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FACILITATION OF TRANSPORT AND TRADE IN LATIN AMERICA AND THE CARIBBEAN

Technology and alternative energy use in motor vehicle transport in Latin America and the Caribbean

This document provides background on energy consumption in the road transport sector, and on the advantages and disadvantages of new propulsion technologies in this field.
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Background

In Latin America, energy consumption in the transport sector accounted for 27% of total energy consumption in 2011. Within this category, motor vehicle transport accounted for 90%, as it represents a large share of the travel mix and is heavily dependent on fossil fuels. The Latin American Energy Organization (OLADE) estimates that energy demand in the region could double by 2030. However, the introduction of efficient technologies and greater use of innovative energy sources in transport, such as biofuels and electricity, could reduce energy consumption by 102 million tons of oil equivalent (Mtoe) per year, or 26% less energy than the projected baseline scenario (OLADE, 2013). Part of this process has already begun, as the energy mix in Latin America and the Caribbean shows that the share of fossil fuel energy is decreasing steadily, down from more than 75% in 1990 to less than 72% in 2012, with oil clearly being replaced by natural gas (the share of which increased from 15% to 27% over the same period).

Similarly, the International Energy Agency (IEA) considers that the fuel economy of new vehicles could be improved by as much as 50% by 2030 in a cost-effective manner, which would reduce fuel use by close to 500,000 tons of oil equivalent (toe) and annual carbon dioxide (CO_2) emissions by almost 1 gigaton (ECLAC, 2014a). Thus, in line with the goal of gradually replacing fossil fuels with renewable fuels, alternative fuels are expected to play an increasingly important role in the next decade, including in fostering growth and employment, competitiveness, the decarbonization of transport and diversification of the energy mix. As a result, the transport sector would not only be able to cut its energy consumption, but also reduce its carbon footprint and move towards more sustainable logistics.

This document provides background on energy consumption in the road transport sector, and on the advantages and disadvantages of new propulsion technologies in this field. It also underscores the importance of

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an intersectoral approach to fine-tuning and coordinating policies to achieve the energy efficiency targets required for a sustainable energy future.

Section I of the document analyses emissions and energy consumption in the sector. Section II examines the most commonly used fuels in motor vehicle transport and the most developed technologies. Lastly, section III presents recommendations for successful implementation.

A. Characteristics of freight transport in Latin America

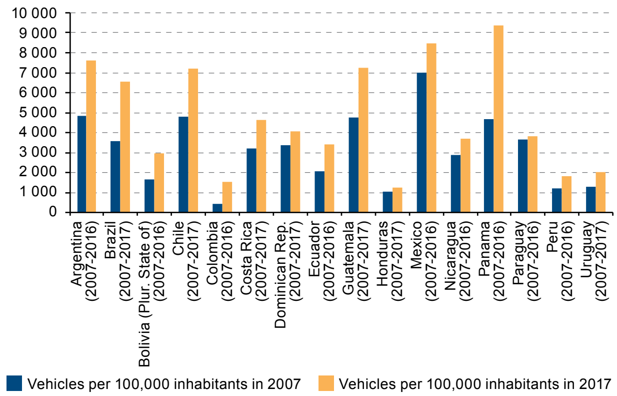
Several aspects of road transport make it particularly attractive for moving general cargo, including its versatility —it can move goods from door to door—; its reliability with respect to meeting deadlines; its modularity and ability to provide high-frequency services; and its ability to facilitate the tracking of vehicles and cargo. Within the road transport category, transport by truck plays a significant role in Latin America, accounting for the lion's share of the domestic cargo transport mix, frequently above 90%.

The expansion of the vehicle fleet, particularly for individual transport, is an important and prevalent issue in the region owing to the challenges it poses in terms of congestion, equitable use of public space and the adverse effects of automobiles on urban mobility. In recent years, diesel consumption has grown in comparison with other automotive fuels, owing mainly to its lower price and the uptick in individual use of sport utility vehicles (SUVs), most of which are equipped with diesel engines. Generally, diesel is cheaper because it is taxed less, as this fuel is typically used in cargo transport, collective passenger transport and agricultural activities. This trend has led to a growing imbalance between product demand and supply in Latin American refineries, with gasoline surpluses and diesel shortages, and worsening local air pollution in cities, since diesel engines often emit higher levels of soot and sulfur oxides (SO_x). In terms of the type of fuel, gasoline engines still dominated the global passenger light-duty vehicle market in 2010, followed by diesel engines, which accounted for roughly 40% of the European and Indian markets (IEA, 2012).

