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A Sustainable Development Assessment to 2050 of the Transport Sector in Mexico

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The growth and variations within the vehicle park of the transport sector in Mexico have not been studied enough. This represents a problem for developing public policies and fulfilling Mexico's commitments to the Sustainable Development Goals (SDG) set by the United Nations in 2015. One of the targets set is reducing CO2 emissions by 45% for the period 2010-2030 and reaching zero percent of emissions by 2050. By 2018, Mexico had a final energy consumption of 5,396.45 PJ. In the same year, the transport sector was responsible for 46.5% of the energetic consumption, with the area of self-transport being the category of highest energy demand. With respect to CO_2 emissions, the transport sector was responsible for 31% of the total emission contribution for 2017. The subsector with the highest CO_2 emission was self-transport, with 93% of the total emitted.
The objective of this research is to evaluate the behavior of the transport sector in Mexico through an energy model implemented by the Long-range Energy Alternatives Planning System (LEAP) software. The data required to develop the base scenario were taken from the database of the National Institute of Statistics and Geography and from the information presented on the virtual portals of the National Commission for the Efficient Use of Energy. Both information sources are managed by the federal government of Mexico and represent the official data of the vehicle park and energy consumption of the country. The items selected to model the self-transport sector were passenger and cargo. The fuels chosen were gasoline and diesel, as they are the most demanded energy sources within the sector. The results show that the transport sector could help the 2030 SDG compliance on a limited basis, mainly due to high dependence on fossil fuel consumption. The application of energy policies in the transport sector is required to have sustainable development by 2050.

1. Introduction

Moreno Ayala (2009) describes that one of the processes that represent a threat of great importance for economic and social development and, therefore, the most serious and immediate danger for sustainable development, is the increase in temperature around five degrees centigrade compared to the one existing in the last 160 thousand years. Martínez Salgado (2018) indicates that, in 2016, the transport sector originated 36% of greenhouse gas emissions in Latin America and the Caribbean. Road transport, in turn, generated more than 80% of these emissions, with a similar distribution between passenger and freight transport.
The aforementioned can be interpreted as a problem in reaching the emission limits established in the Paris Agreement against Climate Change. Olabe, et al. (2018), outline the key points of the Paris agreement in the document entitled The Paris Agreement and the end of the coal era, stating that an increase in global temperature of between 1.5 ° C and 2 ° C should be avoided. Studies carried out by the IPCC (2014) report that total emissions in 2050 should be in a range of between 15 and 20 Gigatons of CO2 equivalent (GtCO2 eq.) (Change, 2014).
In the global panorama, the trend of energy consumption in the transportation sector worldwide has been on the rise since 1990, where the consumption registered for that year was 65,954.10 PJ and for 2018 it was 121,036.20 PJ (IEAc, 2020). The difference between the consumption from 1990 to 2018 represents an

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increase in the demand for energy in that sector by more than 69%. Van der Hoeven (2015) explains that energy trends in passenger transport are given by changes in population and its density, extension of land use, transport infrastructure, travel habits, income level, vehicle equipment, vehicle occupancy rate, consumer preferences, and average fuel consumption.
In the local scenario in Mexico, the data published in the National Energy Balance (SENER, 2018) indicate that, in the course of the year 2018, energy consumption in the country exceeded 29.8% of primary energy production, thus leaving a total consumption of 9,236.86 PJ. National production was 7,027.22 PJ, causing a deficit in the country's energy production. In the same year, there was a 7.7% contraction in energy production compared to 2017. For 2018, the total energy produced in Mexico was generated by 62.4% from the combustion of oil. Natural gas contributed 19.7% of generation, for its part, renewable energies together contributed 10.4%. The sector with the highest consumption for 2018 was transportation, with consumption of 2,454.69 PJ, representing a total of 48.18% of demand. The consumption of this sector had an increase of 4.01% concerning the previous year 2017. The subsector with the highest demand was motor transport, with 2,205.06 PJ of demand, representing 89.83%. Regarding energy sources, the fuel most used by the trucking sector was gasoline, with a 72.8% contribution, diesel ranks second with 24.2%.
As part of the measures implemented by the Mexican State to seek an improvement in environmental quality in the Sustainable Urban Mobility Forum in Mexico (2020), the Chamber of Senators recognizes that by 2030 162 Mt/year must be reduced of GHG emissions. This decision leads to the application of solid policies that aim to reduce vehicle-km traveled, engine and gasoline efficiency, logistics and load modal shift, compact cities, and integrated policies for public and non-motorized transport. Specifically, in the document entitled Mitigation and Adaptation Commitments to Climate Change for the 2020-2030 Period, the Mexican state proposes reducing emissions by 30% compared to the baseline in 2020 and 50% in 2050 in relation to emissions in 2000. The objective of this research is to evaluate the behavior of the transport sector in Mexico through an energy model, implemented by the Long range Energy Alternatives Planning System (LEAP) software.

