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ISSUE BRIEF

A pathway for a green transition of the transport sector in Mexico

Feasible interventions that are environmentally, economically, and socially beneficial

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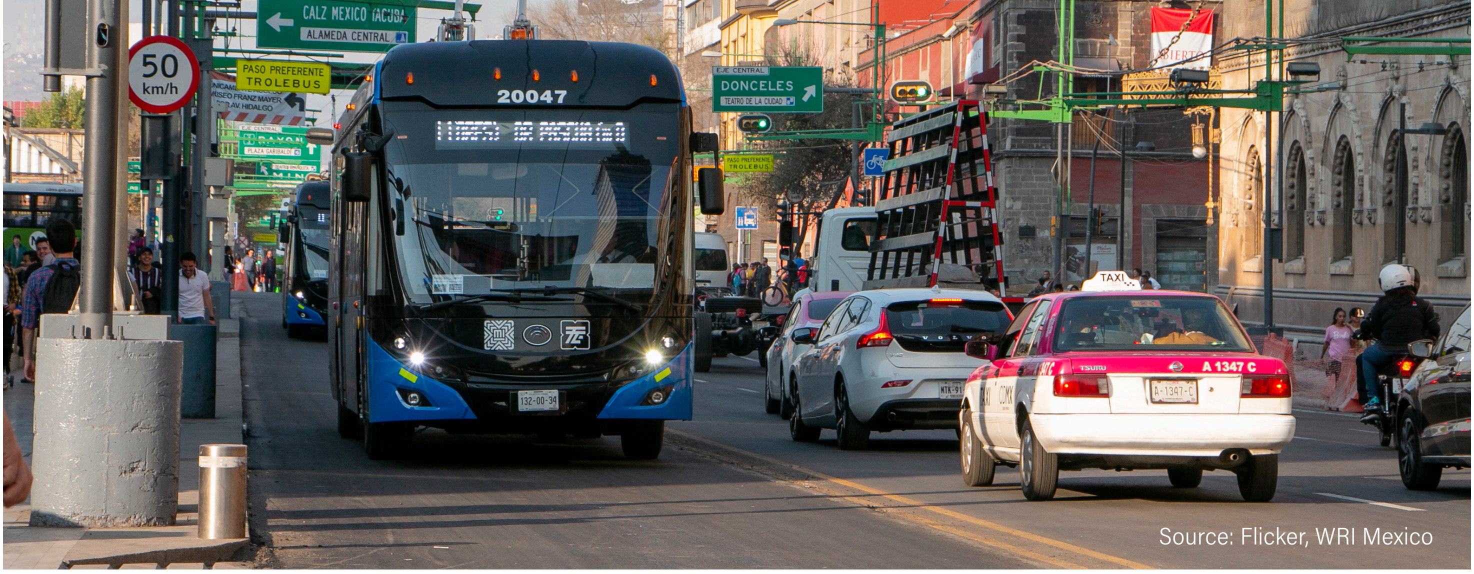

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CONTENIDOS

Issue briefs focus on policy issues, and clearly draw out the implications of existing evidence for decision makers.

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HIGHLIGHTS

- The transport sector contributes roughly with 23 percent of Mexico's greenhouse gas (GHG) emissions, making it the largest single sector source at a national level. Transport-related emissions keep growing and do it faster than those of any other sector in absolute terms at an annual growth rate of two percent. under a business-as-usual scenario transport emissions will go from 166 million tons ($MtCO_2e$) in 2017 to 317 Mt by 2050.
- The Avoid–Shift–Improve framework provides a way for governments and other actors to put the transport sector on a decarbonisation pathway, focusing on: 1) avoiding and reducing the need for motorized travel; 2) shifting passenger and freight travel to more environmentally and socially sustainable modes, and 3) improving the energy efficiency of transport modes.
- The simulations carried out in this exercise show that the proposed decarbonisation pathway for the transport sector could potentially reach a 30 percent reduction of the sector´s GHG emissions below business-as-usual (BAU) by 2030, and about 86 percent by 2050.
- Following this pathway leads to co-benefits such as the reduction in premature deaths per year. By 2050, the transport decarbonisation scenario shows that Mexico can avoid nearly 75,000 premature deaths per year, thanks to having reduced exposure to particulate matter and other air pollutants.

EXECUTIVE SUMMARY

Transport contributes with nearly one quarter of global carbon dioxide (CO_2) emissions (14 percent if all greenhouse gas (GHG) emissions are considered). It is also the sector whose contribution to global emissions grows the fastest, mainly due to an increasing demand and rapid motorization. This has been observed especially in recent times, as global population is becoming more urban, and as a greater proportion is joining the middle class, especially in China and other emerging economies.

In middle-income countries, people who can afford it shift from public transport to private vehicles as soon as they can. This is due in part to the fact that in many of these countries public transport is unreliable, unsafe and uncomfortable. Also, frequently, fossil fuels are subsidized[1]. As a result, the least efficient and most polluting modes of transport become relatively cheaper, at a high external cost to society. While all transport modes tend to grow in use over time, individual road transport does it faster. Current trajectories show that Light Duty Vehicles (LDV), the fastest-growing fleet, will triple by mid-century, and individual transport is projected to reach a 58 percent share of all passenger kilometres travelled in 2050, while buses reduce their share from 47 to 31 percent. On the other hand, freight transport (mostly road freight), is responsible for around 40 percent of total transport CO_2 emissions.

Under a business-as-usual scenario, freight demand could grow between 100 and 230 percent by 2050, raising emissions from 78 Mt in 2017 to 164 Mt by mid-century. With overwhelming scientific consensus about the gravity of the climate emergency and the need to take substantive and fast action, no matter how ambitious GHG mitigation commitments are, emissions are still growing globally. Except for a short period in 2020 due to the COVID-19 pandemic, we are not yet on a trajectory that would avoid surpassing the 2°C threshold, much less the 1.5ºC of maximum warming. Instead, global warming would reach close to 3 degrees. Any serious attempt at tackling climate change and cutting emissions to levels that are consistent with these long-term global temperature goals, as set in the Paris Agreement, must necessarily include the transport sector. In order to achieve said goals, emissions should almost be halved by 2030 in relation to 2005-levels and should reach net zero by mid-century.

The good news is that the decarbonisation of transport is not only technically feasible, but also economically and socially beneficial. Simulations based on the Energy Policy Simulator (EPS) show that the decarbonisation pathway explored and proposed in this report, which was developed as part of the National Carbon Budget project for Mexico and the 2030 Decarbonisation Pathways (CDP, ICM and WRI 2020), achieves a reduction of 30 percent of transport-related emissions below BAU by 2030, and 86 percent by 2050. Besides, it would bring several advantages, including health benefits, improved air quality, safer roads, additional jobs, and economic development. Following this pathway, more than 75,000 premature deaths per year could be avoided by mid-century, considering only the reduced exposure to air pollutants, especially particulate matter (PM).

One limitation of the EPS model is that it uses very general parameters to represent the private and societal costs of achieving the recommended policies and technology adoptions. Policymakers would require more detailed cost analysis, based on data for Mexico, to input into the cost-benefit analysis of specific regulations, programs or public investment along the proposed agenda.

We expect that the mitigation measures and technologies adopted for the Mexican transport sector shown in this report will be inspiring and helpful in strengthening Mexico's planning and decision-making processes and help strengthen its climate mitigation ambition. The way proposed to reach a decarbonisation pathway for the transport sector in Mexico centers around the Avoid–Shift–Improve framework. The strategies included contribute to mitigate emissions through the control of rampant road transport growth through Transport Demand Management (TDM) measures that help avoid trips, support the shift of passenger and freight travel to more environmentally and socially sustainable modes (including zero-carbon modes and energy efficiency improvements of all transport modes), and advocate for measures that help improve energy efficiency for all transport modes.

However, despite how much it makes sense environmentally, socially, or economically, several barriers exist. To be able to reduce travelled kilometres, the desired modal shift, for instance, faces impediments such as limited access to financial resources, lack of capacity, the unequal and unplanned distribution of jobs and housing, and the prevalence of old paradigms and urban physical structures, which favour car usage over public transit or walking commuting. Vehicle electrification, to mention another example, also faces market constraints and technical complexities.

TABLE 1

Transport Sector Emissions in Mexico: Key numbers

(MODEL BASELINE) SITUATION	
23%	Transport GHG emissions share of national total, 2015
2.10%	Annual emissions growth rate per year, from 2005 to 2015
46%	Final energy consumption by the transport sector in 2017
ENERGY POLICY SIMULATOR MODEL BAU	
166 MTCO$_2$e	Transport's emissions in 2017
317 MTCO$_2$e	Transport's emissions by 2050
24%	Transport GHG emissions from national total by 2050
DECARBONISATION ROUTE SIMULATIONS	
140 MTCO$_2$e	Transport GHG emissions by 2030 (30% below EPS-BAU)
44 MTCO$_2$e	Transport GHG emissions by 2050 (86% below EPS-BAU)
Co-benefits	
75k statistical lives	Reduced annual premature mortality by 2050
24%	Energy savings by 2030 compared to EPS-BAU
66%	Energy savings by 2050 compared to EPS-BAU

Source: EPS Mexico 2020 and INECC 2018

INTRODUCTION

Mexico is the world's 13th highest greenhouse gas (GHG) emitter. Its total emissions –excl. land use, land use change and forestry (LULUCF)– have increased by 62 percent between 1990 and 2019. The transport sector is not only the greatest single source of emissions, but also the fastest-growing (INECC 2017). It is responsible for more than 20 percent of Mexico's GHG emissions and thus one of most relevant sectors for achieving the country´s NDC (Nationally Determined Contribution) and completing its path to decarbonisation.

Transport services in Mexico can be divided into two main groups: passengers and freight. The latter, in turn, can be organized into four categories, according to their mode of transport: road, rail, aviation, and maritime. While all transport modes have grown in activity, this modelling analysis estimates that, under a BAU scenario, private road transport will be the fastest growing both in terms of fleet –which will triple from 28 million vehicles in 2017 to 64 million in 2050– as well as in terms of the share of passengers/kilometers travelled, which rises from 42 to 58 percent in the same period. On their turn, freight operations are dominated by medium- and heavy-duty trucks, which concentrate 70 percent of all freight ton kilometers travelled, with an average annual growth of 2.7 percent.

In terms of energy, the transport sector contributed with 46 percent of all energy consumption in 2017. It grew four percent compared to the previous year. Almost 90 percent of the sector's energy consumption is related to road transport, followed by domestic aviation (i.e. departure and destination within the national territory) with 7.8 percent, while marine shipping and rail freight contribute with 1.1 percent each.

Its energy requirement makes this a critical sector for achieving Mexico's decarbonisation goals. According to the official 2017 GHG inventory, which is the basis for this analysis, GHG emissions from transport grew at an annual rate of 2.1 percent, from 2005 to 2015 (SEMARNAT 2017)2. Several factors have contributed to the continuous increase in transport emissions, which imply a growing demand for travel and fuel consumption. Among them, there is a sprawling urban development, economic growth and globalization (cargo moves farther every time), a growing but ageing fleet, and insufficient infrastructure across most modes (except for private passenger transport –cars– which still receives disproportionate investments).

The transport sector produces direct emissions from fossil fuel feedstock burned in internal combustion engines (ICE) of various technologies and levels of efficiency; but it also generates indirect emissions from the consumption of other energy sources like electricity, with its long vehicle manufacturing chain with multiple materials and energy-dependent steps. Among these steps, we find mining, component production, assembly, and distribution.

An effective decarbonisation strategy requires thus a comprehensive and systemic approach that takes into consideration all GHG sources and their interactions. This will help avoid shifting emissions to another sector and will account for an integrated effect of actions across different sub-sectors. A totally successful decarbonisation strategy would have to ensure that energy-producing sectors are zero-carbon before 2050, so other sectors can rely on them to reach zero-carbon themselves.

This report presents a pathway to decarbonise the Mexican transport sector through the modeled results of its implementation. It was produced as part of a more comprehensive economy-wide analysis (ICM, CT, WRI 2020), in which WRI assessed how Mexico could achieve a GHG emissions trajectory aligned to a 1.5 and a 2oC carbon budget for the 2019-2100 period in the sectors of electricity in the sectors of electricity, transport, oil and gas. The carbon budget and the sectoral analysis did not assess a net-zero trajectory for each individual sector, but rather generated scenarios on emission rates for the whole of the economy, under carbon budgets consistent with global warming objectives. In principle, the portion of the carbon budgets allocated to the transport sector is roughly equivalent to their current contribution to emissions (22 percent). In a similar way, modelling assumptions for this study considered that the net-zero target for transport would not be achieved by 2050, so the remaining GHG reductions and carbon removals would be needed in other sectors to compensate for remanent emissions.

The decarbonisation scenario of the transport sector that is described in this report integrates the carbon budget and sector analysis in which the power sector reduces 105 $MtCO_2e$ by 2050, going from 149 $MtCO_2e$ in 2019 to 44 $MtCO_2e$ in 2050. The policy package (combination of policies, measures, and technologies) that achieves decarbonisation objectives at the least cost was defined with a modelling tool: the Energy Policy Simulator (EPS).

The decarbonisation pathway is approached through the Avoid–Shift–Improve framework, oriented to **avoid** passenger trips and freight movement; **shift** passenger and freight travel to more environmentally and socially sustainable modes and **improve** the energy efficiency of transport modes. Through this framework, national and subnational authorities could set policies and actions to reduce energy consumption and advance towards low-carbon and sustainable transport modes. The strategies analysed include:

1. **avoiding** emissions through the reduction of unnecessary motorized travel and control of rampant road transport growth with transport demand management measures,
2. **shifting** to low-carbon modes of transport, increasing the efficiency of trips for transport systems and non-motorized travel like cycling, and
3. **improving** fuel efficiency, electromobility and low carbon technologies.

These strategies require:

- further development of urban public transport nationally,
- shift freight and long-range travel to railways,
- promote active mobility (walking and cycling) and new mobility services,
- improve energy efficiency of all transport modes through direct policies to strengthen fuel economy standards,
- eliminate ineffective and non-progressive fossil-fuel subsidies, and
- develop electric mobility to ensure rapid penetration of zero-emission passenger and freight vehicles.

There are new technologies that require further development and scale to become economically viable, like zero-carbon options for heavy-duty road transport and fully electrified rail services. Aviation and shipping require a 1.5°C-compatible long-term vision, along with the development of technology. In the meantime, management is critical for curbing growth in demand and emissions.

A comprehensive Avoid-Shift-Improve approach will result in more significant GHG emissions reduction than any focus on specific technologies, since it provides a strategy to decarbonise the transport sector drawing on the full range of solutions (Fransen et al. 2019). By modelling the impacts of policy levers, reducing the share of private trips through demand management (Avoid), improving fuel economy standards (Shift), and increasing the sale of electric vehicles through a EV sales mandates (Improve), we conclude that it would be possible to achieve emission reductions of 30 and 86 percent by 2030 and 2050, respectively, in comparison to the baseline scenario. With this, we estimate the sector would achieve its share of the economy-wide 2°C carbon budget. This would be achievable under a technologically and economically feasible scenario (where the technology is commercially available and the economic returns surpass its costs) in which the existing vehicle fleet decreases by 8 and 40 percent in 2030 and 2050, respectively; the penetration of hybrid vehicles reaches 23 and 91 percent, respectively, and internal combustion vehicle efficiency increases by 10 and 15 percent. Further actions in this or other sectors would be required for a 1.5°C consistent mitigation scenario.

Actions will be needed in all three areas, from long-term land use planning (avoid), to inducing and implementing public transport and cycling (shift), to fueling vehicles cleanly and efficiently (improve) to decarbonise the sector. Although these opportunities are all within reach, they will require serious policy commitments and will need to overcome a legacy of dependence on and planning around carbon-intensive travel.