In addition to the higher consumption of diesel resulting from the expansion of the vehicle fleet, there has been a notable increase in the number of heavy-duty vehicles (trucks), as shown in figure 1.

The figure shows that the number of trucks in the region increased on a per capita basis, especially in Panama. Although this could be a reflection of stronger economic growth, it should be carefully analysed since, in several countries of the region, transport companies' excess supply has given rise to transport prices that are lower than real costs or do not cover the fixed costs of equipment maintenance. The expansion of motorization is also the result of vehicles remaining in use beyond the end of their useful life, as will be examined below.

Figure 1
Latin America (selected countries):[a] truck fleet, around 2007 and 2017
(Vehicles per 100,000 inhabitants)



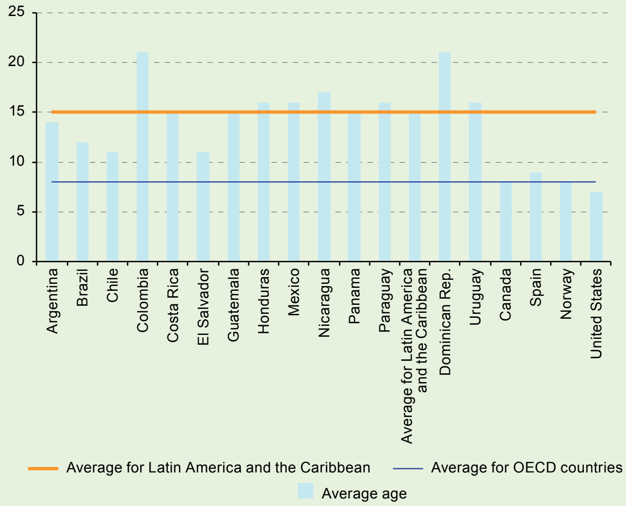
Source: Prepared by the author on the basis of data from the Economic Commission for Latin America and the Caribbean (ECLAC).
[a] Data for all countries are from 2007 and 2017, except in the case of Argentina, the Plurinational State of Bolivia, Colombia, Ecuador, Mexico, Nicaragua, Panama, Paraguay and Peru, where data are from 2007 and 2016.

B. Age of the vehicle fleet and related emissions

It is important to analyse the age as well as the number of trucks in service, although this information is more difficult to extract from national statistics and often corresponds to an underestimation of the real fleet age, as shown in figure 2. Having information on the age of the fleet will allow stakeholders to identify real opportunities to incorporate better technologies that will increase operations' energy efficiency.

This figure shows that the average age of the truck fleet in Latin America is almost double that of OECD countries. This higher average age gives rise to externalities such as increasing emissions of polluting gases, reducing the quality and safety of transport services, increasing fuel consumption, and raising noise levels. These older vehicles lack active and passive safety features for the protection of occupants, which will ultimately affect the number of deaths caused by traffic accidents. Therefore, renewing the vehicle fleet could improve road safety, reduce fuel use, lower emissions and cut the cost of services by generating operating savings. (ECLAC, 2014a).

Figure 2
Latin America and the Caribbean (14 countries) and the Organization for Economic Cooperation and Development (OECD) (4 countries): age of truck fleet
(Years)



Source: Prepared by the author on the basis of Inter-American Development Bank (IDB), *El transporte automotor de carga en América Latina, soporte tecnológico de la producción y el comercio*, Washington, D.C., 2017.

Moreover, other transport equipment, such as trailers and semi-trailers, have been in service for more than 18 years (28%) and more than 13 years (40%). While these mobile units do not have a built-in engine and thus do not produce emissions, their age could increase the likelihood of some of their components failing if they are not properly maintained.

According to the European emissions standards for diesel engines, commonly known as Euro, a 2003 diesel truck (15 years in service) should comply with the Euro III standard, while a 2011 truck (7 years in service) should comply with Euro V, as shown in table 1.

