ISBN: 978-628-96613-1-6. ISSN: 2414-6390. Digital Object Identifier: https://dx.doi.org/10.18687/LACCEI2025.1.1.1536

Energy impact of the introduction of light vehicles for private use in Peru in the medium-term

Russell Nazario Ticse[1], José Ramos Saravia[2], María Quintana Caceda[3], Jorge Wong Kcomt[4], and James Cieza Untiveros [5]
[1]Universidad Tecnológica del Perú, UTP, Perú, c27457@.utp.edu.pe
[2]University of Engineering & Technology, UTEC, Peru, jramos@utec.edu.pe
[3] Association of Energy Engineers, USA, jwong@aeecenter.org
[4,5]Universidad Nacional de Ingeniería, UNI, Perú, mquintana@uni.edu.pe, james.cieza.u@uni.pe

Abstract*– In many countries, road transport is dominated by vehicles with internal combustion engines, whether gasoline or diesel, which represents a challenge for decarbonization in the world. In industrialized countries there is an interest in electric vehicles, Peru is no exception. In order to achieve the emissions reduction objectives, to improve air quality and to reduce GHG, reducing fossil fuel imports and progressively eliminating energy dependency. The impact of electric vehicles on the consumption of fossil fuels and the effects on energy consumption in the transportation sector in Peru were studied. This analysis begins by creating scenarios with different rates of penetration in the local market, with the purpose of forecasting the demand for fossil, as well as the electricity demand that will be generated, LEAP methodology was used for this. In the BAU scenario, the CO_2 emissions projections are made without the introduction of this new technology, then different scenarios are created for different EV penetration rates. The results evaluate how its diffusion impacts the environment in the reduction of polluting emissions. In the moderate scenario (AAP), a reduction in energy consumption of 3.87% is expected, indicating that 6.2x106 GJ of electrical energy will be needed, which represents a 4.75% reduction in GHG. This indicates that electric vehicles are an option to improve the air quality of Lima since it is the city with the worst air quality in Latin America.

***Keywords*-- EV penetration rate, Environmental impact, Electric vehicles, LEAP methodology, Energy demand.**

I. Introduction

Global warming and its effects are of great concern to the scientific community, which is why there are efforts to minimize the use of fossil fuels in energy generation and transportation. The transport sector represents 23% of global CO2 emissions derived from the burning of fuels in vehicles of all types [1]. Of this amount of emissions, road transport represents 77% [2].

In Peru, especially in Lima, due to its high degree of centralism, lack of urban planning, rapid population growth and automobile fleet, problems such as: traffic, noise, air pollution, road accidents and arise; causing the transportation sector to be in a critical and chaotic situation. The automotive park is the largest consumer of energy in Peru since it represents 43% of the demand in the energy matrix. In addition, it contributes 40% of the CO2eq emissions of the energy sector [3]. Furthermore, GHG emissions have an annual growth rate of 3%. According to WHO, this places Lima in 22nd place among the most polluted capitals in the world; this environmental pollution causes respiratory and heart diseases. In Lima, more than 15 thousand people die every year from these cases [4]. Therefore, transportation and the pollution it emits have an impact to a certain degree on public health, so in order to apply policies in the transportation and health sector, information on air quality, noise, safety and other health problems must be available [5]. According to the National Society of Mining, Petroleum and Energy (SNMPE) of Peru, Peru's hydrocarbon trade balance has shown negative results for some years, and this situation has worsened in recent months because it already registered a deficit balance of US$ 3,587 million in 2017 [6]. This makes Peru a country increasingly dependent on oil and its imports, affecting its trade balances, that is, Peru becomes an energy-dependent country and more economically vulnerable.

That is why the government of Peru must urgently focus on solving these problems and mitigating the adverse impacts generated by land transportation. So, a more efficient and environmentally friendly transportation system is needed. To reduce emissions of air pollutants in urban areas, a change to electric vehicles should occur. Current transportation's impact on community health is a growing concern in both developed and underdeveloped countries [7]. Oil production in Peru is decreasing year after year, a non-renewable resource that is increasingly difficult to find, and imports are increasing. Many countries, like Peru, are increasing their dependence on oil to a concerning degree, which is why in many countries there is a conscious decision to start the process of vehicle electrification, resulting in multiple benefits: reduction of cost, energy security, public health and care for the environment. To do this, the electricity supply must be increased by increasing the capacity of hydroelectric plants, as well as greater use of renewable energies (solar and wind); Peru has this energy potential. Therefore, Peru needs to carry out studies to create an ecosystem that helps in the introduction and massification of electric vehicles, promoting more efficient and ecological transportation, as well as reducing dependence on fossil fuels. For this reason, the objective is to determine and evaluate the energy demand of the vehicle fleet, considering various penetration rates of light electric vehicles.

