4	839.0	1067.5	1322.5	1607.1	1924.8

Coach S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	461,542	464,258	466,990	469,738	472,502	475,282	478,079	480,892	483,722	486,568	489,431
Replacement vehicles	30,589	30,769	30,951	31,133	31,316	31,500	31,685	31,872	32,059	32,248	32,438
Additional new vehicles	2,700	2,716	2,732	2,748	2,764	2,780	2,797	2,813	2,830	2,846	2,863
EV vehicle fleet new	1,679	2,174	2,815	3,645	4,720	6,112	6,822	7,615	8,500	9,488	10,590
EV vehicle fleet stock	1,679	3,853	6,668	10,313	15,033	21,145	27,967	35,582	44,082	53,570	64,160
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	6%	7%	9%	11%	13%
GHG reduction WTW in tons	87,942	201,814	349,263	540,189	787,412	1,107,533	1,464,856	1,863,707	2,308,910	2,805,854	3,360,551
Electricity demand GWh	100.7	231.2	400.1	618.8	902.0	1268.7	1678.0	2134.9	2644.9	3214.2	3849.6

LCV S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	8,259,790	8,397,398	8,537,299	8,679,530	8,824,131	8,971,141	9,120,600	9,272,550	9,427,030	9,584,085	9,743,755
Replacement vehicles	406,222	412,990	419,870	426,865	433,977	441,207	448,557	456,030	463,627	471,352	479,204
Additional new vehicles	135,353	137,608	139,901	142,231	144,601	147,010	149,459	151,949	154,481	157,054	159,671
EV vehicle fleet new	13,657	17,874	23,392	30,614	40,066	52,436	59,156	66,739	75,293	84,944	95,831
EV vehicle fleet stock	13,657	31,531	54,924	85,538	125,604	178,039	237,196	303,935	379,228	464,171	560,003
EV fleet as % of stock	0%	0%	1%	1%	1%	2%	3%	3%	4%	5%	6%
GHG reduction WTW in tons	38,036	87,816	152,964	238,226	349,811	495,846	660,599	846,469	1,056,162	1,292,734	1,559,627
Electricity demand GWh	32.8	75.7	131.8	205.3	301.4	427.3	569.3	729.4	910.1	1114.0	1344.0

LCV S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	8,259,790	8,397,398	8,537,299	8,679,530	8,824,131	8,971,141	9,120,600	9,272,550	9,427,030	9,584,085	9,743,755
Replacement vehicles	406,222	412,990	419,870	426,865	433,977	441,207	448,557	456,030	463,627	471,352	479,204
Additional new vehicles	135,353	137,608	139,901	142,231	144,601	147,010	149,459	151,949	154,481	157,054	159,671
EV vehicle fleet new	27,315	35,748	46,785	61,228	80,132	104,871	118,313	133,478	150,586	169,887	191,663
EV vehicle fleet stock	27,315	63,063	109,847	171,076	251,208	356,079	474,392	607,869	758,455	928,343	1,120,005
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	5%	7%	8%	10%	11%
GHG reduction WTW in tons	76,073	175,632	305,929	476,452	699,622	991,692	1,321,197	1,692,937	2,112,325	2,585,467	3,119,254
Electricity demand GWh	65.6	151.4	263.6	410.6	602.9	854.6	1138.5	1458.9	1820.3	2228.0	2688.0