In the next chapter we outline the tools and materials used, emphasizing the general process of the EPS analysis. We then proceed to present the BAU trajectory of the reference case scenario, followed by the framework that shapes the decarbonisation strategy. We then present the modelled results of the pathway implementation, highlighting the impacts on the main GHG drivers. Finally, we share the conclusions of our work and acknowledge the inherent limitations of the analysis.

RESEARCH APPROACH

This report relies on modelling using the EPS (see Annex 1), which helps to assess different policies that affect energy use and emissions in various sectors of the economy. The model is designed to operate on a national scale and includes every major sector of the economy. The model reports outputs at annual intervals with an initial year that can be defined and a final year of 2050.

The model is used to help us determine the level of effectiveness of the policy actions from our policy packages (in terms of emissions, fuel type use, energy efficiency objectives) as well as the costs (or savings) involved. Furthermore, the model can provide an idea of the potential social benefits linked to avoided health and climate damages, providing arguments to further support ambitious policies in the medium or longer term.

In a second stage we carried out expert and stakeholder consultations, to get insights into previous studies and cost calculations, and to get an initial assessment of the feasibility of alternative policies. An additional consultation, in a workshop format, was also convened, to discuss the first set of results.

Additional analysis beyond the modeling exercise was carried out, in order to address how to use the results to develop a more nuanced policy menu in the Mexican context, including considerations on how policy instruments could be pursued, by whom, what some barriers might be, and what investments or financing mechanisms might be needed to achieve them. A potential area of improvement would be a sensitivity analysis, which was beyond the scope of this report.

The development of a decarbonisation pathway for the transport sector was based on effectiveness, including the identification of the effective decarbonisation levers with which to achieve an economy-wide 2ºC and 1.5ºC carbon budget, which do not necessarily require the achievement of a net-zero target for the transport sector. The scope of the analysis included the assessment of financial and technical variables, and considerations to avoid technological lock-ins. This means avoiding short or medium-term GHG-reduction solutions that could block the implementation of decarbonisation measures.

The model employed requires significant data inputs from a variety of sources. To maximize model consistency, the following data prioritisation criteria was followed:

1. Data from Mexican governmental sources were preferred if available.
2. Next was data specific to Mexico published by reputable sources, such as the International Energy Agency or the U.S. Environmental Protection Agency.
3. If the above were not available, the third preferred source was regional or international data used to represent Mexico by proxy, adjusted by population, GDP, or other factors, if applicable.
4. Finally, extrapolated present-day values using projections of Mexico's GDP and population, with relevant scaling factors from official sources or the peer reviewed literature.

Due to interactions and cross sector effects, it was important to analyze the complete energy system to ensure that GHG emissions are not just shifted from one sector to another. The EPS is designed to operate at a national scale, considering all sectors reported in Mexico's climate change policy (shown in Table 2). Output is reported at annual intervals, from 2017 to 2050.

TABLE 2

EPS Mexico – Sectors analyzed

EPS COMPONENT	INCLUDES:	ENERGY FLOW OR AREA
Electricity	Electricity	Energy generation
	Oil and gas	Energy generation / use
	Industry	Energy use
Industry	Agriculture	Energy use / land use
	Waste management	Energy use / cities
Buildings	Buildings	Energy use / cities
District heat	Not used in the Mexico model	Energy use / cities
Transport	Transport	Energy use / cities
LULUCF	Land use, land use change and forestry	Land use

Source: EPS

The transport sector reflects fuel demand and emissions from both on-road and off-road public and private transport. On-road transport includes LDV, heavy duty vehicles (HDV) for passenger and freight use, and motorcycles. Off-road transport includes rail, ship, and air modes.

The EPS policy levers that were considered to model energy consumption and GHG emissions reduction were:

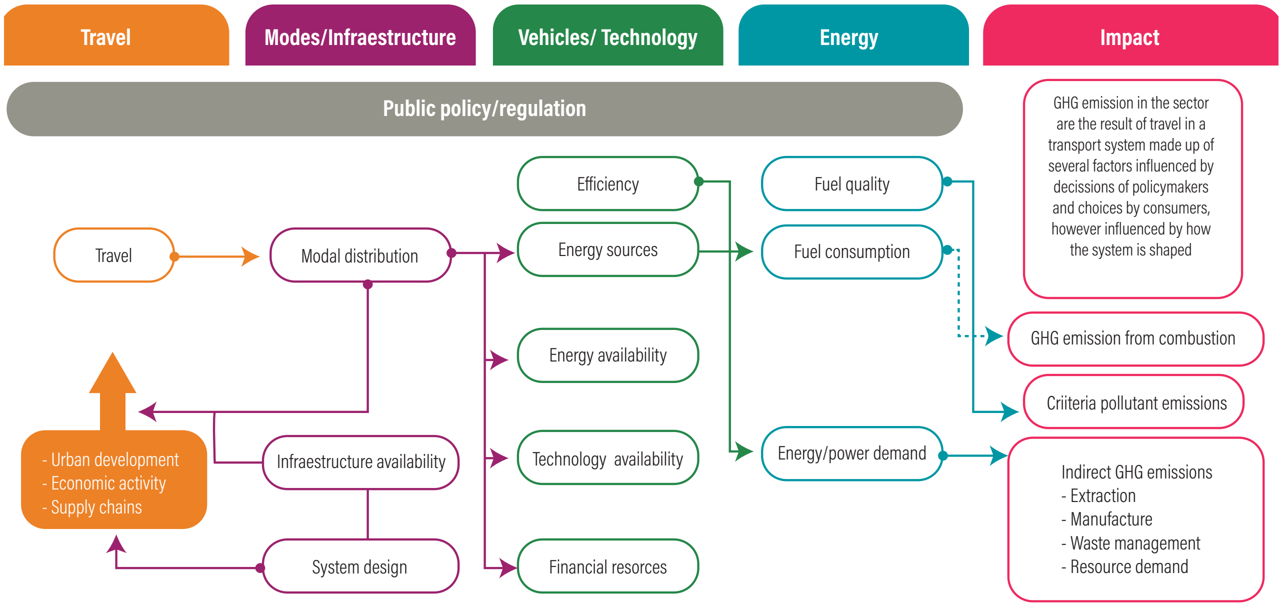
Transport Demand Management: it refers to a broad set of policies that reduce or avoid vehicle use by either increasing the cost of driving or by shifting to lower-emitting forms of transport —like walking, biking, buses, and light rail— making them more attractive. Passenger LDV trips may be shifted to other travel modes, such as buses, rail, walking, biking, or eliminated through technology such as videoconferencing. Aircraft trips may be shifted to inter-city rail or eliminated using technology such as videoconferencing. Freight truck trips can be reduced through improved logistics that avoids backhauls and transporting empty shipping containers.

Electric Vehicle Sales Standard: this policy requires a specified percentage of newly sold vehicles of the selected type(s) to consist of battery electric vehicles. Manufacturers may meet a sales standard through techniques such as more heavily marketing electric vehicles, with technology or government lowering the net price of electric vehicles and raising the net price of non-electric vehicles.

Fuel Economy Standard: this policy specifies a percentage improvement in fuel economy, that is, distance traveled on the same quantity of fuel with the same cargo or passenger loading, due to fuel economy standards for newly sold vehicles of the selected type(s) with fossil fuel-burning engines. It applies to LDVs, passenger and freight HDVs, aircraft, rail, ships, and motorbikes. As previously indicated, GHG emissions in the transport sector are the result of several factors; they are influenced by the decisions of policymakers and designers shaping the system, as well as by the choices of consumers. A causal chain of sector emissions portrays how each component is linked and can be mapped with the Avoid–Shift–Improve framework (further discussed below). The causal chain can help visualize how decarbonisation actions can impact emissions and what are the main conditions and requirements for implementation. This is shown in the diagram in Figure 1.

FIGURE 1

GHG emissions causal chain – Transport sector



Source: WRI, based on Schipper et al. (2000)

In the figure rendered above, travel refers to the use of any mode of transport to satisfy any need. It requires infrastructure such as roads, tracks, ports, airports, sidewalks, or trails; a vehicle; energy to power it, and energy infrastructure to produce, distribute, and generate that energy –usually fuel. The use of this energy to satisfy the demand for travel results in GHG and criteria pollutant emissions and infrastructure congestion, which may bring about other social and demographic effects.

Travel is a function of urban development, economic activity, supply chains, purchasing power, and behavior influenced by system design. Modal distribution is a function of several factors, including system design, policies and regulations, and existing and planned infrastructure.

Vehicles/technology are a function of the available technology, energy and financial resources, public policy, and the available infrastructure coming from system design. The vehicle/technology mix will determine how efficiently can energy be converted, through fuel or electric power, to travel, as well as the resulting emissions of such energy use. In that sense, the climatic impact of travel are the emissions from fuel combustion and electric power use.

Additional factors to consider, but not yet reflected in the EPS, include the following:

- Prices and availability of fuels and other resources
- Policy and regulatory framework
- Sociodemographic and cultural effects
- Financial options for infrastructure development and technological alternatives

The use of the EPS for the analysis presented in this report comes with inherent limitations. The model relies on various scientific studies (e.g. Energy Innovation 2021) to establish the effects of policies on physical quantities and costs. These studies typically investigate these relationships under a set of real–world conditions. The uncertainty of policy effects is smallest when policy levers are set at low values. On the contrary, uncertainty increases as the policy package incorporates a greater number of policies and the settings of those policies become more extreme, meaning that levers are set at a higher penetration level. The decarbonisation effects required to achieve carbon budget emissions depend upon extreme settings to change current trends, as well as on the projected BAU emissions growth.

Due to limitations on the available data, and the need to include extrapolated and rescaled international values for the rest of the variables, some policy responses may differ in magnitude in the model; but this can be controlled if only Mexican data is used (Altamirano et al. 2016). For example, because average household income is lower in Mexico than in the U.S., many price elasticities might be lower in the latter, since wealthier consumers are less price-sensitive, causing the estimated effects of these policies for Mexico to be conservative.

REFERENCE CASE SCENARIO

The model works with a BAU scenario –called the reference case within the EPS– and compares the effects of applied policy levers with respect to such scenario. The BAU scenario is built from historical data and represents Mexico's current emissions trajectory across the modeled sectors[3], with no policies and actions for reduction. It is close –but not exactly the same– to the baseline calculated in Mexico´s Nationally Determined Contribution (NDC) to the Paris Agreement, of which estimation assumptions were not made public. This EPS reference case scenario can be summarized as follows:

Planning horizon: Its base year is 2016 and the modelling horizon comprises 2017 to 2050. It is determined from prospective studies on energy demand (fuels and electricity), emission factors for all pollutants, and emissions from land use, land use change and forestry (LULUCF). Detailed information from most of the currently available prospective studies for Mexico (see Box 1) reach until 2032, so trends were extended from the available data values to reach the year 2050.

National scale: Mexico was modelled only countrywide, with no regional or political divisions. The model includes every major sector of the economy.

Assumptions: Compatible data was used as much as possible from prospective studies that cover the same planning horizon and use the same base assumptions for population, gross domestic product, fuel prices, cost of capital, and sets of policies and standards. The energy prospective considers Mexico's 2013 energy reform and energy transition legislation (SENER 2018), the current carbon tax, and no carbon market.

BOX 1

Main sources of data for the transport sector

Transport

- EPA MOVES Mexico on-road transport fleet database – INECC
- Vehicle prices and fleet composition – INEGI
- Annual railway statistics – SCT
- Commercial aviation in numbers – SCT (1991-2016)
- Annual marine transport statistics – SCT

Cross-sector

- Energy Technology Perspectives (CCS) – International Energy Agency
- Air Quality Program for the Central Mexico Megalopolis 2017-2030 – CAME
- Air pollution impacts – INECC

Source: EPS Mexico, 2020

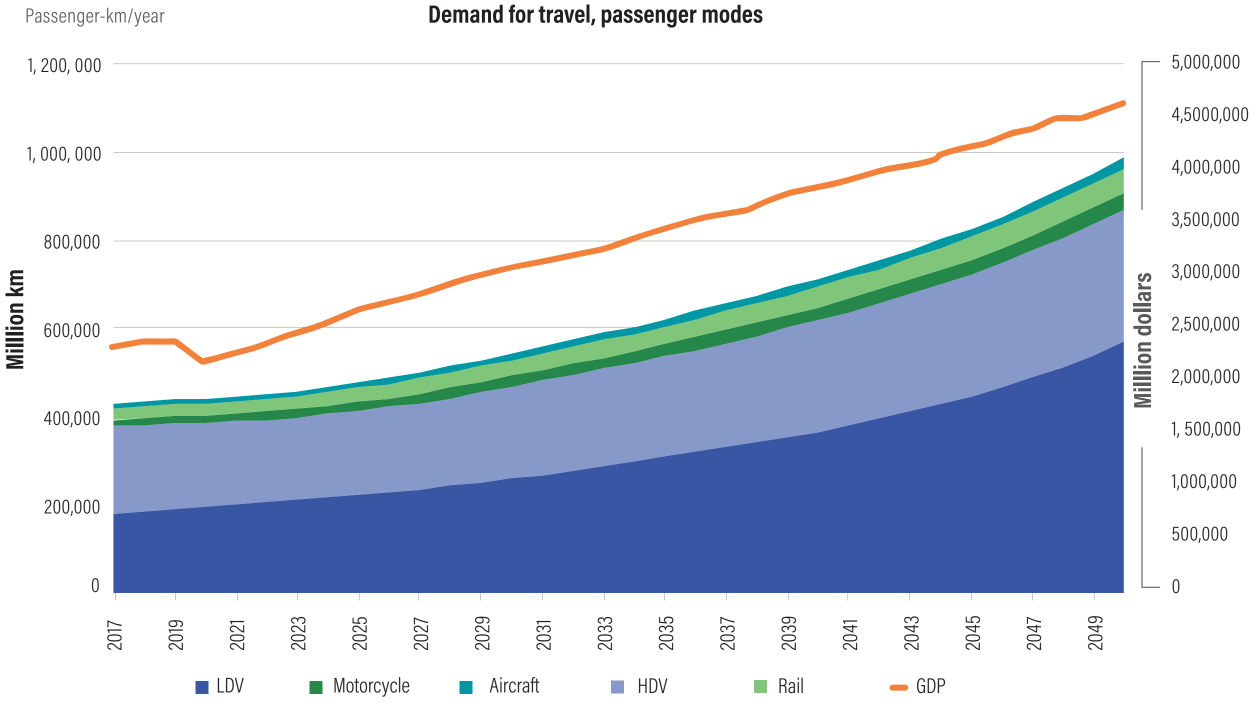
Travel demand and modal share

Business-as-usual projections in our simulation show a gradual growth in private road transport, which increases from 42 percent of all passenger kilometers travelled in 2017 to 58 percent in 2050 (see Figure 2), becoming the single most important mode of passenger transport. This was based on the following assumptions: annual growth in per capita GDP was projected to be 2.25 percent for the 2016-2050 period (OECD 2018); it is foreseen that 88.2 percent of the Mexican population will be urban in 2050 (UN 2018), compared to the current 79 percent (INEGI 2020), and urban sprawling will increase, among other factors.