That is why the government of Peru must urgently focus on solving these problems and mitigating the adverse impacts generated by land transportation. So, a more efficient and environmentally friendly transportation system is needed. To reduce emissions of air pollutants in urban areas, a change to electric vehicles should occur. Current transportation's impact on community health is a growing concern in both developed and underdeveloped countries [7]. Oil production in Peru is decreasing year after year, a non-renewable resource that is increasingly difficult to find, and imports are increasing. Many countries, like Peru, are increasing their dependence on oil to a concerning degree, which is why in many countries there is a conscious decision to start the process of vehicle electrification, resulting in multiple benefits: reduction of cost, energy security, public health and care for the environment. To do this, the electricity supply must be increased by increasing the capacity of hydroelectric plants, as well as greater use of renewable energies (solar and wind); Peru has this energy potential. Therefore, Peru needs to carry out studies to create an ecosystem that helps in the introduction and massification of electric vehicles, promoting more efficient and ecological transportation, as well as reducing dependence on fossil fuels. For this reason, the objective is to determine and evaluate the energy demand of the vehicle fleet, considering various penetration rates of light electric vehicles.

II. State of the Art

The electrification of transport is the primary measure to achieve a sustainable road transport system; emissions will depend on each electricity market, that is, the primary sources used for its generation [8]. Then, there is great interest in electrifying mobility, but due to its technological nature it has limitations that slow down its adoption, and this in turn generates great interest in academics, governments, and other institutions to study what the benefits are in different penetration rates when automotive market [9]. The deployment of electric vehicles began in 2010, today there are more than 10 million on the world's roads, in 2020 it had an increase of 41%, since approximately 3 million electric vehicles were sold worldwide (a share sales of 4.6%) [10], as shown in figure 1. Although a greater presence of EVs is indeed felt, they are still unknown in emerging markets such as Peru.

Technological advances are generating significant cost reductions, developments in battery chemistry and expansion of production capacity at manufacturing plants are key enablers of this [10]. Policies play a critical role, leading countries in electric mobility use a variety of measures such as; fuel economy standards along with incentives for zero and low-emission vehicles, economic instruments that help close the cost gap between electric and conventional vehicles, and support for the deployment of charging infrastructure. This can also open doors to many microbusinesses, like charging stations with renewable sources such as solar and wind, taking advantage of the energy potential, on the long journeys between the cities of Peru.

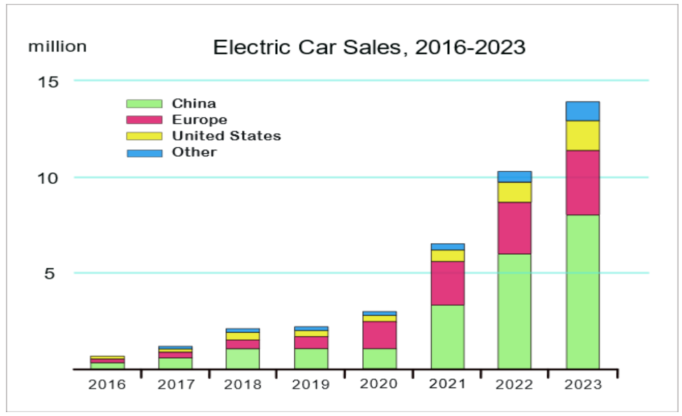

Fig. 1 Distribution of EVs in the world (IEA, 2021).

These dynamic developments underpin a positive outlook for further deployment of electric vehicles and charging infrastructure. In 2030, two scenarios are proposed, the first is the New Policies Scenario, which indicates that there will be global sales of 23 million and stock that exceeds 130 million, which implies a reduction of 127 million tons of the oil equivalent (approximately 2.5 million barrels per day mb/d) and an electricity demand of 640 TWh. While the most ambitious scenario, the EV30@30, expects sales of 43 million worldwide and a stock of 250 million, a reduction of 4.3 mb/d is estimated, and an electrical demand of 1110 TWh [10].

A. *Peruvian Transportation Sector*

According to the energy matrix of Peru, the transportation sector consumes 43% of the total energy, as shown in Figure 2, and is responsible for 21% of CO_2 emissions since it is a large consumer of fossil fuels. Diesel and gasoline are mainly used in cargo transportation.

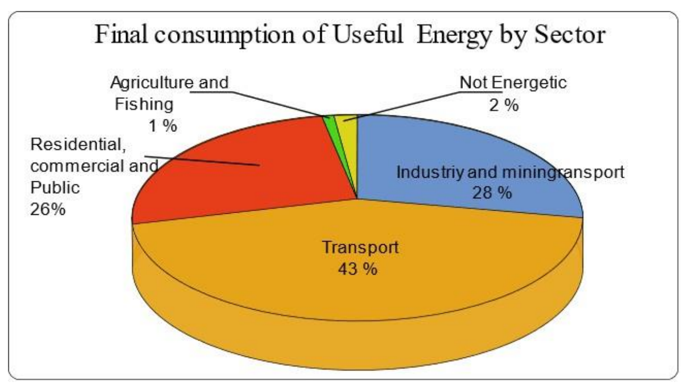

Fig. 2 Final consumption of useful energy by sector, MINEM source.