LCV high growth	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	8,259,790	8,397,398	8,537,299	8,679,530	8,824,131	8,971,141	9,120,600	9,272,550	9,427,030	9,584,085	9,743,755
Replacement vehicles	406,222	412,990	419,870	426,865	433,977	441,207	448,557	456,030	463,627	471,352	479,204
Additional new vehicles	135,353	137,608	139,901	142,231	144,601	147,010	149,459	151,949	154,481	157,054	159,671
EV vehicle fleet new	0	16,751	21,408	44,935	80,164	129,030	193,451	275,351	376,675	499,403	638,875
EV vehicle fleet stock	0	16,751	38,159	83,094	163,258	292,287	485,739	761,090	1,137,765	1,637,168	2,276,043
EV fleet as % of stock	0%	0%	0%	1%	2%	3%	5%	8%	12%	17%	23%
GHG reduction WTW in tons	0	46,653	106,273	231,420	454,678	814,031	1,352,799	2,119,661	3,168,714	4,559,570	6,338,859
Electricity demand GWh	0.0	40.2	91.6	199.4	391.8	701.5	1165.8	1826.6	2730.6	3929.2	5462.5

Truck <7.5t S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	574,653	584,227	593,960	603,855	613,916	624,143	634,542	645,113	655,861	666,787	677,896
Replacement vehicles	28,262	28,733	29,211	29,698	30,193	30,696	31,207	31,727	32,256	32,793	33,339
Additional new vehicles	9,417	9,574	9,733	9,895	10,060	10,228	10,398	10,571	10,748	10,927	11,109
EV vehicle fleet new	950	1,244	1,627	2,130	2,787	3,648	4,116	4,643	5,238	5,910	6,667
EV vehicle fleet stock	950	2,194	3,821	5,951	8,739	12,387	16,502	21,145	26,384	32,293	38,961
EV fleet as % of stock	0%	0%	1%	1%	1%	2%	3%	3%	4%	5%	6%
GHG reduction WTW in tons	9,588	22,137	38,560	60,053	88,182	124,995	166,526	213,381	266,241	325,877	393,157
Electricity demand GWh	16.0	36.9	64.2	100.0	146.8	208.1	277.2	355.2	443.2	542.5	654.5

Truck <7.5t S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	574,653	584,227	593,960	603,855	613,916	624,143	634,542	645,113	655,861	666,787	677,896
Replacement vehicles	28,262	28,733	29,211	29,698	30,193	30,696	31,207	31,727	32,256	32,793	33,339
Additional new vehicles	9,417	9,574	9,733	9,895	10,060	10,228	10,398	10,571	10,748	10,927	11,109
EV vehicle fleet new	1,900	2,487	3,255	4,260	5,575	7,296	8,231	9,286	10,477	11,819	13,334
EV vehicle fleet stock	1,900	4,387	7,642	11,902	17,477	24,773	33,005	42,291	52,768	64,587	77,921
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	5%	7%	8%	10%	11%
GHG reduction WTW in tons	19,177	44,274	77,120	120,106	176,363	249,989	333,052	426,762	532,483	651,754	786,313
Electricity demand GWh	31.9	73.7	128.4	200.0	293.6	416.2	554.5	710.5	886.5	1085.1	1309.1

Truck 7.5-16t S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	574,653	584,227	593,960	603,855	613,916	624,143	634,542	645,113	655,861	666,787	677,896
Replacement vehicles	28,262	28,733	29,211	29,698	30,193	30,696	31,207	31,727	32,256	32,793	33,339
Additional new vehicles	9,417	9,574	9,733	9,895	10,060	10,228	10,398	10,571	10,748	10,927	11,109
EV vehicle fleet new	950	1,244	1,627	2,130	2,787	3,648	4,116	4,643	5,238	5,910	6,667
EV vehicle fleet stock	950	2,194	3,821	5,951	8,739	12,387	16,502	21,145	26,384	32,293	38,961
EV fleet as % of stock	0%	0%	1%	1%	1%	2%	3%	3%	4%	5%	6%
GHG reduction WTW in tons	14,913	34,430	59,973	93,402	137,151	194,408	259,003	331,877	414,093	506,846	611,487
Electricity demand GWh	22.8	52.6	91.7	142.8	209.7	297.3	396.1	507.5	633.2	775.0	935.1