Freight modes exhibit a sustained three percent annual growth until 2030, which tapers slightly to 2.7 percent by 2050, while the economy grows annually by 2.5 percent. Freight modes are dominated by medium- and heavy-duty trucks with 70 percent of all freight-ton kilometers travelled. Both travel demand for passenger and freight modes in the BAU scenario are shown in Figure 2.and 3

FIGURE 2

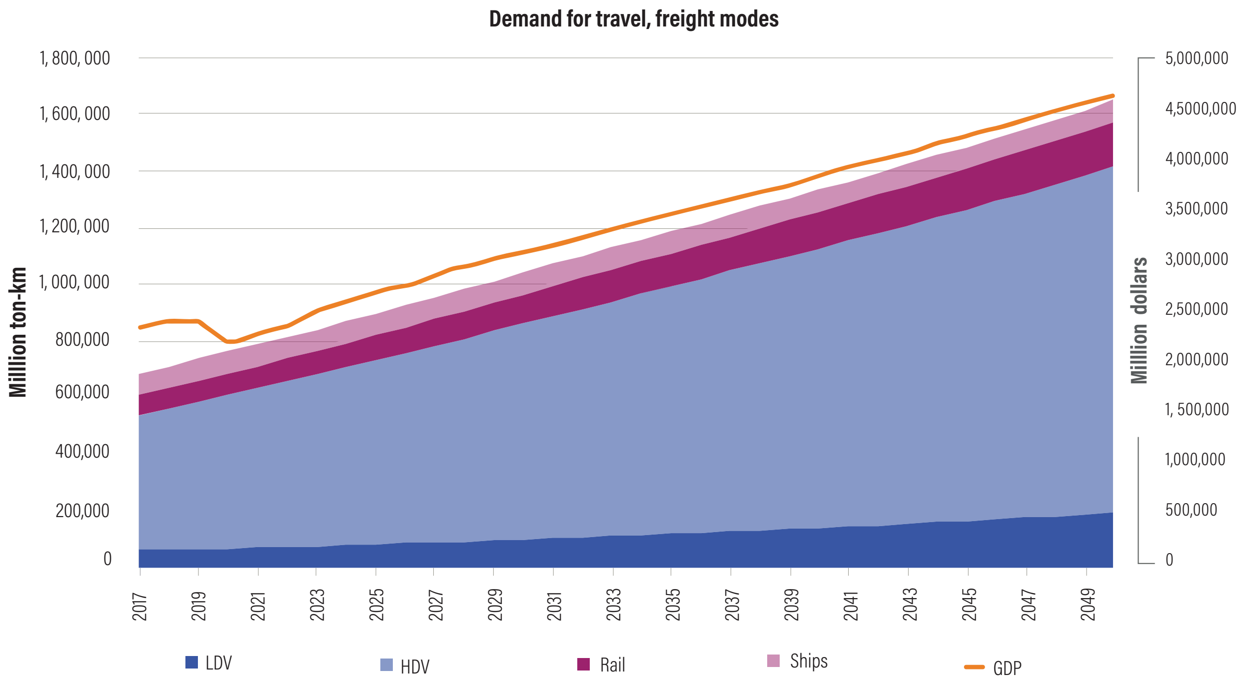
Demand for travel, passenger modes



Source: WRI, based on Schipper et al. (2000)

FIGURE 3

Demand for travel and freight modes



Source: EPS Mexico 2020

TABLE 3

Modal distribution – Reference case scenario

		2017	2030	2050
Passenger modes	**Cars and SUVs**	42%	48%	58%
	Buses	47%	38%	31%
	Motorcycles	3%	4%	4%
	Rail	6%	7%	6%
	Aircraft	2%	3%	2%
Freight modes	**Light and medium trucks**	9%	10%	12%
	Heavy trucks	69%	73%	74%
	Rail	10%	10%	10%
	Ships	11%	7%	5%

Source: EPS Mexico 2020

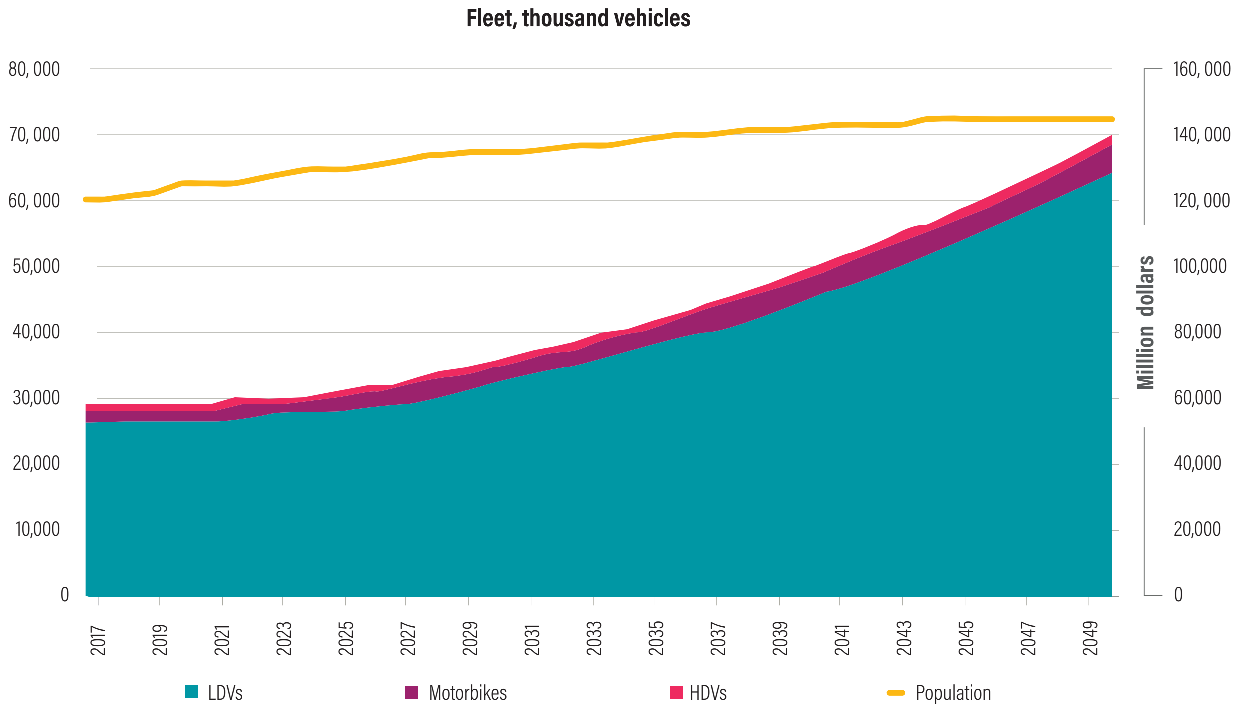
Motorcycle and aircraft modes are reported as passenger travel and all ships are reported as cargo, yet they commonly operate with mixed loads.

Fleet size

Fleet size varies widely by vehicle type. The most numerous are LDVs, which numbered over 26 million in 2017 and are projected to reach 64 million by 2050 under BAU, growing at 2.8 percent per year while GDP grows 2.5 percent per year (OCDE 2018). The only other mode displaying such

FIGURE 4

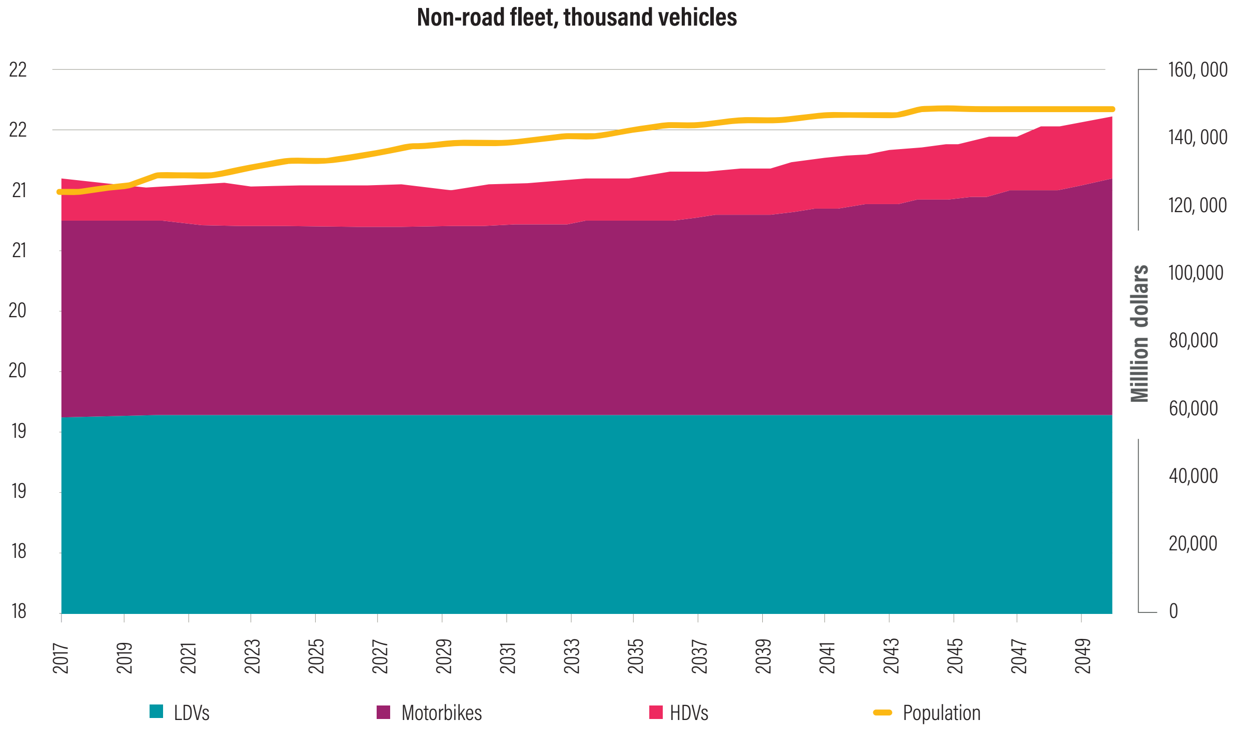
Road fleet under the reference case scenario



Source: EPS Mexico 2020

FIGURE 5

Off-road fleet under the reference case scenario



Source: EPS Mexico 2020

growth are motorcycles, which go from 2 million to over 4 million in the same period (see Figure 4). HDVs and aircrafts are projected to grow each at a 1.6 percent annual rate (see Figure 5)

Fuel technology

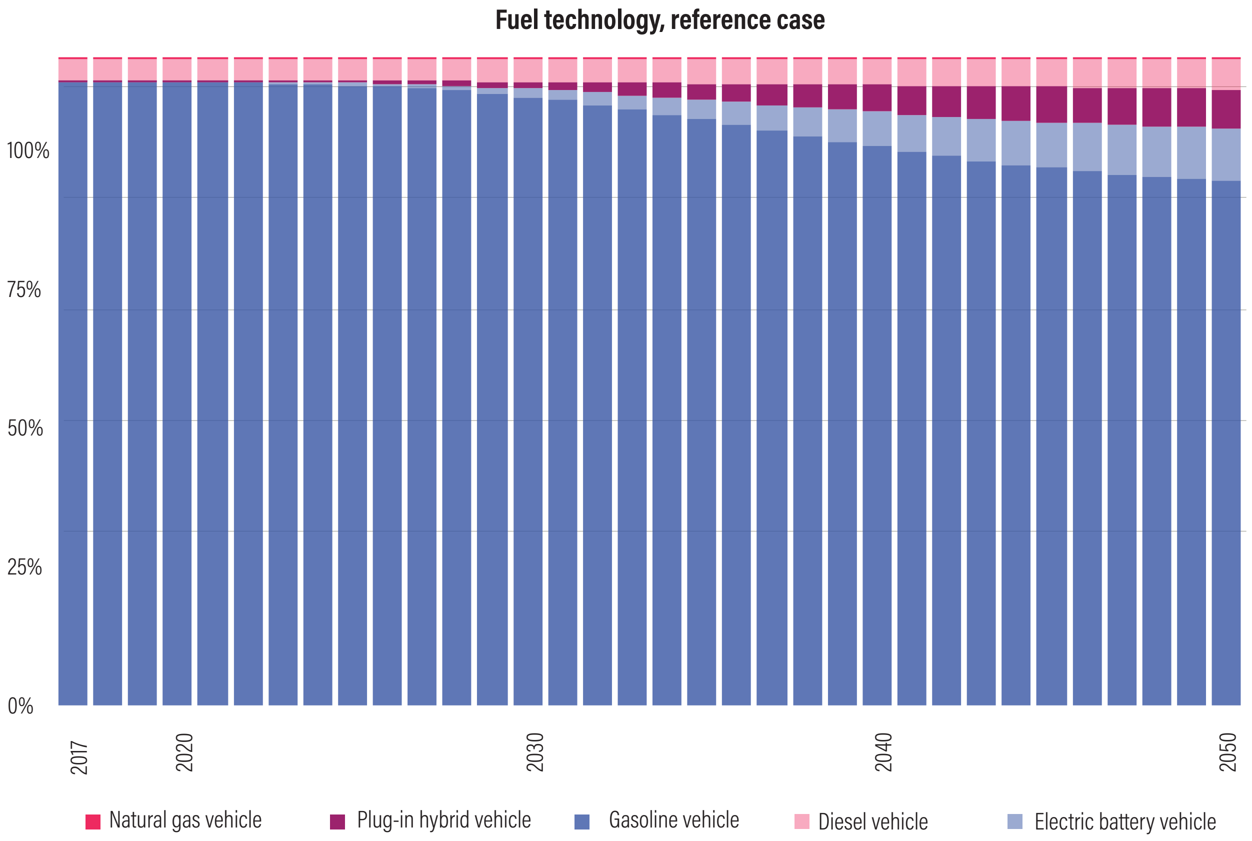
Gasoline vehicles made up 96 percent of the vehicle fleet in 2017. In the BAU scenario, 94 percent of all vehicles will still run on gasoline by 2030, with plugin hybrid and electric vehicles reaching only two percent. Energy prospective scenarios of Mexico´s government, including the Strategy to Transitions towards Clean Technologies and Fuels (SENER 2019), estimate that by 2050 plugin hybrid and electric vehicles will make up 11 percent of all vehicles, while gasoline vehicles retain 81 percent of the share. Based on these prospectives, the fleet will double by 2050. This means a doubling of gasoline vehicles but no change in relative terms (see Figure 6).

Fuel efficiency

Fuel efficiency by vehicle type for the BAU scenario is shown in Figure 7. Based on historical data of vehicles, fuel efficiency and government scenarios, the assumption/parameter chosen is that every year all new vehicles are 1.6 percent more efficient on average than in the previous year. Note how efficiency increases at a much faster rate for light- than for heavy-duty vehicles. This is due to the former having higher growth and a shorter lifespan, which results in a newer fleet of light-duty than of heavy-duty vehicles in any particular year.