The transportation sector in Peru, as in many countries in the world, has a high dependence on fossil fuels, such as gasoline and diesel [11]. Since the beginning of the millennium, the introduction of gas vehicles was gradually introduced, reaching 10% of the total use of energy consumption in the sector. The cost of conversion, since imported cars do not have a gas system, that is, the consumer has to make a conversion, and this means that their use continues to stay away from being widespread. The transportation sector has a very high dependence on liquid hydrocarbons, this causes the sector to consume 74.7% of hydrocarbons making it the majority, as shown in Figure 3.

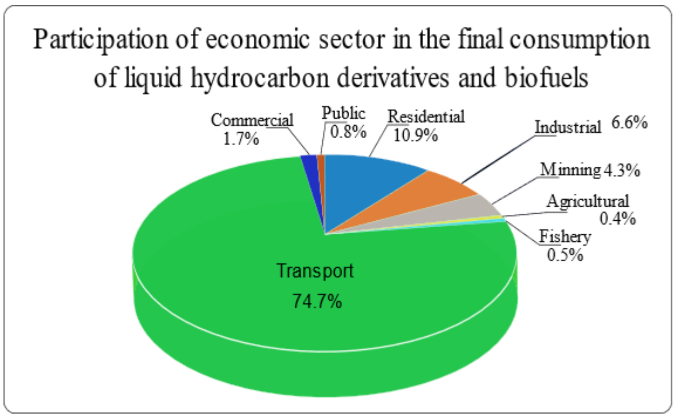

Fig. 3 Participation of economic sectors in the final consumption of liquid hydrocarbon derivatives and biofuels in Peru, source MINEM.

Road transport consumes 5 types of fuel as shown in Table I, this depends on the type of vehicle, in this case for the transport of passengers in light gas vehicles.

TABLE I
FINAL CONSUMPTION OF THE ROAD TRANSPORT SECTOR. MINEM

Fuel	*United*	*2017*	*2018*
LPG	MBLS	5916.8	6359.2
Gasohol	MBLS	14726.3	15422.2
Gasoline Motor	MBLS	1967.6	2065.6
DieselB5	MBLS	32798.9	33937.1
Natural Gas	MMPC	25735.5	26184.1

B. Characteristics of the Lima Automotive Park

Our vehicle fleet is 13 years old. In passenger transport, 58% of vehicles use Diesel, 33% LPG, 5% CNG and 4% Gasoline. In recent years, a notable increase in the conversion process from units that use gasoline to the use of liquefied petroleum gas and the use of natural gas for vehicles has been observed. As can be seen in Figure 2, in Peru, the land transport sector represents 43% of total Peruvian energy consumption. This mode includes light passenger vehicles (VLP): cars and vans, cargo trucks of different sizes, passenger transport vehicles, motorized vehicles with two or three wheels (scooters, motorcycles, tricycles, etc.), and trains, both cargo and passenger. In the case of Peru, in terms of useful energy, three-quarters of consumption corresponds to three uses, with the participation of the transportation driving force being the highest percentage, process heat and process driving force. From Figure 4, the main energy source of the transportation sector in the world is 93% petroleum derivatives, the highest percentage corresponds to DB5 (diesel), which is a mixture of 95% diesel and 5% biodiesel. Likewise, in the case of Peru, we have as a reference the world's energy consumption in terms of percentage, where a large percentage (more than 90%) corresponds to petroleum products and only a small percentage of 7% corresponds to other energy sources such as natural gas, biomass, electricity and natural coal. For Peruvian transportation, table II shows the distribution of vehicles according to fuel.

TABLE II
DISTRIBUTION OF VEHICLES ACCORDING TO THE FUEL THEY USE [11].

Fuel Type			**LPG**	**VNG**	**Diesel**	**Gasoline**
Type of Vehicle Registered 2007-2016 (%)	Car		7.88	9.31	0.15	82.67
	Station Wagon		7.99	29.80	8.09	54.12
	Van	Pick up	1.06	0.29	89.60	9.05
		Rural	3.22	0.87	18.78	77.14
		Panel	9.85	3.40	17.95	68.81
	Bus		0.56	11.98	83.49	3.96
	Truck		0.30	0.31	98.40	3.96
	Tractor		0.00	1.10	98.82	0.08

The rapid growth of energy demand and GHG emissions in the transportation sector in the last decade was affected by the importation of vehicles starting in 1992 and the greater purchasing power of the Peruvian population starting in 2002, (as shown in Figure 4), in turn, government policies identified the conversion of cars with engines powered by less polluting fuels with, in the case of LPG and CNG, scrap.