Truck 7.5-16t S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	574,653	584,227	593,960	603,855	613,916	624,143	634,542	645,113	655,861	666,787	677,896
Replacement vehicles	28,262	28,733	29,211	29,698	30,193	30,696	31,207	31,727	32,256	32,793	33,339
Additional new vehicles	9,417	9,574	9,733	9,895	10,060	10,228	10,398	10,571	10,748	10,927	11,109
EV vehicle fleet new	1,900	2,487	3,255	4,260	5,575	7,296	8,231	9,286	10,477	11,819	13,334
EV vehicle fleet stock	1,900	4,387	7,642	11,902	17,477	24,773	33,005	42,291	52,768	64,587	77,921
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	5%	7%	8%	10%	11%
GHG reduction WTW in tons	29,826	68,861	119,946	186,804	274,303	388,815	518,006	663,755	828,185	1,013,691	1,222,975
Electricity demand GWh	45.6	105.3	183.4	285.7	419.5	594.6	792.1	1015.0	1266.4	1550.1	1870.1

Truck 16-32t S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	574,653	584,227	593,960	603,855	613,916	624,143	634,542	645,113	655,861	666,787	677,896
Replacement vehicles	28,262	28,733	29,211	29,698	30,193	30,696	31,207	31,727	32,256	32,793	33,339
Additional new vehicles	9,417	9,574	9,733	9,895	10,060	10,228	10,398	10,571	10,748	10,927	11,109
EV vehicle fleet new	950	1,244	1,627	2,130	2,787	3,648	4,116	4,643	5,238	5,910	6,667
EV vehicle fleet stock	950	2,194	3,821	5,951	8,739	12,387	16,502	21,145	26,384	32,293	38,961
EV fleet as % of stock	0%	0%	1%	1%	1%	2%	3%	3%	4%	5%	6%
GHG reduction WTW in tons	19,851	45,831	79,832	124,330	182,566	258,781	344,765	441,770	551,209	674,675	813,966
Electricity demand GWh	34.2	79.0	137.6	214.2	314.6	445.9	594.1	761.2	949.8	1162.6	1402.6

Truck 16-32t S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	574,653	584,227	593,960	603,855	613,916	624,143	634,542	645,113	655,861	666,787	677,896
Replacement vehicles	28,262	28,733	29,211	29,698	30,193	30,696	31,207	31,727	32,256	32,793	33,339
Additional new vehicles	9,417	9,574	9,733	9,895	10,060	10,228	10,398	10,571	10,748	10,927	11,109
EV vehicle fleet new	1,900	2,487	3,255	4,260	5,575	7,296	8,231	9,286	10,477	11,819	13,334
EV vehicle fleet stock	1,900	4,387	7,642	11,902	17,477	24,773	33,005	42,291	52,768	64,587	77,921
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	5%	7%	8%	10%	11%
GHG reduction WTW in tons	39,702	91,662	159,663	248,659	365,131	517,562	689,530	883,541	1,102,418	1,349,350	1,627,932
Electricity demand GWh	68.4	157.9	275.1	428.5	629.2	891.8	1188.2	1522.5	1899.6	2325.1	2805.2

Truck >32t S1	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	1,149,305	1,168,452	1,187,919	1,207,710	1,227,830	1,248,286	1,269,082	1,290,225	1,311,720	1,333,573	1,355,791
Replacement vehicles	56,524	57,465	58,423	59,396	60,385	61,392	62,414	63,454	64,511	65,586	66,679
Additional new vehicles	18,834	19,147	19,466	19,791	20,120	20,456	20,796	21,143	21,495	21,853	22,217
EV vehicle fleet new	1,900	2,487	3,255	4,260	5,575	7,296	8,231	9,286	10,477	11,819	13,334
EV vehicle fleet stock	1,900	4,387	7,642	11,902	17,477	24,773	33,005	42,291	52,767	64,587	77,921
EV fleet as % of stock	0%	0%	1%	1%	1%	2%	3%	3%	4%	5%	6%
GHG reduction WTW in tons	46,533	107,432	187,134	291,441	427,952	606,608	808,164	1,035,554	1,292,089	1,581,506	1,908,018
Electricity demand GWh	88.9	205.3	357.7	557.0	817.9	1159.4	1544.6	1979.2	2469.5	3022.7	3646.7