FIGURE 6

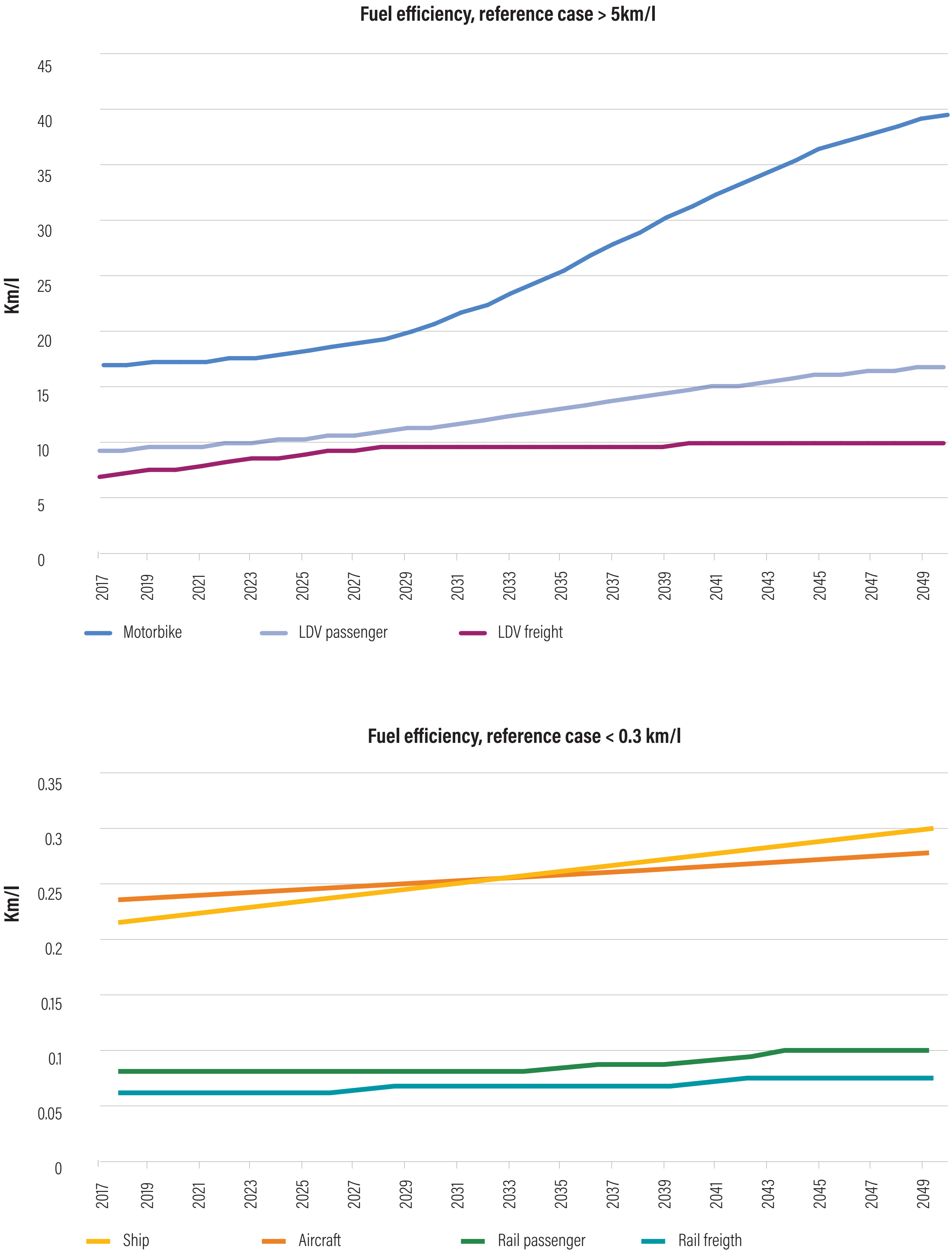
Fuel technology share under the reference case scenario



Source: EPS Mexico 2020

FIGURE 7

Fuel efficiency by mode under the reference case scenario[4]



Source: EPS Mexico 2020

Transport sector GHG emission projections

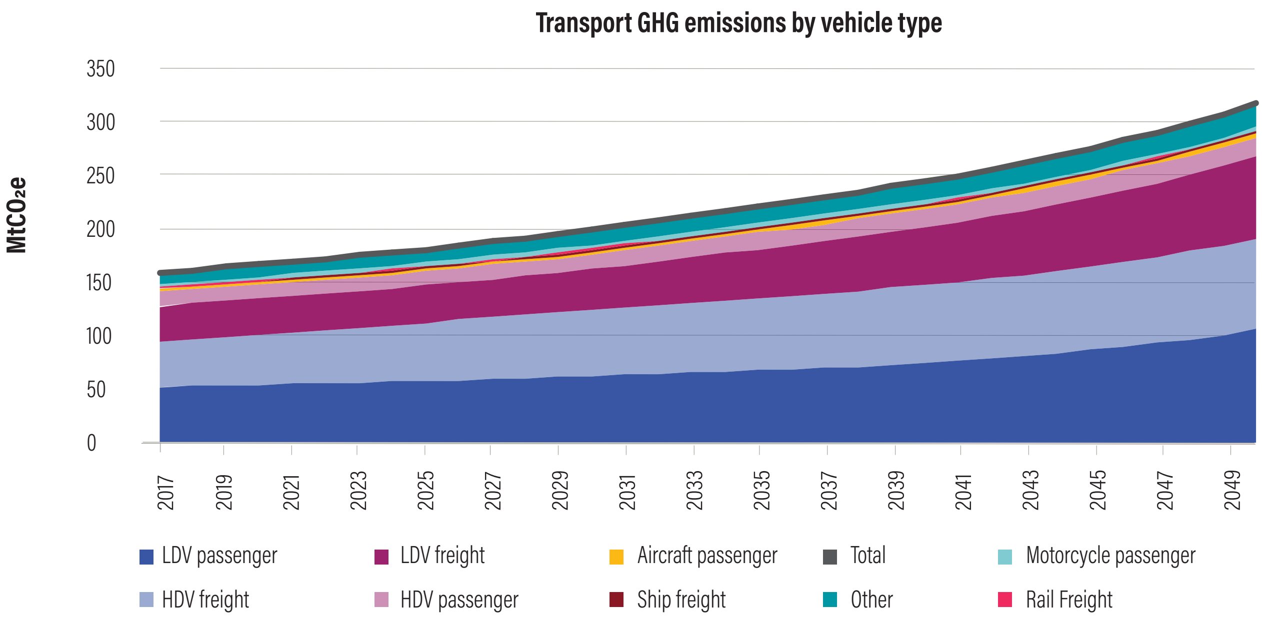
The transport sector contributed to 23 percent of Mexico's GHG emissions in 2015. With almost a quarter of all emissions, it is one of most relevant sectors for achieving Mexico's path to decarbonisation. The main sources of GHG emissions in this sector are LDVs –32 percent of all transport sector's emissions– followed by heavy trucks (27 percent) and finally light and medium trucks (21 percent).

Under the BAU scenario, GHG emissions from the transport sector grow from 166 million tonnes ($MtCO_2e$) in 2017, to 317 Mt in 2050. Under this scenario, transport sector emissions in Mexico are projected to almost double by 2050, as shown in Figure 8. The growth rate of transport emissions increases from 1.8 percent per year in the 2020-2030 period, to 2.4 percent per year in the 2030-2050 period. The simulation shows the transport sector would represent 24 percent of Mexico's total emissions by 2050.


Source: Pexels, Mexico City.

FIGURE 8

Transport GHG emissions by vehicle type in the reference case scenario



Source: EPS Mexico 2020

FRAMEWORK TO DECARBONISE THE TRANSPORT SECTOR

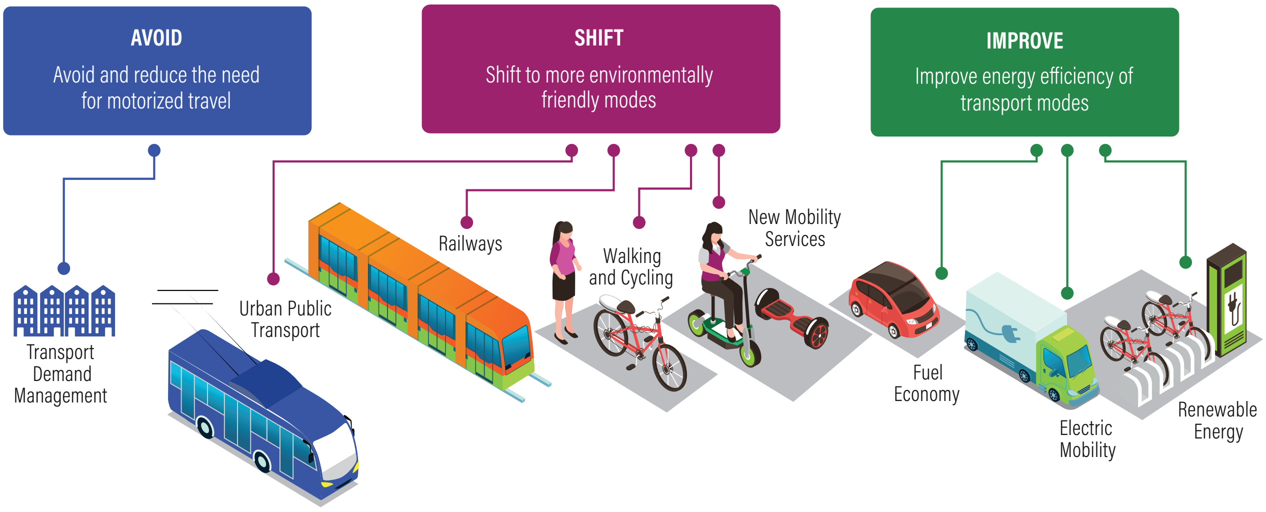
Most decarbonisation measures proposed and analysed in this report fall within the Avoid-Shift-Improve framework (Dalkmann and Brannigan 2007). The framework provides a way for governments and other actors to define policies and actions to reduce emissions in transport in three key areas:

- Avoid passenger trips and freight movement, or reduce travel distance by motorized modes of transport through regional and urban development policies such as integrated transport, spatial planning, logistics optimisation, and travel demand management.
- Shift passenger and freight travel to more environmentally and socially sustainable modes, such as public transport, cycling and walking (for passenger transport), and railways or inland waterways (for freight transport). Low-carbon modes of transport should be retained. Encourage new mobility services such as bicycle and electric scooter sharing.
- Improve the energy efficiency of transport modes through fuel economy, low-carbon fuel, electric mobility, vehicle technologies, increased vehicle load factors, and better managed transport networks with nonpetroleum, low-carbon fuels playing a more significant role –particularly before 2030.

Decarbonisation plans are only comprehensive if they consider efforts to reduce “unnecessary travel” and shift to low-carbon transport modes. The Avoid-Shift-Improve framework provides the critical elements for a potential strategy to decarbonise the transport sector through a comprehensive approach that draws on the full range of solutions (see Figure 9).

FIGURE 9

Avoid-Shift-Improve framework



Source: WRI, based on Schipper et al. (2000)

Avoid and reduce demand for travel

Strategies in the Avoid component aim at reducing both motorized trips of passengers and freight movement as well as trip lengths. These strategies can play a significant role in achieving sectoral benchmarks, through encouraging cities where people need fewer or shorter vehicle trips to travel more by public transport, cycling, or walking. These strategies can also contribute to providing rural areas with better access to services and opportunities. Next, we take a deeper look into examples about the main policy solutions at hand for avoiding and reducing trips.

Managing transport demand

The objective of managing demand for transport is to disincentivize the use of motorized transport, particularly the private one. An example of a transport management strategy is congestion pricing, which reduces "unnecessary" travel by charging a fee to transit through designated areas, usually in a city's core. This particular strategy has been successfully implemented to reduce vehicle emissions and induce sustainable transport options in Singapore, Stockholm, and London (WRI 2018). Most recently, congestion pricing was approved for New York City (MTA 2022). As ride-hailing applications make the comfortable, time-saving private transport more accessible for more people, public transit networks must improve fast not only to keep their share of total passenger transport in a city, but also to make it grow over time. Congestion pricing is just one of various forms of transport demand management, others include low-emission or car-free zones, strict parking policies, and employer-commuter policies.

Enacting sustainable land use planning and regulations

A good land use plan is a good transport plan. Land use plans and zoning regulations that promote connected streets, mixed uses, and compact development centered around public transport discourage vehicle travel and cut emissions (Ewing 2008). Transport planning should always be linked to national urban development policies to promote compact growth with connected street networks focused on urban roads rather than expressways. Commitments to national policies that encourage land use plans to favor people over motor vehicles are critical when thinking of mobility planning.

Examples of good measures are national urban growth, economic development, housing construction programs that promote compact urban development connected to public transport, and street-based and mixed land use planning that encourages cycling, walking, and other forms of sustainable transport. Examples of actions in this area include the Colombian Nationally Appropriate Mitigation Action (NAMA) on transit-oriented development (DOTS), which integrates sustainable mobility with land use development. It focuses on public and private development around transit stations and provides a strategy for implementing this approach on a larger scale (Kooshian and Winkelman 2018).

Sustainable mobility plans

Land use planning should be supplemented by national sustainable transport plans and city-level sustainable urban mobility plans (SUMPs) designed along certain guidelines, potentially in connection with federal transport funding programs (SLoCaT 2018). SUMPs should prioritize sustainable modes of transport and active mobility: public transport, cycling, walking. Investment should shift from urban motorways and infrastructure that focuses on vehicles to strategic plans aimed at improving access to jobs and opportunities (e.g. investing more in mass transport than in elevated highways in urban areas).

Removing fuel subsidies

Fuel subsidies make vehicle travel less expensive, thus inducing people to travel more and consume more fuel, regardless of the vehicle's fuel economy standards. Fuel subsidies are popular yet regressive instruments that promote unnecessary travel, induce congestion, and weaken fuel efficiency initiatives. They also constitute a burden to the government, especially with fuel price volatility. Coady et al. (2019) have estimated that fossil fuel subsidies-imposed costs reached nearly 5.2 trillion USD in 2017. They have also estimated that removing all fossil fuel subsidies observed in the late 2010s, if permanent, would cut global carbon emissions between 6.4 and 8.2 percent by 2050, globally. In the case of Mexico, it has been proven that subsidies are not effective ways to help low-income population groups, since most of the resources end up benefiting wealthier households and individuals who are not overtly sensitive to fuel prices (Arze del Granado et al. 2012). Ensuring a just transition is important in this context and fuel subsidies are far from it.

BOX 2

Opportunities for enhancing freight and logistics targets in national climate plans

Globally, freight transport, mostly road freight, was responsible for 41 percent of total transport CO_2 emissions in 2015 (SLoCaT 2018). Under a BAU perspective, freight demand (measured in metric tons per kilometer) is expected to grow between 100 and 230 percent in the period from 2015 to 2050 (ETC 2018), raising emissions along with it. According to this report, road freight emissions alone are projected to grow significatively, nearly doubling from 2.5 $GtCO_2$ in 2014 to 4.6 $GtCO_2$ in 2050.

Despite its significant share in transport emissions, in the totality of NDCs to the Paris Agreement submitted by countries, freight transport is mentioned only a third of the times (SLoCaT 2018).

Mexico's 2015 NDC mentions the support of multimodal transport as a strategy for mitigating emissions in the transport sector but does not include specific lines of action or goals. This gap in the current NDCs, combined with significant technological advances over the past several years, sets the stage for countries to strengthen their NDCs by addressing freight emissions. Although emissions from freight can be reduced via Avoid-Shift-Improve strategies, the largest reduction potential lies in accelerating the transition to zero-carbon fuels (ETC 2018).

Source: Fransen et al. 2019

Strategies to improve logistics, increase load factors and reduce backhauls

Improving logistics and operational efficiency, for example by using information technology to optimize freight routes, improve load factors, and eliminate backhauls, has the potential to globally abate an estimated 0.8 $GtCO_2e$ in 2050 (32 percent of global total emissions from heavy road transport) (ETC 2018). For urban freight, last-mile solutions, such as consolidating delivery at the city, neighbourhood, or building level, can cut emissions and improve safety and air quality in densely populated urban areas.

Shift between modes of transport

Shift strategies refer to switching to low-carbon travel. Strategies include increasing investment in public transportat, active mobility, or any other modes other than private motor vehicles. Efforts to achieve this require the creation of policies and financial environments that allow countries and cities to plan and implement high-quality, affordable, efficient, and public transport systems, which are connected to citywide bicycle and pedestrian infrastructure that is well planned, safe, and compatible with urban life. In the following lines we expand into examples of policies within the shift framework.

Providing high-quality public transport

High-quality public transport should be reliable, safe, frequent, direct, connected, affordable, and accessible. Furthermore, it should be an integrated public system that attracts commuters and prioritizes safe cycling and walking. Public transport plays a key role in decarbonisation and urban mobility efforts. An important part of the benefits comes from investments, adding BRT, subway, LRT, and commuter rail.

By investing in high-quality public transport, governments can shift passenger travel toward travel modes with less emissions. There is a need for consistent programs to finance efficient systems that offer people access to opportunities within cities and reduce emissions, enabling the development and use of metro systems, bus rapid transit (BRT), trams, light rail transit (LRT), and commuter rails, as well as other improved bus services required for shifting away from networks of informal transit (or paratransit), such as minibus and taxi networks which do not offer safety to neither the users nor the operators. While we get there, programs to improve informal transit services should also take priority.