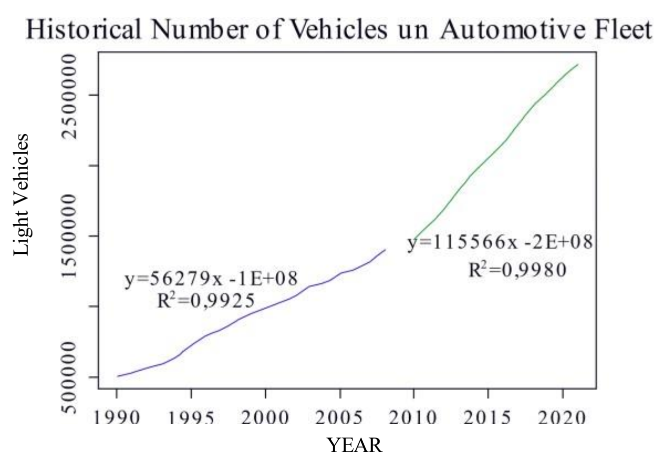

Fig. 4 Participation of economic sectors in the final consumption of liquid hydrocarbon derivatives and biofuels, MINEM source. own elaboration.

Another evidence that economic growth has modified the quality of the vehicle fleet is that since 2009 there has been a greater purchase of new vehicles over used vehicles, as shown in Figure 5, since the entry of lower-cost Chinese brand vehicles and the facilities purchases are leading to greater acquisition of new vehicles. Figure 6 shows that there is a greater acquisition of SUV model vehicles, another sign that the purchasing power of the national market is increasing.

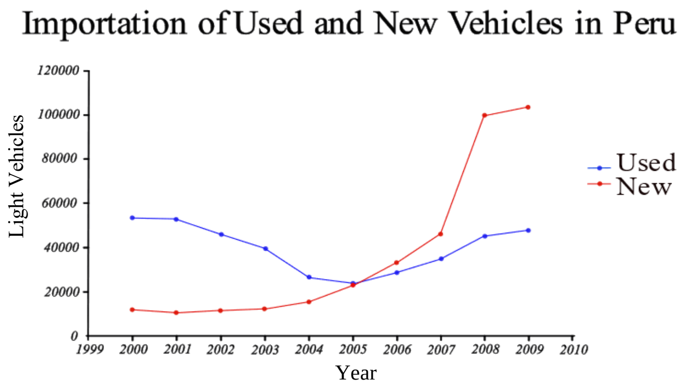

Fig. 5 Importation of used and new vehicles in the national market. Source: INEI, own elaboration.

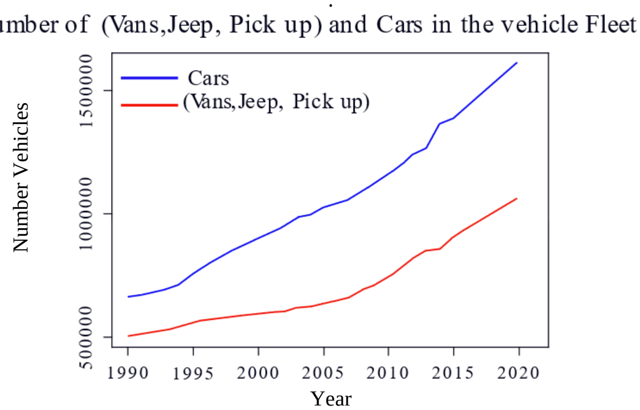

Fig. 6 Numbers of Vans and cars in the vehicle fleet. Source: INEI, own elaboration.

The importance of knowing the distribution of vehicles is to know the performance, that is, how many gallons are consumed per km traveled. Figure 7 (passengers) shows the average performance in km/gallon of different types of vehicles and fuels, at the national level, for passengers.

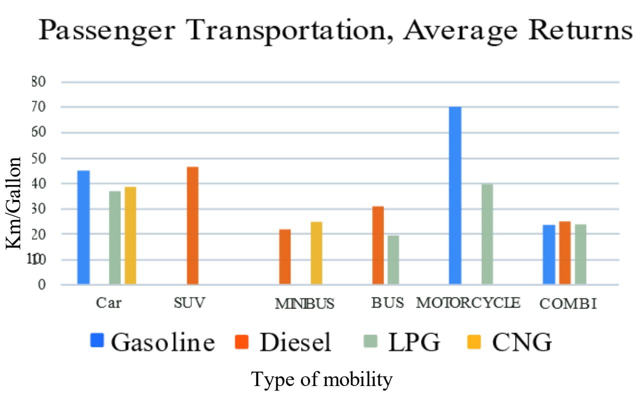

Fig. 7. Passenger transportation. Average returns. Source National Balance of Useful Energy [12]

As is already known, the main fuel used in the vehicle fleet is oil and its derivatives, but we want to know the percentage of participation for each type of fuel. Passenger transport uses oil and LPG Regarding the type of fuel used in the passenger transport fleet, the largest share is “diesel” with 58%, 33% LPG, 5% CNG, and 4% Gasoline. As seen in Table III, the percentage of vehicles intended for passenger transportation that uses each of the mentioned fuels can be seen [12].