2. Method

2.1 Energy modeling tool

Scenario modeling allows us to consider different factors and organize large amounts of data, providing a framework for testing hypotheses and reflecting understandable forms of complex systems (Heaps, 2002). The LEAP software is widely used for energy policy analysis and climate change mitigation assessment. It was developed at the Stockholm Environment Institute (Heaps, 2016), its users include government agencies, academics, non-governmental organizations, consulting companies, and energy service companies. It has been used on many different scales, from cities and states to national, regional, and global applications. One of the advantages of LEAP software compared to other analysis tools is that it was specifically designed to perform different energy scenarios using the Bottom-Up methodology.

2.2 Definition and scope of the energy model

For the elaboration of the future projection of the autotransporter sector in Mexico, a base scenario called Business As Usual (BAU) was developed, the year 2014 was established as the base year with a time horizon of 34 years. Only passenger transport and cargo transport technologies were chosen for the analysis. Gasoline and diesel were selected as energy sources since they are the fuels with the highest consumption in the transportation sector. To determine the grow rathe of the vehicle fleet database an historical analysis was developed, starting in the year 2014 an ending in the year 2018.
The types of vehicles were classified into two sectors: cargo and passengers. The passenger sector is made up of cars, passenger trucks and motorcycles. The cargo sector is composed of the sum of trucks and cargo vans in a single parameter.

2.3 Characteristics of the BAU model

The statistical input data were taken from the National Institute of Statistics and Geography (INEGI) and of the Portal of Energy Efficiency and Vehicle Emissions Indicators of the National Commission for the Efficient Use of Energy. The BAU baseline scenario is composed of the number of vehicles in circulation, minus the removal of vehicles that exceed 22 years of use, plus the total cars sold at the end of each year. The total of passengers and cargo transported are taken into consideration as well. In total, 1,537,861 transportation units were sold for 2014. Being 98% of passengers the remaining 2% of cargo (Table 1).

Table 1: Vehicle sales, year 2014.

Type	Number of units
Cars	1,136,93
Buses	35,237
Motorcycles	365,701
Cargo trucks	27,179

The efficiencies for each type of transport were consulted from the online database of the Department of Energy of the United States of North America. The parameters are presented in Table 2.

Table 2: Average efficiency by vehicle type. Source: www.Fueleconomy.gov, 2020.

Type	Km/l
Cars	13.15
Buses	1.80
Motorcycles	9.80
Cargo trucks	3.16

For the environmental effects of the fuels used they were selected for; CO_2, CO, NO_x, PM10 particles. Figure 1 shows the data schema used for the BAU model.