Expanding cycling and walking

In Mexico, there is a clear opportunity to integrate robust cycling and walking plans and policies. Given the nearly zero-carbon emissions of walking and cycling, shifting toward these modes provides large potential benefits in mitigating emissions from transport. An in-depth analysis of global cycling potential found that a dramatic increase in cycling could save society 24 trillion USD in energy, vehicle, and infrastructure costs cumulatively between 2015 and 2050, and cut CO_2 emissions from urban passenger transport by nearly 11 percent in 2050 compared with an alternative "Shift" scenario without a strong emphasis on cycling (Mason et al. 2015).

Many countries can build on existing policies. A 2016 UN Environment Programme report that surveyed cycling and walking issues and policies in 25 low- to middle-income countries across Africa, Asia, and Latin America found that most had a policy at some level intended to give cycling and walking more attention (UNEP 2016). But it also found that commitments varied widely, from "relatively insubstantial" sections in a general transport or mobility policy to "standalone national walking and cycling policies." Options include commitments to develop and implement cycling and walking policies, to designate dedicated funding to such programmes, and to dedicate a certain amount of transport budgets to cycling and walking infrastructure. Commitments to gather better data and to address concerns of key users such as women, children, and the elderly can also provide valuable benefits.

Shift strategies to maximize more sustainable transport modes

Shifting strategies, for example, toward lighter non-motorized modes like bicycles could be deployed for urban freight. Shifting diesel road freight to less carbon-intensive rail and shipping is also possible in some countries, offering an estimated 0.6 $GtCO_2e$ in global abatement potential in 2050 (24 percent of global total emissions from heavy road transport (ETC 2018)).

Policymakers have explored options such as disincentivizing road freight through heavy-duty vehicle road tolls, investing in infrastructure to reduce rail bottlenecks, and mandating longer trains on major rail corridors (Frey et al. 2014). Table 4 summarizes WRI´s recommendations (Fransen et al. 2019) to improve road freight efficiency, potential energy savings globally, and their enabling policies, which are part of the ASF framework. We acknowledge that no costs for them have been estimated in this analysis. Some of them require regulation, others only coordination. These proposals were used to estimate fuel savings and GHG reductions of the decarbonisation scenario described in the following section.

TABLE 4

Available road freight efficiency strategies

STRATEGY	ESTIMATED POTENTIAL ENERGY BENEFIT	ENABLING POLICIES AND HOW THEY REFLECT IN NDCs
High-capacity vehicles (larger trucks that improve efficiency)	20% or more, depending on rebound effect	Performance-based standards
Optimized routing	5 – 10% intracity, 1% long haul	Real-time routing data based on geographic information systems (GIS), easing of delivery time constraints
Platooning (driving heavy-duty trucks [primarily tractor-trailers or rigid trucks] in a single line with small gaps between them to reduce drag to save fuel during highway operations)	5 – 15%, depending on assumptions	Vehicle communication and automation technologies
Improved vehicle use	Substantial but difficult to quantify	Better data collection (enabled by ICT); collaboration and alliances among carriers and logistics companies
Backhauling (using return trips formerly run without cargo to transport goods, thereby reducing trips)	Substantial but difficult to quantify	Collaboration and alliances among carriers and logistics companies (through freight exchanges)
"Last-mile" efficiency measures	1 – 5%	Allocation and prediction of dynamic demand to prepare for demand peaks; increased competition, including market entry of freight services providers
Re-timing urban deliveries	Difficult to estimate and generalize	Incentives to shipment receivers to accept the insurance and logistical impacts of shifting to early-morning and off-hour deliveries

TABLE 4 (CONT.)

STRATEGY	ESTIMATED POTENTIAL ENERGY BENEFIT	ENABLING POLICIES AND HOW THEY REFLECT IN NDCs
Urban consolidation centres (grouping shipments from multiple shippers and consolidating them onto a single truck for delivery to a given geographic region)	Vehicle activity, fuel use, and CO_2 emissions within urban centres can be reduced by 20 to 50%.	City regulatory policies to reduce congestion and promote air quality
Co-loading (using supply chain collaboration within a company or across firms to increase vehicle load on outbound operations)	5 – 10%	Legal and regulatory frameworks to promote energy savings while protecting companies' intellectual property rights
Physical internet (open, global logistics system enabling efficient delivery based on sophisticated real-time data)	Work to date suggests 20% systemwide efficiency improvement.	Legal and regulatory frameworks; ICT to collect, process, and protect proprietary data

Source: Fransen et al. 2019, adapted from IEA 2017

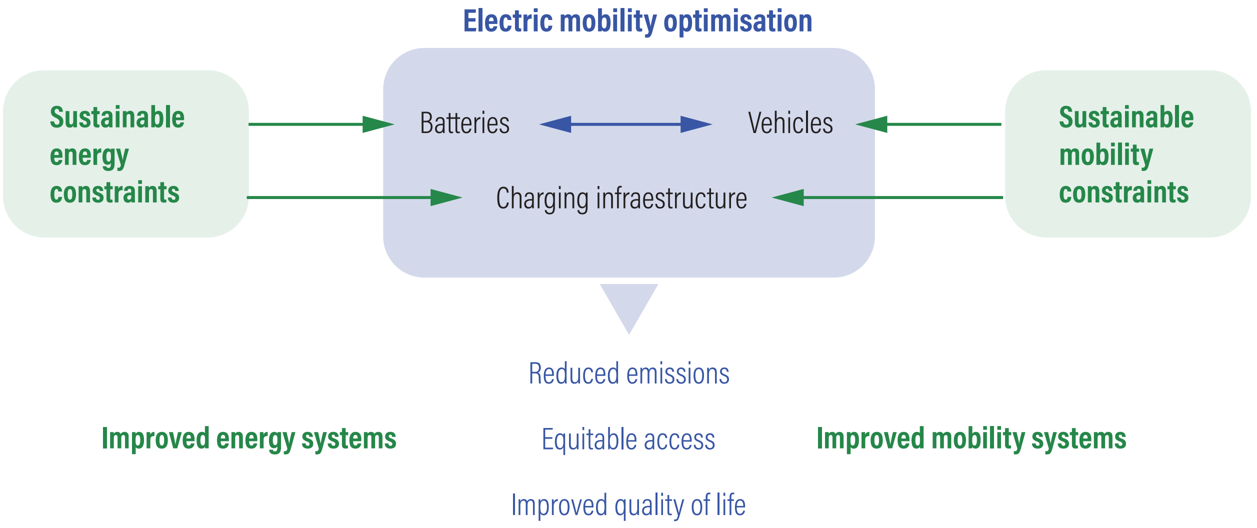
Improve efficiency

Improvements that are reflected in greater energy efficiency, better technology, or travel-related decisions —such as car-pooling/ride-sharing— are required to reduce polluting emissions, greenhouse gases, and congestion. Among them, two policy tools are paramount to improve fuel efficiency and enhance the introduction of low carbon technologies: 1) robust national fuel efficiency standards, and 2) comprehensive electric mobility policies. Fuel efficiency standards form the baseline policy by which car-makers are compelled to reduce GHG and air pollutant emissions from vehicles. The Global Fuel Economy Initiative (GFEI) calls for an aggressive increase in fuel economy standards, including a 90 percent reduction in CO_2 per kilometer emissions by 2050 (Fransen 2019a), only achievable by introducing hybrid and electric vehicles into the mix.

Although fuel efficiency standards are needed to reduce GHG emissions from the transport sector, electrification —in conjunction with decarbonisation of the power sector— would be indispensable to reach net-zero targets. Therefore, both strategies (improving fuel efficiency and increasing the penetration of electric vehicles) must be promoted in parallel. An overarching framework for optimizing electric mobility systems to maximize benefits to both the power and transport sectors based on the following common sustainability goals is needed (Figure 10).

FIGURE 10

WRI electric mobility systems framework



Source: Fransen 2019a

The implementation of the "Improve" strategies, particularly through vehicle electrification, aims to bring the following benefits:

- Reduction of GHG emissions in the energy and mobility sectors.
- Improvement of local air quality by reducing small particulate emissions in the energy and mobility sectors.
- Provision of equitable access to safe, reliable, and sustainable electricity and transport.
- Improvements in the overall quality of life of communities that incorporate electric mobility.

While the introduction of electric vehicles is essential to achieve net-zero targets, it is also a measure that enables the improvement of public transport and the amplification of Avoid and Shift strategies. The transport sector is undergoing a particularly important transformation through the integration of electric buses into transport fleets in cities around the world. This has helped reduce local air pollution, provide more comfort to passengers compared to conventional diesel buses, and lower operation costs. Despite their current higher cost of purchase (in cities such as Santiago de Chile, electric buses almost double the cost of diesel buses (ICCT 2022)), electrifying municipal bus fleets presents a unique opportunity to reduce GHG emissions in the transport sector while also bringing co-benefits to cities (Sclar 2019).

BOX 3

Electric vehicle penetration needs to work alongside power sector decarbonization and should also be combined with incentives to shift to other modes

Transport

In both the US and Europe, electric vehicles (EVs) bring a substantial reduction in the lifecycle of GHG emissions compared to average conventional vehicles. This has been a consistent finding across most studies examined by the Carbon Brief (2017).

As electricity generation becomes less carbon intensive —particularly at the margin— electric vehicles will become preferable compared to all conventional vehicles in virtually all cases. There are fundamental limitations on the efficiency of gasoline and diesel vehicles, whereas low-carbon electricity and increased battery manufacturing efficiency and electrification can cut most of the manufacturing emissions and nearly all electricity use emissions from EVs.

A transition from conventional gasoline and diesel vehicles to EVs plays a large role in mitigation pathways that limit warming to meet the Paris Agreement targets (Carbon Brief 2017). However, the transition depends on rapid decarbonisation of electricity generation to be effective. If countries do not replace coal and most natural gas with non-carbon sources, then electric vehicles will remain far from being "zero emissions".

Source: Carbon Brief (2017)

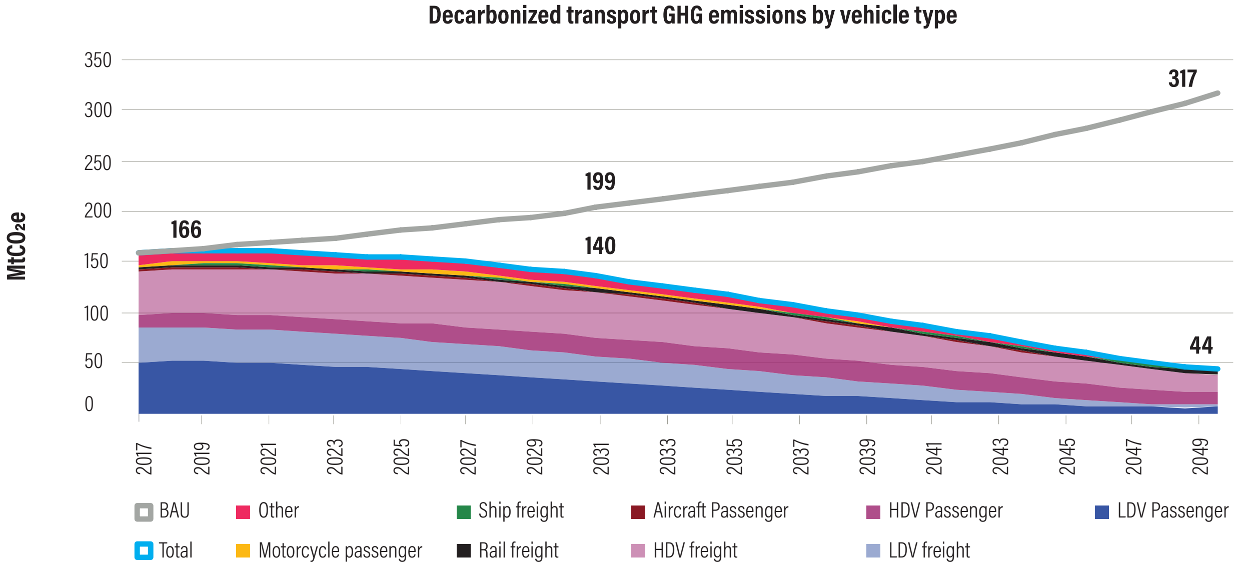
Decarbonisation scenario of the transport sector

The development of a decarbonisation scenario for the transport sector in Mexico was based on the Avoid-Shift-Improve frameworks and the effectiveness of policy levers that promote transport demand management, a fuel economy standard, and an electric vehicle sale standard. The simulations (Figure 11) result in sector GHG yearly emissions of 140 $MtCO_2e$ by 2030 (30 percent below from our BAU scenario), and 44 $MtCO_2e$ by 2050 (86 percent below BAU), which would be consistent with a 2°C warming scenario if all sectors and countries achieve a similar reduction. For global warming not to exceed the 2°C limit, global emissions must be reduced by about 25 percent by 2030 and be equal to zero by around 2070 (IPCC 2018).

Following this route, the simulations point to the reduction of approximately 75 thousand premature deaths per year, considering the reduced exposure to particulate pollution by mid-century.

FIGURE 11

BAU and decarbonisation trajectories of the transport sector



Source: Fransen 2019a

Impact on travel and modal share

Through the application of strict Transport Demand Management (TDM) policies, our simulations show that the demand for travel in freight modes is reduced by 15 percent freight ton-km by 2030 and 45 percent by 2050 compared to BAU. Passenger modes do not reduce their travel demand compared to BAU but change their modal share as shown in Table 5.

TDM can include policies to reduce the use of inefficient forms of transit, such as policies that introduce congestion pricing or driving restrictions aimed at private cars. TDM also includes policies to make more efficient forms of transit more attractive, such as developing efficient public transit, building bike lanes, and promoting walking through better urban design. Policy and investment in transport demand management should be targeted

TABLE 3

Modal distribution – Reference case scenario

		2017	2030	2050
Passenger modes	LDV	42	33	17
	HDV	47	51	68
	Motorcycle	3	2	0
	Rail	6	11	14
	Aircraft	2	2	0
Feight modes	LDV	9	12	23
	HDV	69	66	42
	Rail	10	14	27
	Ships	11	9	9

Source: EPS Mexico 2020

Impact on fleet size and fuel technology

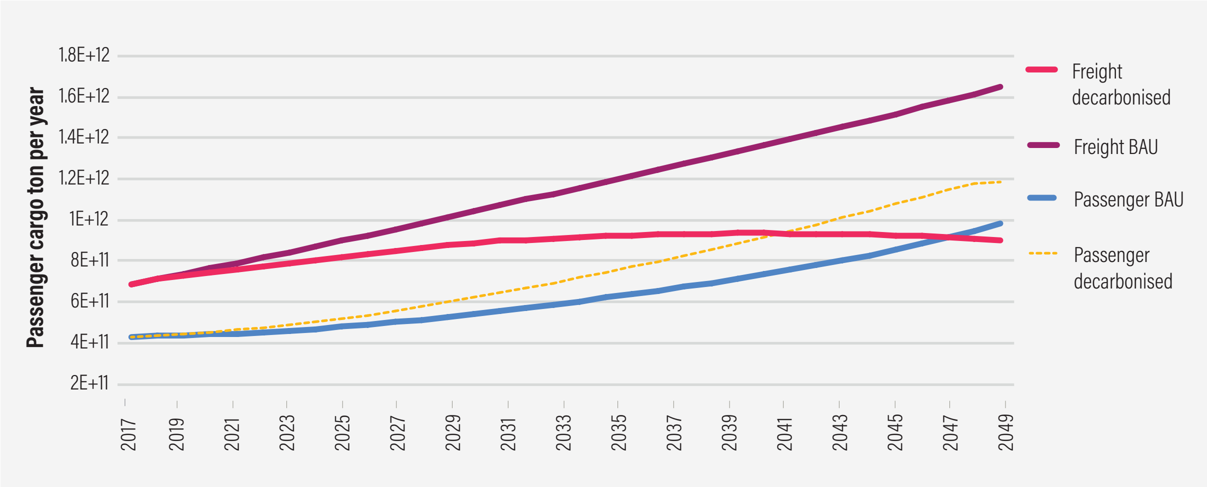
Changes in demand for travel have an impact on fleet size. For emissions to reach the proposed decarbonisation route, total fleet size should be eight percent (almost three million vehicles) lower than BAU by 2030 (see Box 4), which is estimated to grow by six million vehicles from 2020 to 2030. By 2050, the fleet size in this decarbonisation pathway simulation becomes 40 percent (27 million vehicles) lower than BAU, instead of the 70 million vehicles in the BAU simulation's output. This is due to the way the model reacts to reduced demand in travel and because of a shift to more efficient modes of transport[5]. first at the most densely populated regions of Mexico, where the benefits from reduced congestion and local air pollution will be the largest.