TABLE III
PERCENTAGE OF VEHICLES INTENDED FOR PASSENGER TRANSPORTATION ACCORDING TO FUEL USED [12].

Passenger transport	
OIL	58.1 %
LPG	32.53 %
CNG	5.45 %
GASOLINE	3.94 %

C. *Environmental Problems Due to the Transportation Sector*

The main problems that the city of Lima has are; firstly, public safety since 81.1% of Lima residents consider it to be the main problem that affects the quality of life of Lima habitants. Secondly, public transportation, 49.4% of Lima residents consider public transportation as the main problem of the city and 20.6%. environmental pollution and 14.9% the lack of citizen culture [13], as shown in Figure 8.

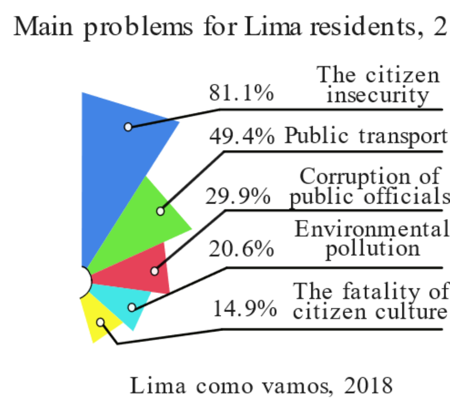

Fig. 8F Social Problems in Lima. According to Lima, how are we doing in 2018? [13].

Table IV shows the main mode of transportation in Lima, where it is observed that 68.2% use public mobility or mass transportation and that only 10.8% use private transportation [14]. The poor consumption of fossil fuel brings many direct and indirect consequences that affect the population of Lima, to give some examples, global pollution (greenhouse effect) and local pollution (particles, soot, carbon, sulfur, lead, etc.). Consequences such as an increase in respiratory diseases, allergies, an increase in the mortality rate. Additionally, it can cause increased stress in people [15],[16]. Table V shows the main mode of transportation in Lima, where it is observed that 68.2% use public mobility or mass transportation and that only 10.8% use private transportation.

TABLE IV
THE MAIN MODE OF MOBILIZATION OF CITIZENS WITHIN THE CITY METROPOLITAN LIMA AND CALLAO, 2018. SOURCE [13].

Type of Mobility	Lima	Callao
Combi or custer (custer)	29.2%	39.4%
Bus	29.1%	23.6%
I walk or go on foot	12.0%	13.0%
Own car	10.8%	11.1%
Mototaxi (tuk tuk)	4.5%	2.9%
Metro of Lima	3.0%	0.0%
Metropolitan	2.9%	0.5%
Taxi Collective	2.3%	5.8%
Complementary Corridors	1.7%	0.0%
Own motorcycle	1.5%	1.0%
Taxi Normal	1.2%	0.5%
Bicycle	1.1%	0.0%
Other	0.6%	2.4%

The distribution of the vehicle fleet and the choice or preference of means of travel make some of them more polluting than others per passenger per kilometer traveled, as shown in Figure 10. In Lima today, the transport of one million passengers by taxi generates 250 MT CO_{2equ} vs 15 MT CO_{2equ} by Metro [3]. In Peru, the Transportation Sector represents 48.5% of GHG emissions.

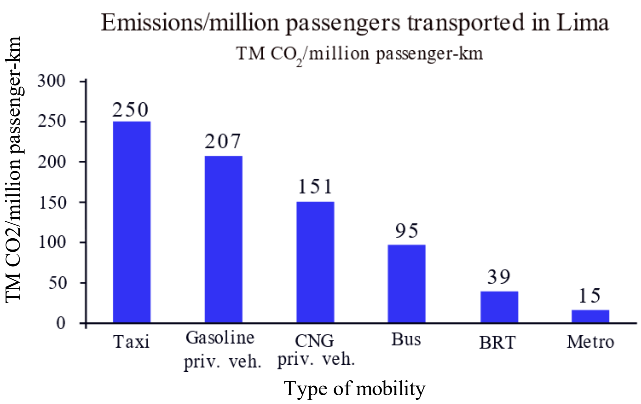

Fig. 9. Emissions/Million Passengers transported in Lima (TM CO2 / million passenger-km), source [3]. own elaboration.