By 2017, only four countries in South America (Argentina, Brazil, Chile and Colombia) had implemented emissions standards stricter than Euro III. Compliance with Euro III was required in Peru and Uruguay. Standards in the Bolivarian Republic of Venezuela, Ecuador and the Plurinational State of Bolivia were weaker than Euro III, while Paraguay had no vehicle emissions standards in place (GFEI, n/d).

Table 1
European emissions standards for heavy-duty diesel engines
(g/KWh)

Type	Date	Test cycle	CO	HC	NOx	PM
Euro I	1992, < 85 kW	ECE R-49	4.5	1.1	8	0.612
	1992, > 85 kW		4.5	1.1	8	0.36
Euro II	Oct. 1996		4	1.1	7	0.25
	Oct. 1998		4	1.1	7	0.15
Euro III	Oct. 1999 EEV only	ESC & ELR	1.5	0.25	2	0.02
	Oct. 2000	ESC & ELR	2.1	0.66	5	0.10
Euro IV	Oct. 2005		1.5	0.46	3.5	0.02
Euro V	Oct. 2008		1.5	0.46	2	0.02
Euro VI	Jan. 2013	ESC & ELR	1.5	0.13	0.4	0.01

Source: Prepared by the author on the basis of information from the European Union.
Note: EEV: Enhanced environmentally friendly vehicles.

I. Greenhouse gas emissions and energy consumption

Air pollution poses a significant risk to human health. It was estimated to cause 4.2 million premature deaths worldwide per year in 2016 owing to exposure to small particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$), which causes cardiovascular and respiratory disease, and cancers. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma (WHO, 2018).

When analysing the energy consumed and fuel emissions in the transport sector the different phases in the processes that underpin the provision of transport for people or goods must be considered (see table 2). The first phase accounts for the energy expended in the steps required to extract the primary energy source and deliver the fuel to the vehicle, or well-to-tank (WTT). The second phase leads to motive power, whereby the energy stored in the vehicle's tank (or battery) is converted into traction power that can move the vehicle and its payload, or tank-to-wheel (TTW). WTT and TTW analysis are sometimes combined to calculate the total energy consumption involved in the energy transformations and the vehicles' operational characteristics, known as well-to-wheel (WTW).

Alternative fuels are an important part of the public discussion on transport and, although most reduce greenhouse gas emissions and dependence on oil products, few reduce final energy consumption. The details and potential of each alternative fuel are outlined below.

II. New combustion technologies for mobility and cargo logistics

As discussed in the previous section, the transport sector uses mainly non-renewable fuels, particularly diesel, because of its competitive edge over alternatives and the difficulties of replacing it on a large scale. However, automobile manufacturers have been developing increasingly efficient engines that use other sources of energy, such as natural gas, liquefied petroleum gas (LPG), electricity, biofuels and hydrogen.

The development and massification of this new generation of vehicle not only depend on engine combustion technology, but also a series of other factors including fuel availability, supply network coverage and the availability of maintenance and spare part services. With regard to cutting-edge technology, such as electromobility, hydrogen or even natural gas, energy efficiency savings and reducing other negative externalities, such as pollution in its various forms, justify not only private but also public investment given the social benefits that these technological changes could bring to society as a whole. Hybrid propulsion systems in buses are one example, as they can reduce fuel consumption by up to 30%, depending on the type of journey, but they still require around 25%–30% more investment than conventional options. Some European Union countries have taken various measures to promote vehicle replacement in order to take advantage of this technological shift. In Belgium, for example, car owners receive bonuses for replacing old cars with ones that produce CO_2 emissions lower than 146 gr/km. In Stockholm, a congestion charge is applied to non-electric vehicles. In other countries, highway tolls also depend on a vehicle's emission levels (UNECE, 2015).

Some energy sources used for transport around the world, including their main characteristics and differentiating elements, are set out below and their relative market penetration analysed.