In Mexico, demand management also involves the expansion of the supply of well-located social urban housing that is adequate, secure, and affordable, complemented with inclusive and resilient mass transit options. An example of this type of policy has been the creation of metropolitan authorities that may enable integrated land use and transport planning, following the case of the Guadalajara Metropolitan Authority (CUT 2020).

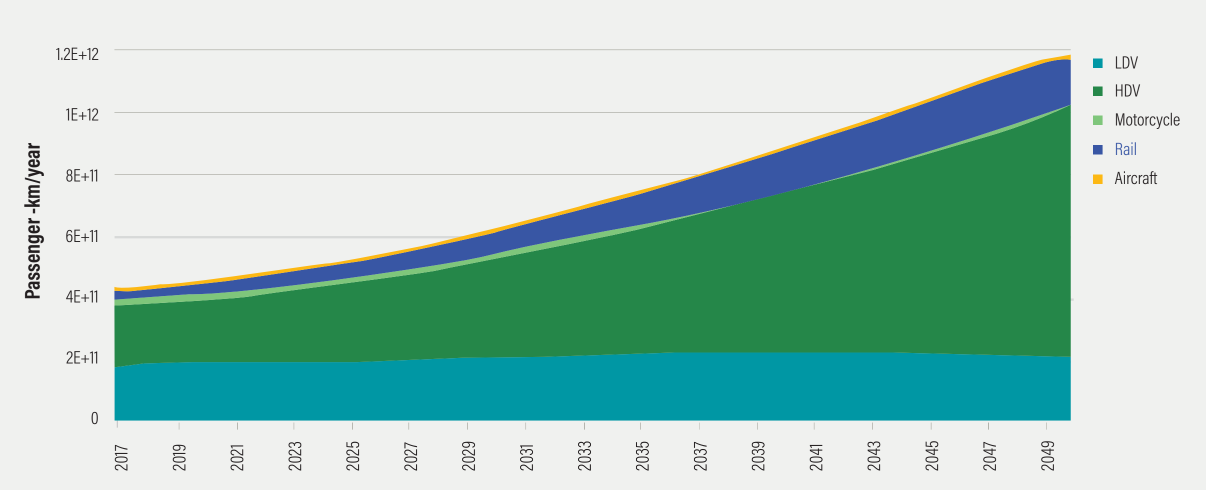
BOX 4

Travel demand – Decarbonisation pathway

Demand of travel



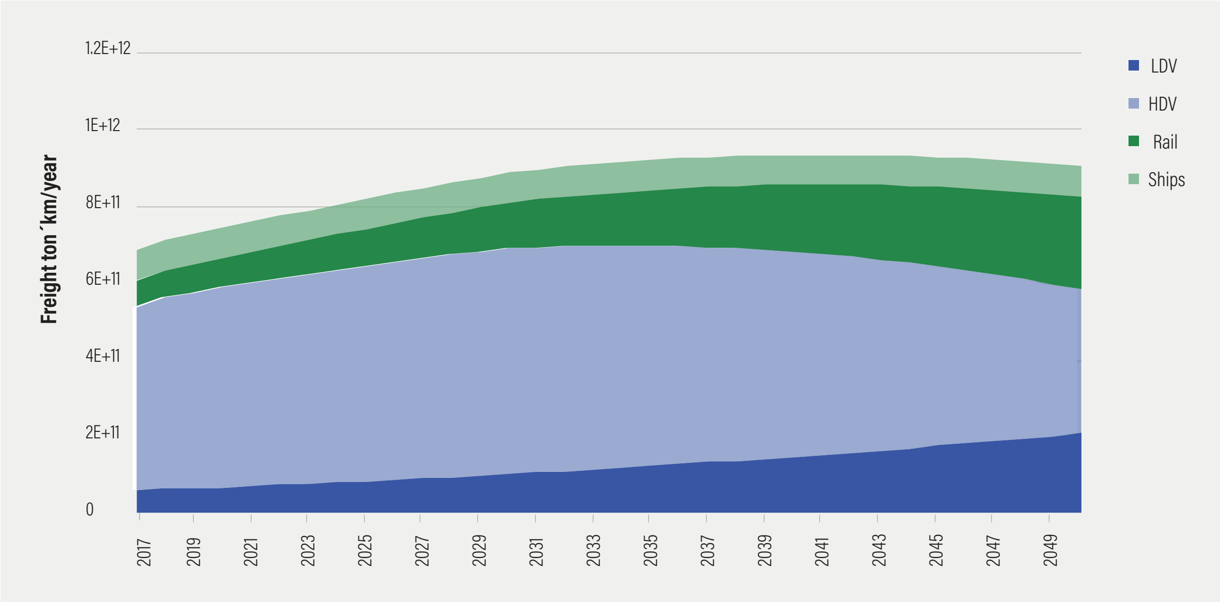
Demand for travel - Passenger modes - Decarbonised



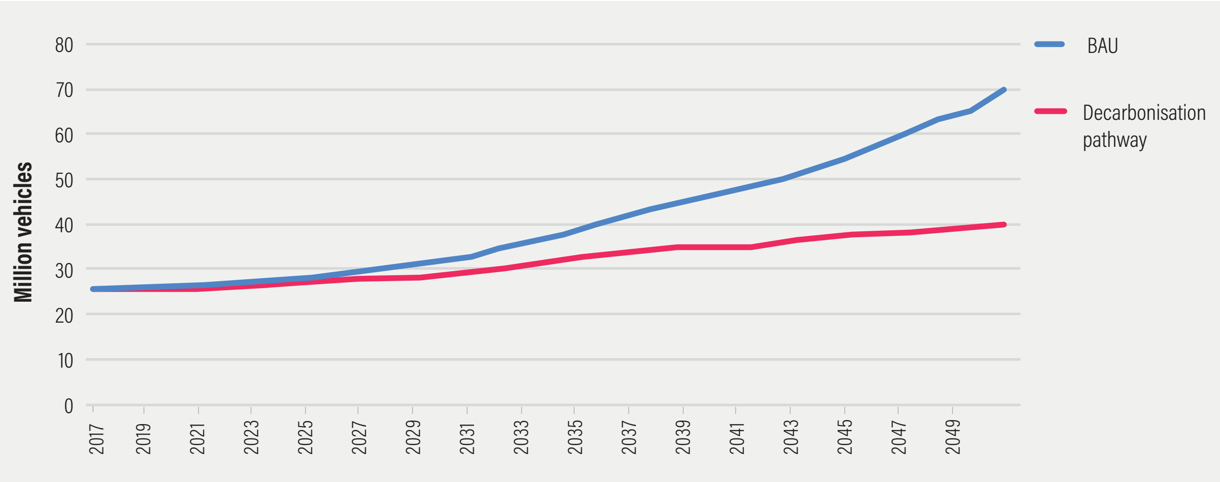
BOX 4

Travel demand – Decarbonisation pathway

Demand of travel



Fleet size



Source: EPS Mexico 2020

Regarding fleet composition, the decarbonisation route implies 20 percent more EVs against BAU by 2030, and an 80 percent increase, reaching 91 percent of all fleet by 2050, as shown in Figure 12.

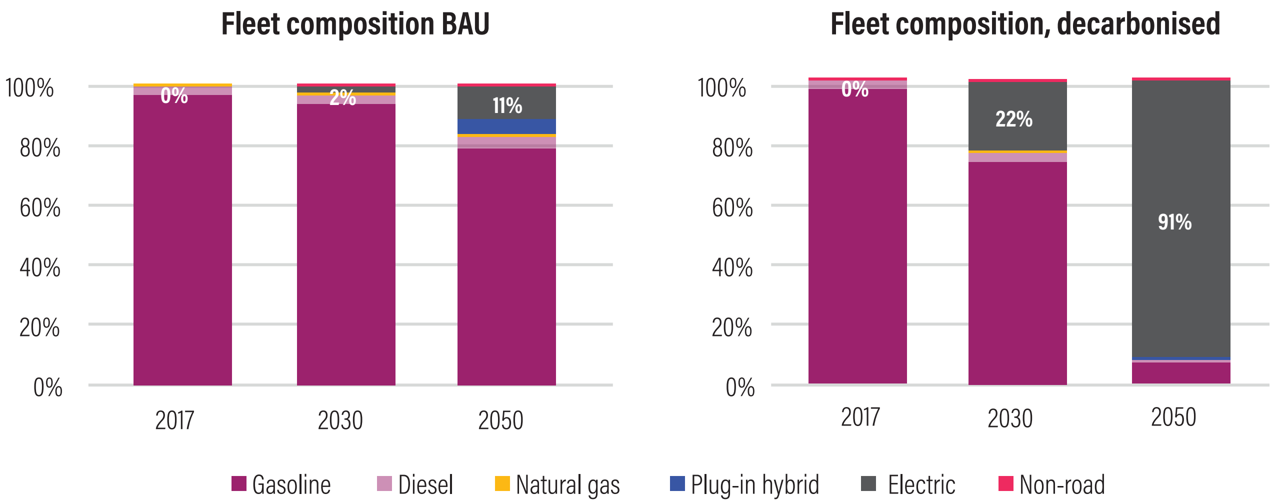
A momentum is building to increase the adoption of light-duty passenger EVs. The countries of the European Union, for instance, have set the goal to phase-out internal combustion engine vehicles by 2035. The 2020 Climate Action Tracker report, Paris Agreement Compatible Sectoral Benchmarks, projects that to be aligned with the 1.5oC pathway, fully electric vehicles will need to account for 75-95 percent of global annual passenger vehicle sales by 2030, and 100 percent by 2035 (WRI 2021). The International Council on Clean Transport (ICCT) has stated that to decarbonise the global transport sector by 2050, nearly a 90 percent penetration of zero-emission vehicles in the European Union (EU) and China would be necessary, and for the rest of the global market, including the United States, a 66 percent electric share of the total vehicle stock (ICCT 2020).

Although passenger EVs may have an exponential growth over the coming decades, the share of electric penetration that entails the decarbonisation route in Mexico will only be within reach if carmakers make commitments to transition to EV fleets for the national market, and if government regulation requires it backing it with increasing investments to enable infrastructure and EVs purchase incentives. In addition, along with the consolidation of public transport systems, states and municipalities need to consider electrification as part of the renovation of bus fleets.

Source: Pexels, Japan

FIGURE 12

Evolution of the transport fleet composition by fuel (BAU vs Decarbonisation scenario)



Source: EPS Mexico 2020

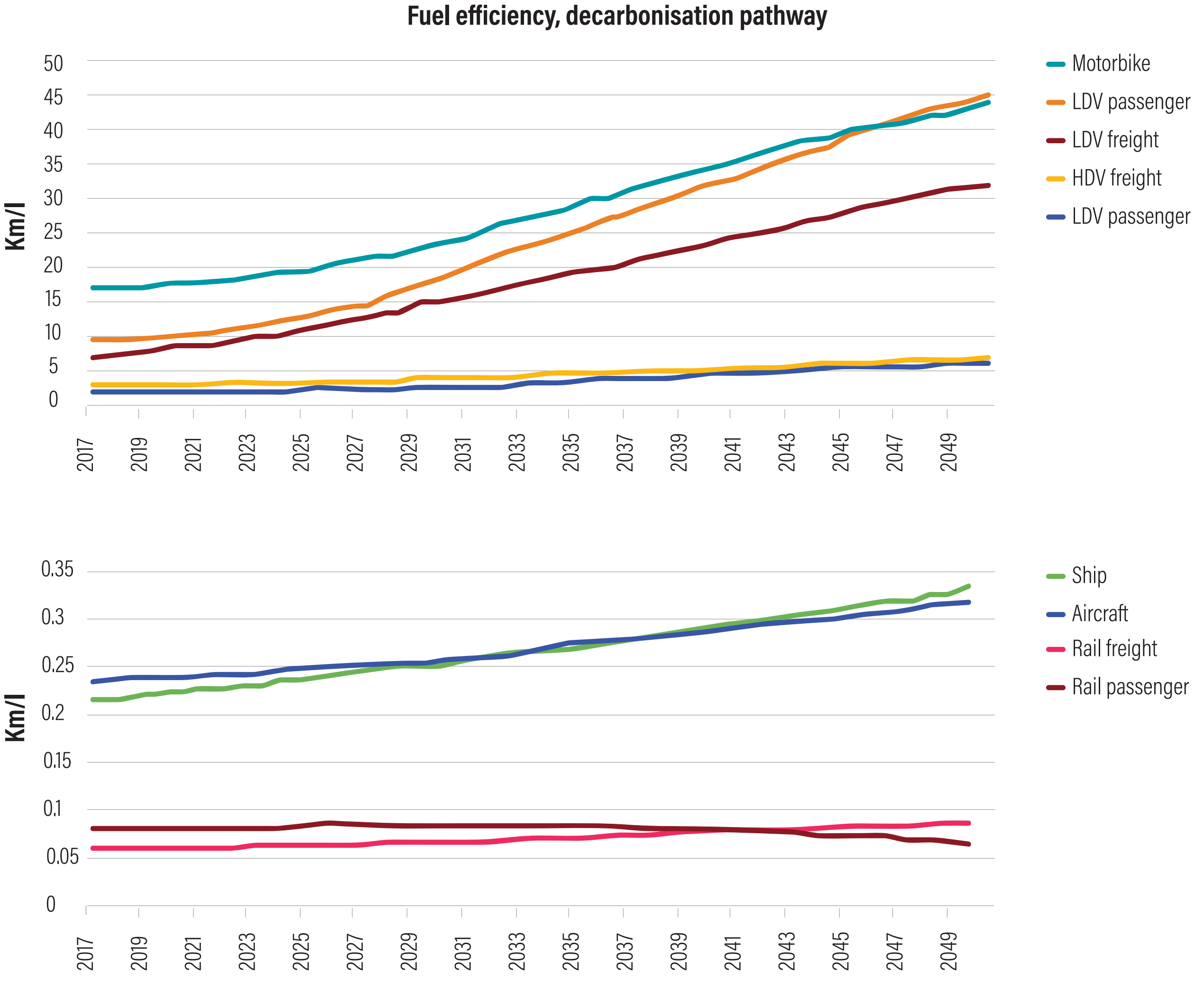
Impact on fuel efficiency

The fuel economy of newly sold vehicles has evolved based on the combined effect of fuel prices and fuel economy standards. Fuel economy standards are minimum efficiency standards for new vehicles. These standards curb GHG emissions by improving the fuel efficiency of the new vehicle fleet. Fuel-economy standards should be administered upstream (applied at the first sale) to capture 100 percent of the market for new vehicles, requiring each vehicle manufacturer to meet a fleet average fuel-economy standard for all new vehicles sold during a year, on average –as designed by regulation–, because of the diversity of models. Fuel-economy standards can also be designed to provide flexibility and reward performance by allowing credit trading between manufacturers (rewarding manufacturers that offer more fuel-efficient product mixes by allowing them to sell credits to underperforming manufacturers). More stringent standards should phase-in gradually with a clear path to meet a final target. This approach gives manufacturers time to meet the final target while promoting continuous improvement and strengthening fuel economy on an ongoing basis.