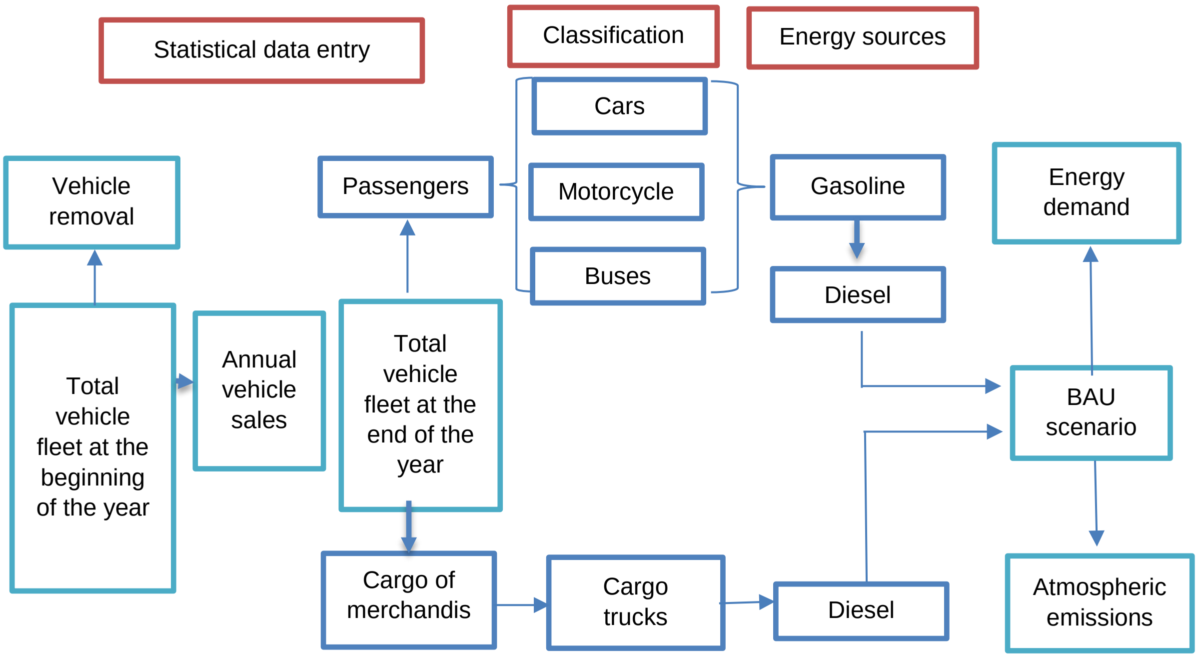

Figure 1. BAU scenario scheme representing the interactions between the different selected variables.

3. Results

The results obtained for the period from 2015 to 2017 present minimal percentage variations compared to the real data of the vehicle fleet reported by INEGI. Table 3 shows the percentage of the difference between the results and the data reported in official sources.

Table 3: Percentage variation of results compared with recorded data.

Year	2014	2015	2016	2017
Results variation	0%	1%	4%	8%

By 2030, the vehicle fleet will have doubled in size. Figure 2 shows that there is a substantial increase in the number of automobiles starting in 2027, with an uninterrupted increase in subsequent years. Gasoline vehicles show the highest growth trend.