In other words, this makes the transportation sector the main emitter of greenhouse gases, which represents an important agent for studying, analyzing, optimizing, or mitigating GHG emissions, even more so when there are deficiencies in a sector.

III. METHODOLOGY

D. LEAP methodology for the study of energy impact

Energy system models were reviewed, finding different methodologies used for this purpose. The purpose is to generate an energy and environment model, for thus a proposal to create scenarios considering different penetration rates of electric vehicles in the Peruvian market and analyze how these rates influence energy consumption by considering the energy supply and demand of the national market by 2030 was made. Motivated by the current policy as well as the national and international commitments of Peru for 2022, that is why it, was decided to use the LEAP program since it is an integrated modeling tool based on scenarios that can be used to observe energy demand [17],[18], production and resource extraction in all sectors of a national economy [19].

According to [20], crude oil exports and imports play a crucial role in the trade balance of Colombia, Ecuador and Peru. Faced with declining oil production rates and growing demand, these countries are studying fossil fuel-saving measures [21]. However, studies on the long-term effects of these measures are lacking. Long-term scenarios were created by using a LEAP model, analyzing future fossil fuel energy demand and electricity supplies. A review has been carried out of some studies on energy modeling and planning obtained in the literature of recent years [20]. Using the LEAP methodology in different regions, both developed countries (China, Korea, Thailand) and developing countries (Iran, Ethiopia, Pakistan, Turkey, Bangladesh, Nigeria, Malawi, Argentina, Brazil, Chile, Colombia, Ecuador, Peru, Bolivia and Panama), were studied. In Türkiye [22], carried out a study on energy planning and, used LEAP as an energy modeling tool, to study and explore the energy efficiency and CO_2 emissions reduction potential of the metallurgical industry in Turkey to 2030. In Iran [23], LEAP was used, to study various energy supply and demand management strategies, including the use of electric stoves instead of natural gas-fueled stoves.

In Chile [24], a study on their energy system was carried out, supply and emissions for Chile to 2030, a long-term energy plan was developed that includes all sectors of Chile, describing alternative energy scenarios and analyzing current policy. In this same country [25], a study on the electrical system to analyze the impacts on the planning of the expansion of the electrical system with the implementation of taxes on CO_2 emissions and local pollutants in five different relevant scenarios was [26]. The policies create scenarios with the introduction of both large-scale distributed generation power plants based on renewable sources, in particular, adding 1.5 GW of hydroelectric capacity to the Chilean system allows for avoiding around 32 GWh of fossil fuel generation per year, saving more than 1.5 billion dollars over the 10-year horizon considered. In Colombia [27], a study for long-term energy planning using LEAP, having 2015 as a base year and with two future scenarios (positive and negative), this research allowed the projection of energy demand for 2030 and 2050, as well as the amount of emissions of CO_2 for two different scenarios. In Peru [28], a study on residential demand was, having 2017 as a base year and a projection to 2050. In Ecuador [29], a forecast study in the energy sector to 2030 was, using the LEAP model, according to its model and the proposed considerations it will result in a final energy consumption of 158 million BOE (Barrels of Oil Equivalent) in 2030 [30]. The transportation sector is the main consumer of energy. In addition, energy savings of 15 million BOE are forecast, as well as the reduction of GHG emissions. In Argentina [31], the LEAP model was to evaluate the impact of a variety of long-term climate change control, on primary energy consumption, final energy consumption and electricity. The results indicate that the ProBiomass program will reduce GHG emissions by 16% compared to a normal scenario. A low CO_2 price scenario in LEAP results in the replacement of coal by nuclear and wind power in electricity expansion. These models predict reductions of approximately 37% and 94% in the high CO_2 price scenario, respectively. In comparison, the LEAP model, which uses an approach based on the evaluation of a limited set of mitigation options, predicts a reduction of 11.3% [32].

E. Case Study

This study proposes a general approach to medium-term transportation sector planning for Peru. Energy security and the reduction of environmental emissions have become priorities to ensure the supply of energy at affordable costs, for continued economic growth and development. These issues it depends not only on the supply of renewable energy, which already plays a vital role in the long-term future of sustainable development, but also on, the modification of demand, that is, changing what is consumed as an energy source. Up to now, there is no scientific study in the literature related to all models of the energy sector, specifically the transportation sector for Peru. As mentioned previously, scenarios will be created with different penetration rates of Electric Vehicles in the Peruvian market, with the intent of measuring the energy and environmental impact of the introduction of Electric Vehicles.