Table 2
CO_2 emissions produced and energy consumed during the well-to-tank, tank-to-wheel and well-to-wheel stages

Vehicle type	CO_2 emissions *(g/km)*			Energy consumed *(MJ/100km)*		
	WTT	TTW	WTW	WTT	TTW	WTW
Electric	78	0	78	118	52	170
Gasoline and electric hybrid	36	75	111	52	116	168
Diesel and electric hybrid	36	68	105	52	107	159
Biodiesel	-101 to -22	125	44 to 103	45-437	163	207-600
B7 – diesel containing up to 7% v/v fatty acid methyl esters (FAME) (Biodiesel)	14-19	120	137-140	31-56	163	193-219
Ethanol	-127 to 30	146	19-176	187-427	204	391-630
E10 – gasoline containing up to 10% v/v ethanol	17-28	150	166-178	48-64	204	252-268
E85 – gasoline containing up to 85% v/v ethanol	-82 to 29	143	61-171	142-312	199	341-459
Compressed natural gas (CNG) (European Union mix)	30	132	163	38	232	271
Biomethane	-290 to -33	132	-158 to 99	231-503	232	463-736
Liquefied petroleum gas (LPG)	17	142	160	26	216	241
Gasoline	29	156	185	39	211	250
Diesel	25	120	145	33	163	196

Source: Joint Research Centre of the European Commission (JRC), "Well-to-Wheels analysis of future automotive fuels and powertrains in the European context", *WELL-TO-WHEELS Report Version 4.a*, 2014.

A. Biofuels

Biofuels are already included in the transport fuel list (for example, E10, E85 and B7) and infrastructure is in place to supply them in areas where they are widely used (for example, ethanol in Brazil). They are currently the most commonly-used alternative fuels and are blended with conventional fuels (ethanol-gasoline and biodiesel-diesel). A gasoline automobile works better with a blend containing up to 20% ethanol, which does not require engine modifications, as it increases the engine's power and decreases consumption. At the global level, biofuels accounted for 2% of fuels used for transport worldwide in 2012 and this share is expected to continue growing, to 3% by the end of the current decade, 3.8% by 2030 and 4.6% by 2040 (IEA, 2017b).

Biofuels are obtained from a wide range of materials and can be used directly or mixed with conventional fossil fuels. They include bioethanol, biomethanol, biodiesel made from vegetable oils, dimethyl ether (DME) and organic compounds, and are grouped by generation. First-generation biofuels include ethanol produced using crops rich in sugar or starch and fatty acid methyl esters (FAME) biodiesel made from vegetable oils. Second-generation biofuels are made from non-food raw materials, lignocellulosic materials, the organic elements of solid and liquid waste, vegetable oils, animal fats, and forest and agricultural waste. They include bioethanol and biodiesel produced using conventional technology, starch bases or energy crops. Production technologies for this generation of biofuels tend to be more complex and costlier than those of first-generation biofuels, and are generally considered more sustainable, with the potential to produce fewer greenhouse gas emissions. Third-generation biofuels include those made from algae, biomass hydrogen and synthetic methane.

Most current production uses agricultural crops such as corn, sugarcane and rapeseed, although just 1% of globally available arable land is used to produce biofuels. Overall, 16% of global vegetable oil supplies (rapeseed, soybean, palm and sunflower) were used for biodiesel production, and around 15% of the world's corn was used to make bioethanol. Based on an assessment of the availability of sustainable biomass, it is estimated that biofuels derived from forest residue and waste could supply between 12% and 15% of energy to the transport sector in 2030, representing total greenhouse gas savings of around 8% to 11%.

The cost of vehicles and infrastructure is not a barrier to the introduction of biofuels to the market, as, up to certain concentrations, they are already compatible with the existing fuel distribution infrastructure. The highest blends require some vehicle modifications, notably the materials used for fuel lines and engines. Second- and third-generation biofuel production requires more start-up capital, so long-term initiatives are essential to finance this type of project.

Biofuel blends could produce slightly less particulate matter, carbon monoxide (CO) and hydrocarbon (HC) emissions, but increase nitrogen oxide (NO_x) emissions and produce other pollutants such as aldehydes. Bioethanol blends would reduce NO_x emissions significantly.

B. Natural gas and biogas

Natural gas and biomethane are considered to be the same fuel (CH_4, methane). However, natural gas is a fossil fuel, while biomethane comes from renewable energy sources or raw materials (energy crops, agricultural waste, organic fraction of livestock manure or sewage sludge) and must be treated for use in engines. Global natural gas reserves are accessible and vast, exceeding oil reserves considerably. Moreover, it is estimated that available reserves have increased almost threefold in recent years, thanks to new extraction techniques.