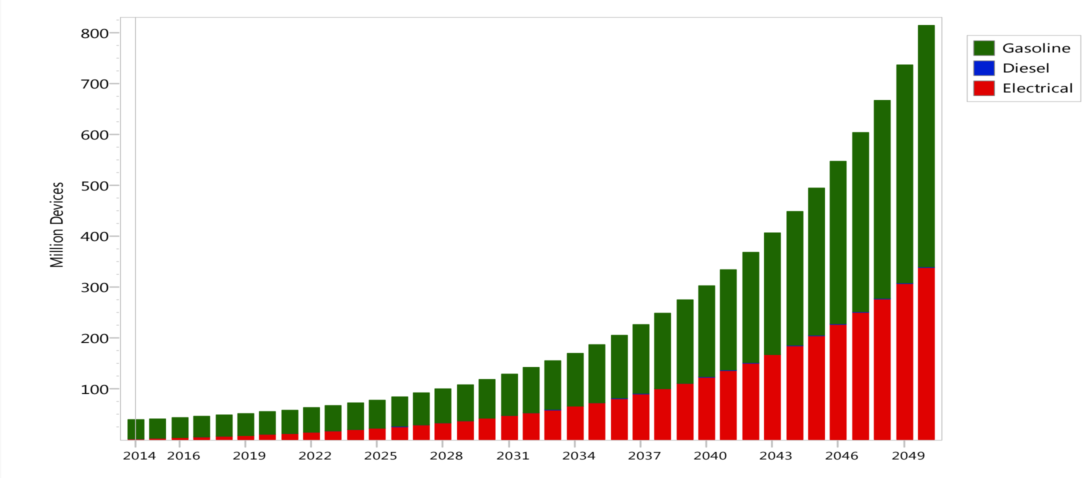

Figure 2. Number of vehicles projected during 2014 to 2050.

The automobile is the one that will have the greatest energy demand, having a decrease in consumption starting in 2015, reaching 60 billion GJ by 2050. Figure 3 represents the projection of demand for the scenario BAU.

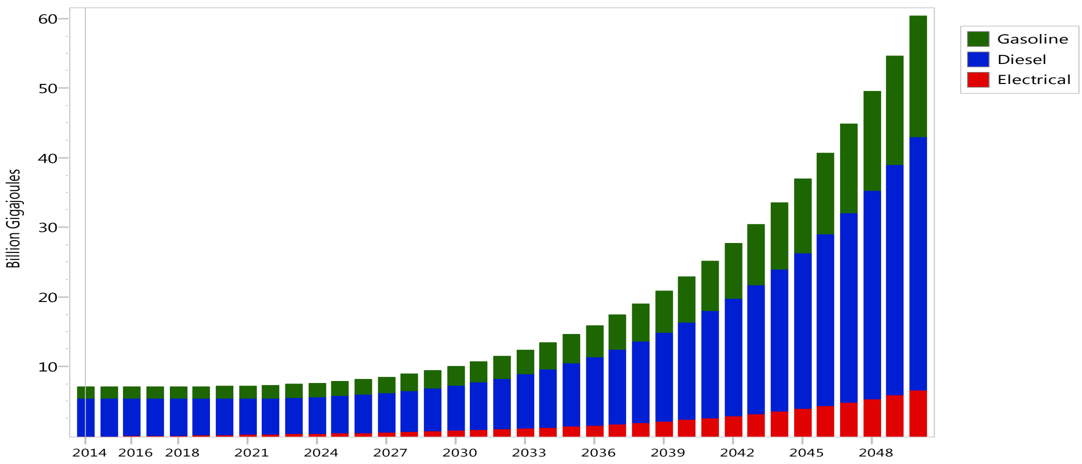

Figure 3. Behaviour of the energy demand of the sector for the years 2014 to 2050.

In terms of emissions, a marked growth trend is reflected, with passenger transport by bus being the largest emitter of CO_2. Figure 4 reflects the emission trends of the vehicle fleet, with bus transportation being the largest emitter of all the technologies described.