The information available is variable and the supposed growth is:

- Key assumptions:
  - Population growth 1.0%
  - Economic growth 4.0%
  - Vehicle fleet growth 1.0%
- Energy resources
  - Oil reserves
  - Hydroelectric potential
  - Energy imports and exports
- Energy demand
  - Consumer sectors
  - Residential
  - Production Industry
  - Commercial and public
  - Transport

F. Energy Analysis for Peru

Peru and Lima in particular may need assistance with the planning, construction and financing of the Lima metro, which is planned to carry 4 million passengers. Full electrification of new buses and private vehicles will require these technologies to become the new regulated standard for transportation use; this will only happen if it is the case globally, given the interconnected nature of global transportation manufacturing and the economies of scale needed to make battery and fuel cell vehicles affordable. While electric buses and cars are probably already cheaper than their fossil counterparts on a life cycle basis, and may eventually be cheaper than petrol and diesel versions up front depending on what happens to battery costs, they currently cost more [33].

Policies are needed to address this, including but not limited to low-cost financing for bus fleets, targeted and degressive subsidies, GHG intensity performance regulations that match global efforts, and building charging networks [34]. The transportation sector focuses on land transportation since it is more dynamic and is the main energy consumer in Peru with 87% of the total consumption in this sector [34].

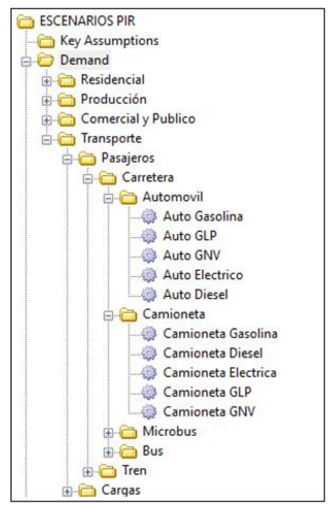

Fig. 10 Structure of land transportation in the Peruvian model

The transportation sector focuses on land transportation since it is more dynamic and is the main energy consumer in Peru with 87% of the total consumption in this sector.

The first level of disaggregation corresponds to the type of use: passengers or cargo, which have completely different practices and behaviors. Passenger usage is correlated with demographic parameters, while cargo usage is related to economic parameters, and each type of use has a certain preferred fuel. The second level of disaggregation corresponds to vehicle types; for individual transport: Car and SUVs, each type has a different focus of use. Public transportation has two types: Buses and minibuses, this is a type of mass transportation, in urban and interurban form. The fourth level refers to the energy source that powers the vehicle: gasoline, NGV, diesel, LPG and electric. Without a doubt, internal combustion engines have the highest proportion. Therefore, the fleet of electric and hybrid vehicles has a minimal participation in passenger use. However, the model considers the penetration of only EV technology. It is expected that, with policies, the development and maturation of the technology will increase. The fifth level refers to the type of fuel, in which diesel covers almost all of the demand, due to the large number of gasoline engines, followed by CNG, then LPG, and finally diesel. At this level, the introduction of electric vehicles and electricity as an energy source in the transportation sector will be placed, for light vehicles, with different penetration rates. Additionally, to calculate the performance and the annual distance traveled in each division, the model includes the results of the studies carried out by [29],[35].

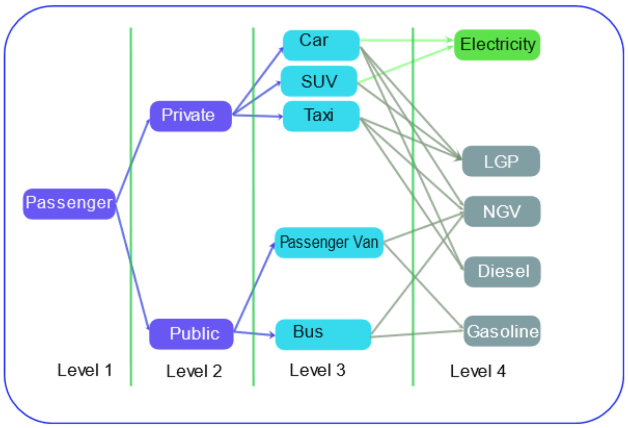

Fig. 11. Structure of the model for the passenger transport sector.

G. *Scenario Construction*

Forecasting the future is a challenging task, a widely used method to forecast the future consists of establishing a baseline, usually a BAU scenario as usual [36], and then selecting scenarios that refer to the penetration rate, such as the global penetration, penetration rate equal to gas vehicles and finally the penetration rate according to the AAP, the automotive association of Peru, comparing them with that baseline. In this research, these four scenarios were considered to study the impact of different urban transportation policy initiatives that would reduce the total energy requirement in Peru's transportation sector and also reduce emissions. These scenarios are defined below:

a) Scenario 1: Business-As-Usual (BAU)

This scenario was based on a continuation of recent trends. Specifically in this scenario, there is no penetration of electric vehicles. By extrapolating these trends, the values were projected through 2030 without any change.

b) Scenario 2: Growth equal to the global EV trend (GT)

In this scenario, it was assumed that the growth of electric vehicles in Peru would be the same as the penetration rate worldwide, representing 0.9% of light vehicles in the world.