Truck >32t S2	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Stock all vehicles	1,149,305	1,168,452	1,187,919	1,207,710	1,227,830	1,248,286	1,269,082	1,290,225	1,311,720	1,333,573	1,355,791
Replacement vehicles	56,524	57,465	58,423	59,396	60,385	61,392	62,414	63,454	64,511	65,586	66,679
Additional new vehicles	18,834	19,147	19,466	19,791	20,120	20,456	20,796	21,143	21,495	21,853	22,217
EV vehicle fleet new	3,801	4,974	6,510	8,520	11,150	14,592	16,463	18,573	20,953	23,639	26,669
EV vehicle fleet stock	3,801	8,775	15,285	23,804	34,954	49,546	66,009	84,582	105,535	129,174	155,843
EV fleet as % of stock	0%	1%	1%	2%	3%	4%	5%	7%	8%	10%	11%
GHG reduction WTW in tons	93,066	214,865	374,267	582,882	855,904	1,213,217	1,616,328	2,071,107	2,584,178	3,163,011	3,816,036
Electricity demand GWh	177.9	410.7	715.3	1114.0	1635.9	2318.8	3089.2	3958.4	4939.0	6045.3	7293.4

GHG Transport Projections WTW

Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BAU	360,968,534	366,236,123	371,580,582	377,003,033	382,504,612	388,086,476	393,749,795	399,495,759	405,325,574	411,240,462	417,241,667
EV15@30	360,552,153	365,276,384	369,911,773	374,408,888	378,702,885	382,708,799	386,599,153	390,350,473	393,936,208	397,326,346	400,486,977
GHG reduction EV15@30	416,382	959,740	1,668,810	2,594,145	3,801,727	5,377,677	7,150,642	9,145,286	11,389,366	13,914,116	16,754,689
Electricity usage	483	1,113	1,935	3,009	4,411	6,242	8,302	10,622	13,232	16,171	19,478
EV30@30	360,135,771	364,316,644	368,242,963	371,814,743	374,901,157	377,331,122	379,448,511	381,205,187	382,546,842	383,412,231	383,732,288
GHG reduction EV30@30	832,763	1,919,480	3,337,619	5,188,289	7,603,455	10,755,354	14,301,284	18,290,573	22,778,732	27,828,232	33,509,378
Electricity usage	965	2,225	3,870	6,018	8,822	12,484	16,605	21,244	26,465	32,341	38,956
EV scenario high growth	360,172,805	364,141,366	367,972,626	371,297,064	373,906,258	375,540,176	376,421,866	376,385,945	375,249,192	372,809,776	368,892,614
GHG reduction high growth	795,729	2,094,757	3,607,956	5,705,969	8,598,354	12,546,300	17,327,930	23,109,814	30,076,382	38,430,686	48,349,053
Electricity usage	788	2,047	3,529	5,573	8,377	12,191	16,783	22,307	28,930	36,839	46,198