In most cases, fuel economy standards save customers money over the lifetime of the vehicle due to reduced spending on fuel. However, many purchasers of new vehicles often do not account for lifetime fuel use in their purchase decisions and higher vehicle costs may be perceived as increasing costs to consumers (EI 2021). Fuel-economy standards improve new vehicle efficiency (Figure 13), but in the absence of complementary fuel-price or emissions tax policies, some of this gain may be offset by increased vehicle use due to the cheaper cost per kilometer traveled. This “rebound effect” phenomenon is exacerbated if fuel is subsidized rather than taxed. Fuel taxes are thus a useful complement to fuel economy standards (EI 2021).

BOX 13

Fuel efficiency evolution under the decarbonisation pathway



Source: EPS Mexico 2020

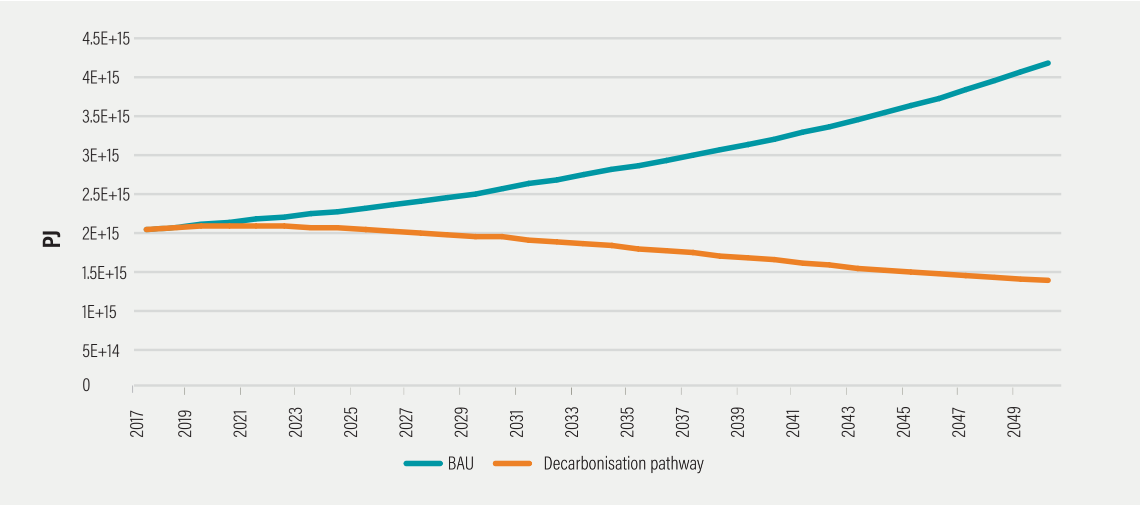
Fuel consumption

The proposed decarbonisation pathway could bring energy savings of 24 percent as compared to BAU by 2030, and up to 66 percent against BAU by 2050. This effect comes from avoiding growth in travel demand, a shift in transport modes and an improvement in energy efficiency. Use of electricity for transport reaches ten percent of transport energy by 2030, compared to only two percent in BAU. By 2050, electricity would represent 59 percent of total transport energy, displacing liquid hydrocarbons from 97 percent of all energy consumed in BAU to only 41 percent in the decarbonisation pathway (see Box 5).

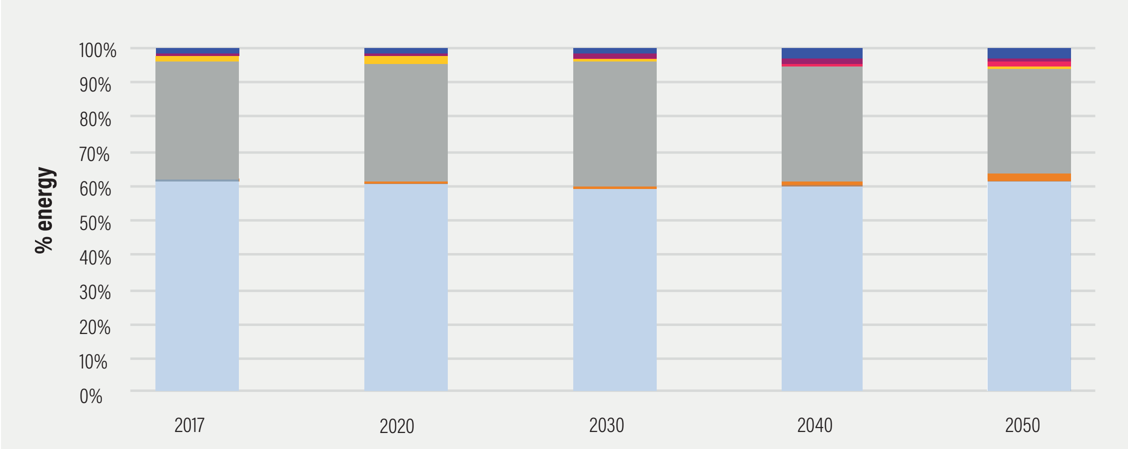
BOX 5

Travel demand – Decarbonisation pathway

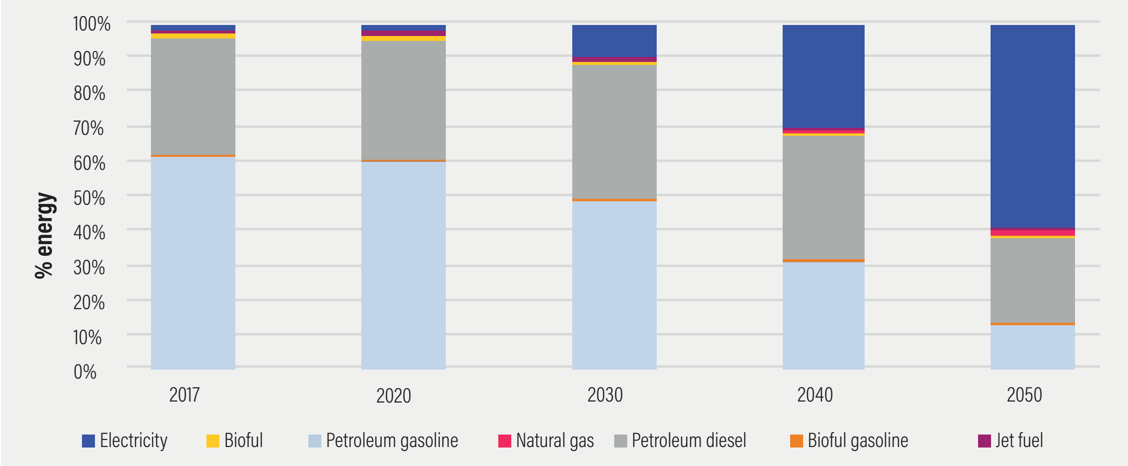
Energy consumption - transport sector



Transport sector fuel mix, BAU



Transport sector fuel mix. decarbonisation pathway



GHG emissions

The proposed decarbonisation pathway results in sector GHG emissions of 140 $MtCO_2e$ by 2030 (30 percent below BAU) and 44 $MtCO_2e$ by 2050 (86 percent below BAU), as seen in Figure 10. TDM could account for 30 $MtCO_2e$ of total reduction by 2030 and remains similar throughout the modelling horizon.

Vehicle fuel economy standards add 2 $MtCO_2$ of potential reductions in 2030, which may be small due to the difficulty in the implementation of fuel economy standards in the past. Nevertheless, these actions are important and become relevant in the long term, adding up to 150 $MtCO_2e$ of abatement by 2050. A policy-driven high penetration of EVs could allow for a considerable additional abatement, as much as 28 $MtCO_2e$ by 2030 and up to 99 $MtCO_2e$ by 2050.

Marginal abatement cost curve

Based on the previous assumptions and calculations, Figure 14 presents the marginal abatement costs curve and emissions reduction potential for the transport sector by 2050. We find a potential of 273 $MtCO_2e$ abatement (86 percent below BAU) which includes two action types:

- those that avoid and shift, grouped in the TDM, and
- those that improve vehicle/technology mix: fuel economy standards and an Electric Vehicles Sales Mandate.

It is notable that TDM levers have a negative marginal cost in the long term, on top of the co-benefits discussed in the following section. This can only be explained, for private decisions, if there are some regulatory restrictions or some costs the model is not considering, while for public decisions it stems from a problem of coordination, inspiration, public finance, or from having other priorities with higher rates of (social) return.

Co-benefits of decarbonising the transport sector

Transport sector decarbonisation brings sustainable development benefits, including those related to improved air quality, road safety, increased physical activity, access to opportunities, and economic development.

Air pollution and black carbon

The World Health Organization estimated that, globally, in the mid-2010s, air pollution was responsible for 4.2 million premature deaths every year (WHO 2018). This term captures the difference in life expectancy in areas with good air quality compared to those with poor air quality, at similar income per capita levels. A report by the ICCT and the Climate and Clean Air Coalition (CCAC) estimated that, in 2015, transport emissions contributed to about one in ten of these premature deaths (Anenberg et al. 2019). The rest can be attributed primarily to burning wood or other materials for cooking, which generates excess smoke in closed or open areas, and secondarily to criteria pollutants emitted by industrial and power generating facilities.

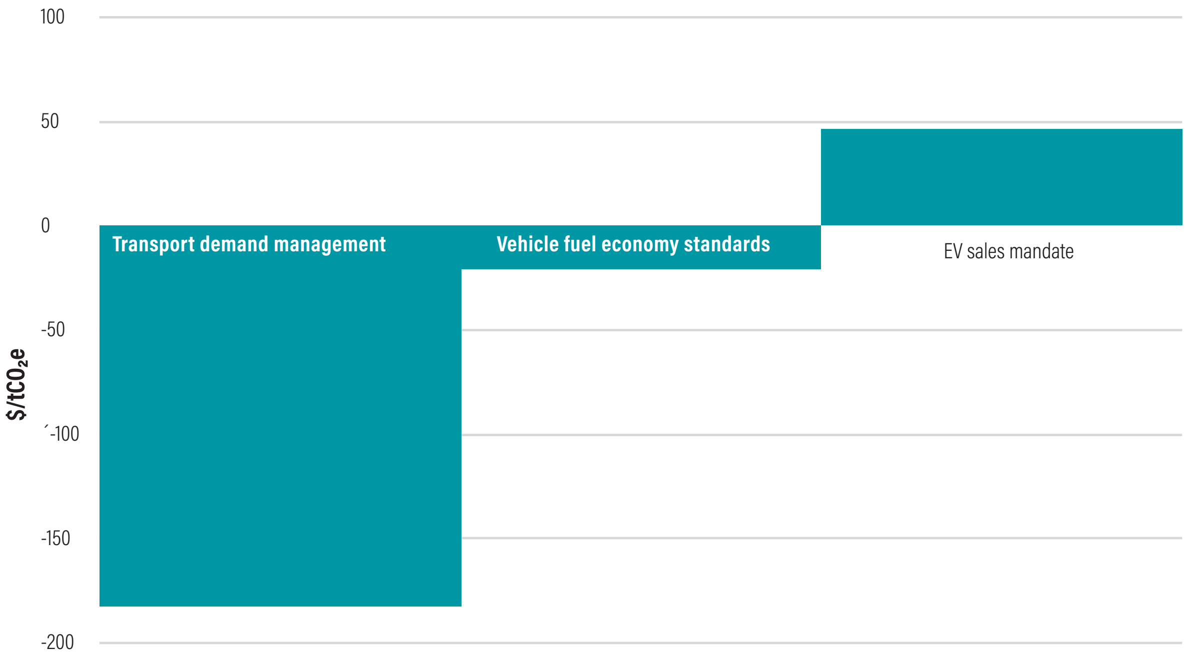
For Mexico, our decarbonisation pathway scenario allocates the number of statistical lives saved from reduced particulate pollution attributable to the decarbonisation of the transport sector. These start at 227 in 2017 and adds up to 75 thousand over the whole modelling horizon. Figure 15 shows how this annual figure is projected in the simulation.

Among the local pollutants generated by dirtier fossil fuels consumed by the transport sector, black carbon, or soot, stands out as a major threat to human health. This type of particulate matter is associated with a wide range of respiratory and cardiovascular diseases and thus with statistically premature deaths (Health Effects Institute 2010). In addition to its health effects, black carbon emissions have been identified as a significant short-term contributor to global climate change (Bond et al. 2013). After CO_2 emissions, black carbon emissions are the second substance with the strongest warming influence in the atmosphere when measured in the time-frame of a few decades (Ramanathan and Carmichael 2008, Bond et al. 2013). These studies show that curbing black carbon emissions may slow down the atmospheric warming expected by 2050 and thus allow for better timing of strong action on CO_2. Reducing emissions of black carbon presents an opportunity to slow the rate of near-term climate change and simultaneously achieve substantial public health benefits.

Freight electrification and freight efficiency improvement also offer important benefits in reducing urban air pollution. Heavy-duty trucking, for instance, is substantially and disproportionately responsible for nitrogen oxide (NOx) emissions. NOx is central to the development of ground-level ozone and small particulate matter (PM2.5) (ICCT 2017). Road transport as a whole was responsible for 40 percent of NOx emissions in the EU in 2011, more than any other sector (Icopal, a.d.). Heavy-duty trucks contribute with 55 percent of NOx emissions generated by India's transport sector (Guttikunda and Mohan 2014) and are suspected of contributing a third of NOx emitted by the transport sector in the U.S. (US EPA 2018).

FIGURE 14

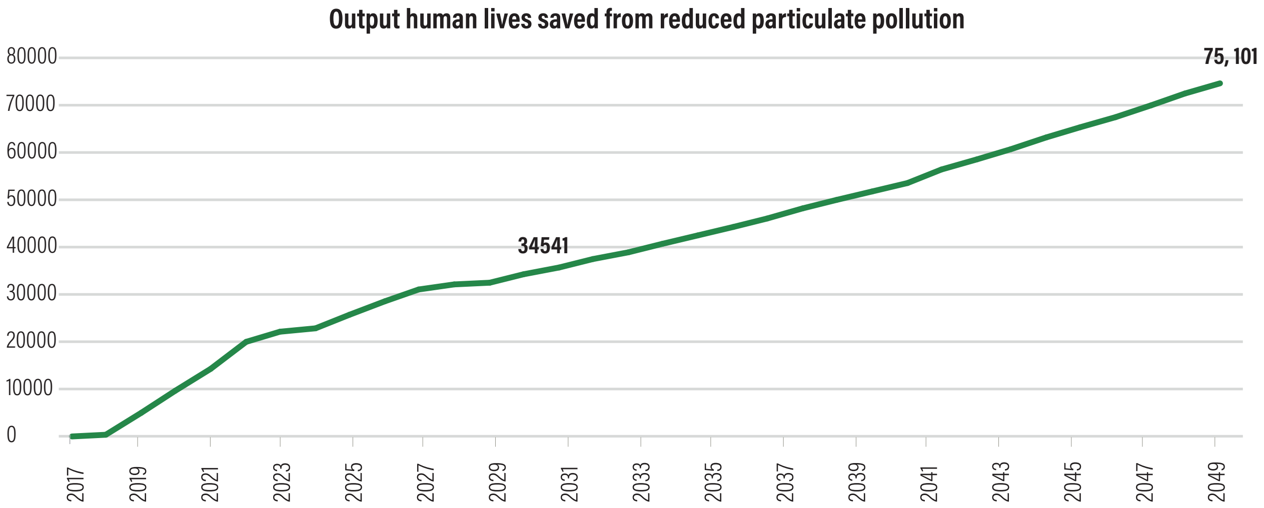
Marginal abatement cost curve for the transport sector in the decarbonisation scenario by 2050



Source: EPS Mexico 2020

FIGURE 15

Statistical lives saved – decarbonisation pathways



Source: EPS Mexico 2020

Physical activity

Globally, in the first decade of the 2000s, 5.3 million premature deaths per year were attributed to inactivity (Lee et al. 2012). Several countries like the U.S. were experiencing steep declines in physical activity since 1965, and many rapidly motorizing countries now experience similar trends. China, for example, had a 45 percent decrease in physical activity between 1991 and 2009, and Brazil was slated to see a 34 percent decline between 2002 and 2030 (Ng and Popkin 2012). Turning active transport —such as cycling and walking— safe, convenient, and accessible —and thus more appealing— can encourage people to exercise. A growing body of research shows that aggressively expanding active transport is an effective, but underutilized, policy option with significant health co–benefits for mitigating GHG emissions (Maizlish et al. 2017).