Technological maturity has given rise to a wide range of automobiles, buses and trucks with combustion engines that run on compressed natural gas (CNG) or liquefied natural gas (LNG), as natural gas is the only alternative fuel that can compete with the energy efficiency and performance of diesel engines (JRC, 2014). In the case of CNG, natural gas must be compressed to 200 bar and dispensed in a gaseous state. LNG must be handled in a cryogenic liquid state (at - 162 °C). The construction of regasification terminals has provided non-producer countries with access to LNG from international markets at more competitive prices. There is an extensive refuelling network in some countries that can supply both types of gas to the same facility thanks to satellite regasification plants. The gases are distributed through gas pipelines or by tankers (in the form of LNG).

Driving autonomy ranges from 500 to 900 km with CNG (plus reserve gasoline), while it exceeds 1,000 km with LNG, and is even higher with converted mixed-fuel engines (diesel-gas).

Using natural gas and biomethane produces low levels of polluting emissions (mainly NO_x), almost zero SO_x emissions and zero particulate matter emissions. Another advantage is that noise levels are lower compared with traditional fuels.

C. Liquified petroleum gas (LPG)

LPG is a mixture of hydrocarbons (propane, butane and small percentages of propylene and butylene) and is produced naturally during natural gas processing and oil refining. It is stored in liquid form in pressurized tanks but is converted to vapour in the vehicle's engine. It is distributed to service stations in tankers and has an extensive supply network in countries where it is widely used.

As LPG is produced along with natural gas and oil products, it is expected to remain readily available. Renewable bioLPG can also be produced through the gas-to-liquids (GTL) process, which synthesizes natural gas into liquid fuel. In the future, there are plans to use wind energy to synthesize liquid fuels by harnessing excess electricity and capturing atmospheric carbon in the form of CO_2, known as power-to-liquids (PtL).

The use of LPG in Otto cycle (spark ignition) engines has been rising in recent years, driven by the supply of enabled vehicles and growth in charging infrastructure, which is very similar to that of traditional fuels in terms of equipment and cost. Moreover, the main markets for this type of fuel have developed conversion models for vehicles that are already in service and are constantly producing parts, so those vehicles can continue to be used.

The latest technological advances have shown that the injection of LPG in liquid form improves volumetric efficiency and produces a cooling effect that enhances engine efficiency. Thanks to its simple chemical composition and gaseous combustion, LPG mixes easily with the air in the engine and its combustion properties are generally superior to those of liquid fuels. Burning LPG produces virtually no emissions of particulates and less NO_x, HC and CO than traditional fuels (JRC, 2014).

D. E-mobility

Electric transport, or e-mobility, is being developed aggressively by several vehicle manufacturers, who are constantly improving battery technology in terms of performance and cost. Meanwhile, the network of charging stations is still being developed to improve recharging times and the number of supply points.

An electric vehicle's autonomy is determined by the number of batteries it has, and each additional battery also means extra weight to be propelled by the engine. Vehicle electrification helps to reduce greenhouse gases and noise levels, and electric vehicles do not produce emissions of NO_x or particulate matter when operating in electric mode. Nevertheless, sustainability depends on the source of electricity generation, so it is fundamental that countries move towards a renewable and low-carbon energy mix to ensure that this solution is sustainable.

E. Hydrogen

Hydrogen (H_2) is obtained through steam methane reforming (the decarbonization of hydrocarbons) or from renewable energy (electrolysis). Production methods differ in terms of cost, environmental performance, efficiency and technological maturity. Hydrogen can be stored in large quantities in underground salt caverns or as part of a network's natural gas mix. It can be converted to synthetic methane (CH_4) by reacting it with CO_2 produced from biogas waste products or taken from the atmosphere. This synthetic natural gas (SNG) has the same chemical composition as natural gas and biomethane, and can therefore be injected as a blend (up to 5% of H_2 is permitted in the gas network). In terms of mobility and fuel supply, it does not require a change in user habits and offers substantial benefits with respect to environmental and energy sustainability.

At present, hydrogen is produced in large quantities mainly for industrial and refining purposes, hydrodesulfurization and other production processes. However, hydrogen used in fuel cells must be highly purified so as not to affect their performance. This fuel is considered one of the key large-scale energy solutions in the long term, but its limited autonomy must be resolved. A tank of hydrogen stored at 800 bar produces 13% of the energy that the same amount of diesel would generate. In 2008, the public and private sectors joined forces to form the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), with the aim of promoting coordination and collaboration throughout