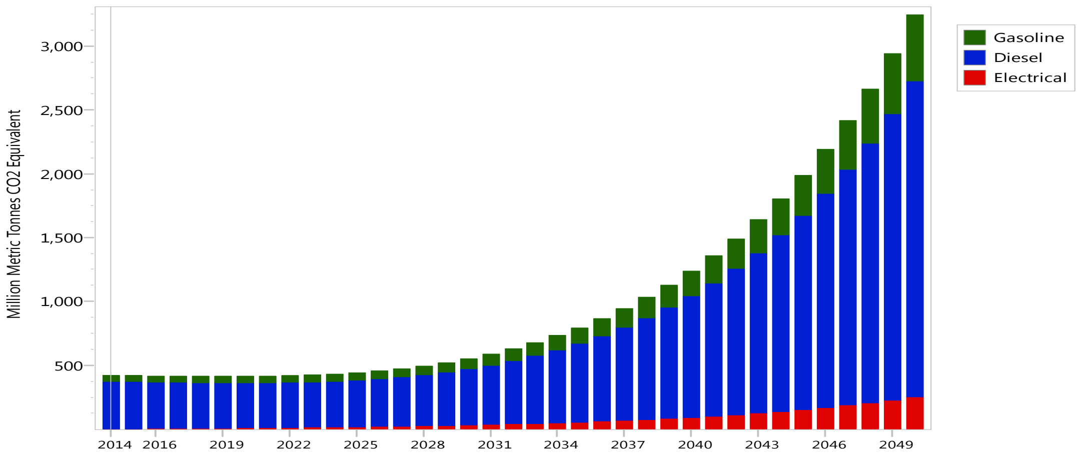

Figure 4. CO_2 emissions from the people motor transport sector for the years 2014 to 2050.

In a general view of the transport sector, the subsector with the highest CO_2 emission is passenger transport. Figure 5 reflects the difference in emissions between each subsector.

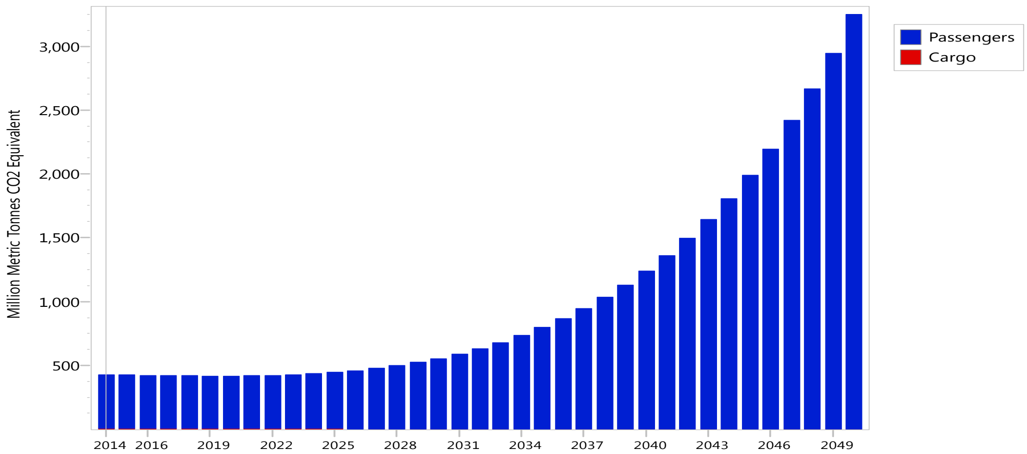

Figure 5. CO_2 emissions from the cargo and people transport sector for the years 2014 to 2050.

The total emissions for the year 2050 from the transportation sector exceed a total of 3,200 million metric tons of CO_2 equivalent.

4. Conclusions

An energy model based on LEAP of the Mexican vehicle fleet was obtained, starting with 2014 as the base year and 2050 as the limit. The results of the growth projections when compared with the real data reported by INEGI show a Minimum variation in terms of the calculated quantities, for which they are taken as feasible results of future trends in the sector. In the medium and long term, the uncertainty of the baseline calculations can be considerable. Energy dependence on the part of the transport sector will continue to increase due to the fact that under current conditions there is no tendency to change public policies in terms of mobility and transport. By 2030 the proposed reduction conditions will not be met, the growth trend will continue to increase. The BAU projection indicates that, at the current growth rate of the vehicle fleet, and if new transport technologies are not used combined with an implementation of alternative fuels, the objectives proposed by Mexican authorities, as a follow-up to the SDG for the reduction of emissions from the transportation sector for the year 2050, will not be met by 2030. The application of energy policies in the transport sector is required to have sustainable development by 2050.

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