Equitable access and travel time savings

Equitable access is an emerging issue in the transport sector. It refers to the possibility of providing users across all income levels not just proximity to transport options, but also access to jobs and services. Focusing on access means looking at how many opportunities can be reached within a set amount of time for all residents across different modes of transport. Better access can mean shorter trips, and thus lower emissions, as well as less time spent on congested city streets or along rural road networks. Transport improvements often disproportionately benefit wealthier residents while leaving poorer residents disproportionately impacted by the negative externalities, including poor air quality, unaffordable transport options, dangerous walking infrastructure, and exclusion from opportunities (Lucas et al. 2016). Addressing "transport poverty" means taking a nuanced look at the mobility options, accessibility, transport's affordability, and negative externalities faced by the most vulnerable residents, including the disabled and women (Lucas et al. 2016). Currently many cities fail to offer all residents access to transit without major time delays, poor quality, or unaffordable service (Venter et al. 2019). The proposals for decarbonisation here presented should be measured against this criterion, but they have not been evaluated rigorously for it. The aim is to use evidence to guide decision-making so that any decarbonisation pathway chosen improves equitable access in every step of the way.

CONCLUSIONS

This study analyses modelling scenarios aligned with a carbon budget compatible with global temperature increases of 1.5°C and 2°C (reducing its GHG by 30 percent in 2030 and 86 percent in 2050 compared to BAU), in order to propose a decarbonisation pathway for the transport sector in Mexico. The transport sector contributes with the largest GHG emissions nationally and is projected to continue a sustained 2.2 percent annual growth under a BAU scenario. Hence the need of a substantial transformation of the sector to achieve the climate goals set by Mexico, to increase its mitigation ambition in accordance with what the global climate emergency demands, but also to achieve several social and economic co-benefits.

Opportunities for decarbonisation have been classified through an Avoid–Shift–Improve framework, which proposes the following:

- Avoid emissions through the reduction in demand for carbon-intensive travel.
- Shift trips to efficient public transport systems and non-motorized travel like cycling and walking.
- Improve on technologies to accelerate electrification, move freight more sustainably and develop solutions for shipping and aviation.

Actions in land use planning (part of the Avoid agenda), plus inducing and implementing public transport and cycling (part of the Shift strategy), and fuelling vehicles cleanly and efficiently (part of the Improve section), include the following:

- Development of electric mobility for all modes and sizes of road transport.
- Confirmation of rapid penetration of zero-emission passenger vehicles, with the last internal combustion engine car to be sold by 2035–2050.
- Technology shifts for heavy-duty road transport to zero-carbon options, though the technology is not yet as advanced.
- Electrification of all rail services.
- Development of a 2°C-compatible long-term vision for aviation and shipping, including alternative options and improved technology.
- In the meantime, demand management is critical to curb the accelerated growth in transport activity.


Source: Flicker, WRI Mexico

Scenario analysis results show that it is technically feasible to decarbonise the transport sector, the technology is available in the market. Some elements of the strategy have negative marginal abatement costs, and the social co-benefits suggest that it would be economically beneficial to strongly advance the decarbonisation of transport in Mexico. However, reaching a 1.5oC trajectory still appears technically difficult and extremely costly, at least with the assumptions made in this study, whereas a 2oC compatible emissions trajectory is far more reachable for Mexico, with strong economic and social rates of return.

However, the assumptions made about EVs penetration may be conservative given recent international developments in the policy sphere, with several countries and subnational jurisdictions establishing ambitious targets, in many cases in line with their long-term carbon neutrality goals. In the case of Mexico, neither has been set so far, but the way international markets will likely move in regard to this technology may accelerate transport electrification in Mexico in spite of the lack of a specific policy driver.

A final remark on a particular limitation of this study is that it does not conduct an analysis of policy implementation or enabling conditions, both of which have a complexity of their own. This is a necessary supplementary analysis and should become a next step to advance in this important agenda.

ANNEX A. THE ENERGY POLICY SOLUTIONS (EPS) MODEL

The EPS was developed by Energy Innovation LLC as part of its Energy Policy Solutions project (EI 2015). It is an effort that aims at informing policymakers and regulators about the most effective and cheapest climate mitigation and energy emission-reduction policies. The model is open source and widely documented. The model and the files for running simulations and editing it, as well as and extensive documentation, can be obtained online[6].

The EPS uses a business-as-usual scenario that is affected by policy settings applied by the user. This reference case is built into the model from official reports such as the National GHG Emissions Inventory (INECC 2018), the National Forestry and Soil Inventory (CONAFOR 2009), energy use data from the Secretariat of Energy (SENER), prospective studies (SENER 2018), as well as from recognized technical studies such as the Poles baseline model (Danish Energy Agency 2015) or the EPA Moves Mexico fleet projection (INECC 2016). This approach enabled the use of existing work and official data while providing novel capabilities to analyze policy options.

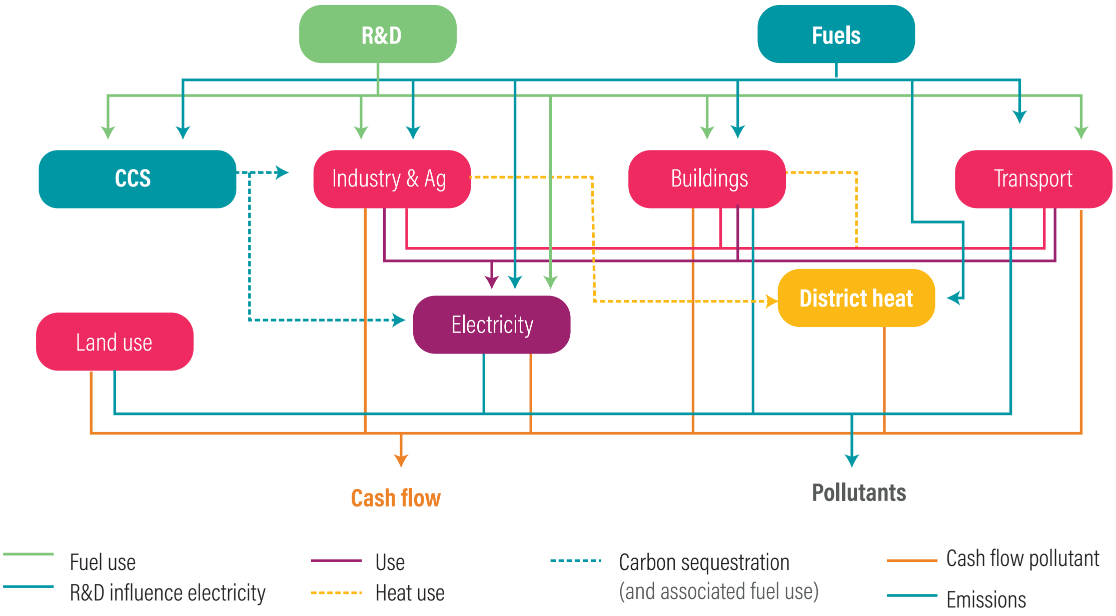
The EPS allows the user to control 58 different policies that impact energy use and emissions (see Figure 18). Among them, we find a carbon tax, fuel economy standards for vehicles, control of methane leakage from industry, and accelerated research and development advancement of various technologies. The model allows customized implementation schedules for different policies to better represent possible actions.

The model produces the following outputs (Energy Innovation 2021):

- Emissions of 12 different pollutants: carbon dioxide (CO_2), nitrogen oxides (NOx), sulphur oxides (SOx), fine particulate matter (PM2.5), and eight others, aggregating GHGs according to their carbon dioxide equivalency (CO_2e).
- Direct cash flow impacts (costs or savings) for consumers, industry, and the government. The parameters that enter the simulation are documented in Energy Innovation (2021).
- Health benefits from reduced exposure to critical pollutants.
- Electricity generation capacity and output by technology and fuel.
- Energy consumption by technology and fuel.

FIGURE A1

Simplified EPS structure diagram[7]



Source: EPS Mexico 2020

A variety of approaches exist to represent the economy and the energy system in a computer simulation. The Energy Policy Solutions is based on a theoretical framework called "system dynamics." As the name suggests, this approach views the processes of energy use and the economy as an open, ever-changing, nonequilibrium system. This may be contrasted with approaches such as computable general equilibrium models, which regard the economy as an equilibrium system subject to exogenous shocks, or disaggregated technology-based models, which focus on the potential efficiency gains or emissions reductions that could be achieved by upgrading specific types of equipment.

System dynamic models have the following recognized weakness: they may lead to incorrect inferences since they do not assess social and economic exogenous variables that interact and impact energy systems as well as uncertainties. Assumptions are also based on available data, which in the case of electric vehicles and fuel efficiencies consider mainly global data as the standard. They are not intended to have predictive power but allow an understanding of the impact that technological changes and behaviors could have on energy use and emissions. The use of a system dynamics model allows for stock carry-over between periods, allowing to register changes in capacities, populations/fleets, and accumulated benefits in comparison to a reference scenario; it also allows for a gradual change in parameters that does not require recalculations of a general parameter for a specific sector —a useful feature in the industry sector that grants progressive improvements in efficiency (EI 2015).

ANNEX B. DESCRIPTION AND GUIDANCE FOR SETTING VALUES OF EPS TRANSPORT POLICIES

TABLE B1

	POLICY	DESCRIPTION	GUIDANCE FOR SETTING VALUES
Shift & Avoid	Transport Demand Management	Implementation of TDM policies aimed at reducing demand for travel. Passenger TDM focuses on private automobiles and includes public transit systems, more walking and bike paths, zoning for higher density along transit corridors, zoning for mixed-use developments, roadway and congestion pricing, and increased parking fees. Freight TDM is aimed primarily at shifting freight from trucks to rail.	Passenger LDVs: The International Energy Agency's BLUE Shifts scenario (IEA 2009) includes a 26% reduction in usage of cars and SUVs in OECD countries by 2050 relative to a reference case case. Freight Trucks: The U.S. Federal Highway Administration reports that approximately 25% of mileage for trucks larger than pickups/minivans or light vans are for empty backhauls and empty shipping containers.
Improve	Electric Vehicle Sales Mandate or Target	Vehicle electrification targets set criteria for the minimum number or percentage of electric vehicles that must be sold in a given year. Electrification policies should include interim targets, with a steady increase leading to the desired final year value. Because electric vehicles are still an emerging technology, vehicle electrification policies are often coupled with rebates or other incentives to encourage consumers to invest in the often more expensive electric vehicle.	Passenger LDVs: California's Zero Emission Vehicle (ZEV) program requires automakers to sell ZEVs in California and 10 other states, which will likely require about 7% to 10% new vehicle sales in 2025. California recently passed an executive order to phase out sales of new gas cars by 2035, which would be equivalent to a setting of 100% in 2035. Freight Trucks: Today, the share of electric freight trucks is very low, but electrification is particularly promising for certain types of trucks, such as those used to make deliveries within cities, those involved in port operations, garbage trucks, and others with frequent starts and stops. Passenger HDVs: Electric bus manufacturer Proterra believes all new transit bus sales could be electric as early as 2030, but transit buses make up roughly 15% of the bus fleet.
Improve	Fuel Economy Standard	Fuel-economy standards are minimum fuel efficiency standards for new vehicles. These standards curb GHG emissions by improving the fuel efficiency of the new vehicle fleet. Fuel-economy standards should be administered upstream to capture 100 percent of the market for new vehicles, requiring each vehicle manufacturer to meet a fleet average fuel-economy standard for all new vehicles sold during a year.	LDVs: U.S. combined fuel economy standards for cars and light trucks were 35.5 mpg in 2016 and are scheduled to rise to 54.5 through 2025, then remain constant. The National Research Council has identified a maximum 4.5% annual improvement in LDV fuel economy through 2040, which corresponds to a policy setting of 88% (NRC 2013). Passenger HDVs: U.S. fuel economy standards for heavy-duty vehicles vary by vehicle characteristics, but proposed standards for vocational vehicles (the category that includes buses) would reduce GHG emissions by 24% for 2027 model year vehicles relative to the 2018 model year, then remain constant. Extrapolating this trend to 2050 would imply an 85% improvement relative to 2018, compared to a 40% improvement relative to 2018 in the reference case. This could be represented by a policy lever setting of 45%. Freight HDVs: U.S. fuel economy standards for heavy-duty vehicles vary by vehicle characteristics, but proposed standards for combination tractor-trailers (which are responsible for roughly 60% of HDV emissions) would reduce GHG emissions by 25% for 2027 model year trucks relative to 2018 model year, then remain constant. Extrapolating this trend to 2050 would imply an 96% improvement relative to 2018, compared to a 40% improvement relative to 2018 in the reference case. This could be represented by a policy lever setting of 56%.

Source: Fransen et al. 2019, adapted from IEA 2017

ABBREVIATIONS

BAU	Business-as-usual
BRT	Bus Rapid Transit
CACC	Climate And Clean Air Coalition
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalency
DOTS	Transit-oriented Development
EPS	Energy Policy Simulator
EU	European Union
EV	Electric Vehicles
GDP	Gross Domestic Product
GFEI	Global Fuel Economy Initiative
GHG	Greenhouse Gas
HDV	Heavy Duty Vehicles
ICCT	International Council On Clean Transport
ICE	Internal Combustion Engines
LDV	Light Duty Vehicles
LULUCF	Land Use, Land Use Change And Forestry
LRT	Light Rail Transit
$MtCO_2e$	Million Tonnes Of Carbon Dioxide Equivalent
Mt	Million Tonnes
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NOx	Nitrogen Oxides
PM	Particulate Matter
PJ	Petajules
SOx	Sulphur Oxides
SUMPS	Sustainable Urban Mobility Plans
TDM	Transport Demand Management
US	United States
USD	United States Dollar

END NOTES

1. Government support for fossil fuels in 51 countries almost doubled in 2021 as energy prices rose with the rebound of the global economy. In Mexico, petroleum subsidies went from 7,553 USD million in 2020 to 17,927 USD million in 2021. Consumption subsidies are anticipated to rise even further in 2022 due to higher fuel prices and energy use (OCDE and IISD 2022).
2. This report uses the National GHG Inventory 1990-2015 published in the Sixth National Communication (SEMARNAT 2017), which was the latest official one available at the time of the analysis. The 2019 GHG Inventory was published in 2021 (INECC 2022a).
3. EPS Mexico reference case (BAU) and Mexico's GHG emissions baseline are not compatible due to differences in methodologies, data sources, and availability. Any differences between them do not imply an increase or abatement in emissions, since most deviations correspond to differences in data, emission factors, activity levels and methodologies.
4. Fuel efficiency is a result of the average efficiency of all types of vehicles within the same category.
5. However, there is no evidence-based analysis, yet that links reduced and shifted demand with vehicle fleet size.
6. See https://energypolicy.solutions/docs/
7. Energy demand is determined in each sector (industry, construction and transport) and fulfilled from fuel stocks or electricity generation which in turn determines pollutant emissions and cash flows (EI 2015).

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