Euro 4/IV									
Vehicle category	**Fuel**	**Fuel consumption**	**NO_x**	**$PM_{2.5}$**	**CO_2 TTW**	**BC**	**CO_2 WTW incl. BC**	**Energy Usage MJ**	**Annual distance**
Passenger Car	gasoline	66	0.061	0.001	203	0	241	2.9	9,500
Passenger Car	diesel	55	0.580	0.031	175	25	240	2.4	20,000
Passenger Car	CNG	63	0.056	0.001	189	0	264	3.0	15,000
Taxi	gasoline	66	0.061	0.001	203	0	241	2.9	45,000
Taxi	diesel	55	0.580	0.031	175	25	240	2.4	50,000
Taxi	CNG	63	0.056	0.001	189	0	264	3.0	50,000
3-wheeler	gasoline	24	0.000	0.000	75	0	89	1.1	20,000
3-wheeler	diesel	19	0.500	0.050	61	11	86	0.8	20,000
3-wheeler	CNG	32	0.500	0.000	96	0	134	1.5	20,000
Motorcycle	gasoline	36	0.194	0.004	111	1	132	1.6	5,000
Small bus	gasoline	148	0.000	0.000	455	0	541	6.6	60,000
Small bus	diesel	152	5.092	0.040	484	27	622	6.5	60,000
Urban standard bus	diesel	371	5.420	0.046	1183	31	1,487	16.0	60,000
Urban standard bus	CNG	490	2.500	0.005	1,470	0	2,051	23.5	60,000
Coach bus	diesel	247	4.520	0.035	787	24	992	10.6	60,000
LCV	gasoline	70	0.064	0.001	215	0	256	3.1	12,000
LCV	diesel	80	0.831	0.041	255	32	346	3.4	30,000
Truck < 7.5t	diesel	101	1.640	0.011	322	7	403	4.3	30,000
Truck 7.5-16t	diesel	155	2.650	0.016	494	11	618	6.7	30,000
Truck 16-32t	diesel	210	3.830	0.024	669	16	839	9.0	30,000
Truck >32t	diesel	251	4.610	0.027	800	18	1,002	10.8	30,000

Source and Assumptions

Emission factors and fuel consumption EEA, (2020), COPERT Tier 2 except for small buses, 3-wheelers and standard urban buses (standard urban buses based on Tier 3 with 15km/h and 50% load)

car/taxi: medium size

Motorcycle 4-strooke<250cm3, Euro 1 respectively Euro 2

all units g/km

General Parameters

Parameter	Value	Unit	Source
NCV of diesel	43	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of diesel	74.1	gCO_2/MJ	IPCC, 2006, table 1.4
Density of diesel	0.844	kg/l	IEA, 2005
Well-to-tank mark-up factor diesel	23%		UNFCCC, 2014, Table 3
NCV of CNG	48	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of CNG	56.1	gCO_2/MJ	IPCC, 2006, table 1.4
Density of NG	0.714	kg/m^3	IGU, 2012
Well-to-tank mark-up factor CNG	18%		UNFCCC, 2014, Table 3
Methane slip as % of NG consumption TTW	1.1%		Average low and high value of ICCT, 2015, table 4 for crankcase and tailpipe
Methane slip as % of NG consumption WTW	3.4%		Average low and high value of ICCT, 2015, table 4 for well-to-pump and fuelling station plus TTW slip
NCV of gasoline	44.3	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of gasoline	69.3	gCO_2/MJ	IPCC, 2006, table 1.4
Density of gasoline	0.741	kg/l	IEA, 2005
Well-to-tank mark-up factor gasoline	19%		UNFCCC, 2014, Table 3
GWP_{100} of BC	900		Bond, 2013; see also IPCC, 2013, Table 8.A.6
GWP_{100} of CH_4	28		IPCC, 2013, Table 8.A.
BC fraction Euro 2 gasoline passenger car and LCV	25%		EEA, 2020, tabla 3-92
BC fraction Euro 4 gasoline passenger car and LCV	15%		
BC fraction Euro 2 diesel passenger car and LCV	80%		
BC fraction Euro 4 diesel passenger car and LCV	87%		
BC fraction Euro II HDV	65%		
BC fraction Euro IV HDV	75%		
BC fraction Euro 1 Motorcycle	25%		
BC fraction Euro 2 Mot	25%		
Conversion kWh to MJ	3.6	MJ per kWh	https://home.uni-leipzig.de/energy/energy-fundamentals/03.htm#:~:text=Power%20units%20can%20be%20converted,%3D%203.6%20MJ%20%5B
Battery manufacturing emissions	110	$kgCO_2$/kWh	ICCT, 2018, table 1 (per kWh battery set); average value not taking into account 2nd life usage of batteries