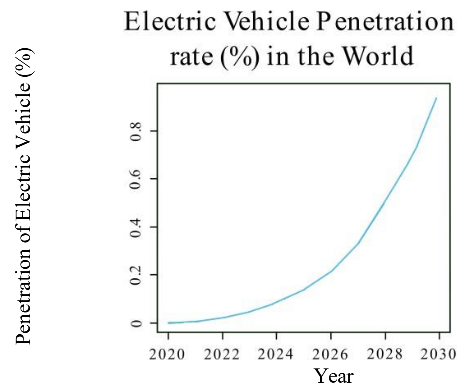

Fig. 12. Penetration rate of electric vehicles in the world

c) Scenario 3: Growth Equal to Natural Gas Vehicles

The growth in the NGV sector can be taken as a reference, the introduction of gas vehicles began in 2005 and to date has a penetration rate in the vehicle fleet of 12%, and according to projections the percentage in 2030 will be 14.3%.

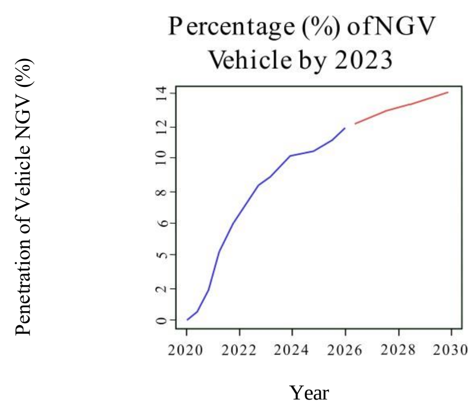

Fig. 13. Penetration rate of vehicles NGV in Peru.

d) Scenario 4: Automotive Association of Peru (AAP)

According to the Automotive Association of Peru, the penetration rate of electric vehicles in Peru will be 5% in 2030.

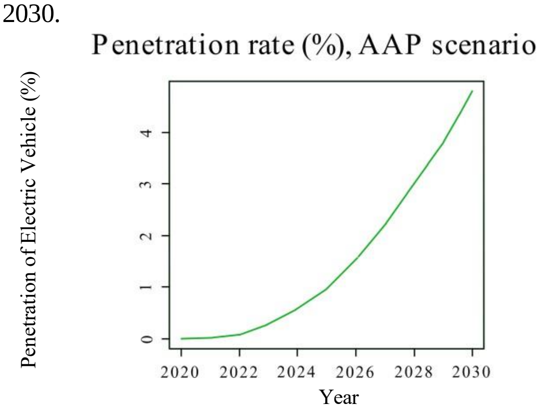

Fig. 14. AAP penetration rate in Peru.

e) Scenario 5: Optimistic growth (EV30@30)

An optimistic scenario, which took as a reference the European market, which aims to have a penetration rate of 30% in the vehicle fleet by 2030.

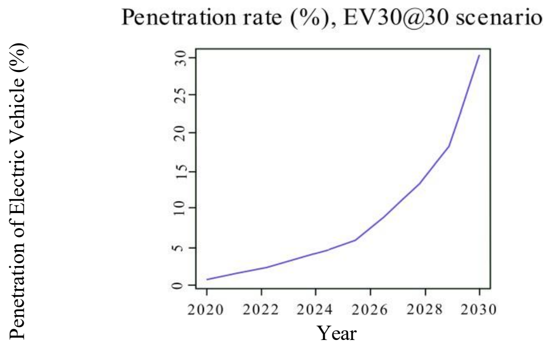

Fig. 15. Penetration rate scenario EV30@30.

IV. RESULTS AND DISCUSSIONS

H. Results on Energy Efficiency

With each scenario, the percentage of the penetration rate of electric vehicles was determined, using the LEAP program. In addition, a performance for the EV of: 100Km/12.65kWh = 7.90 Km/kWh was considered.

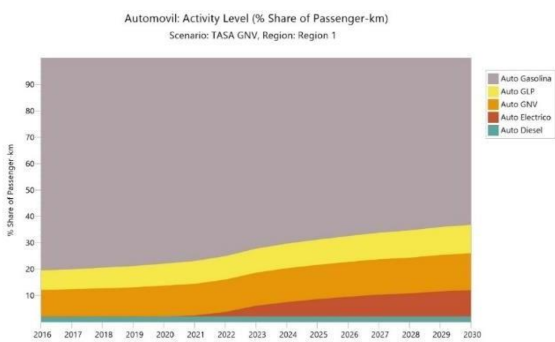

Fig. 16 Participation level by fuel type (NGV scenario), projected to 2030.

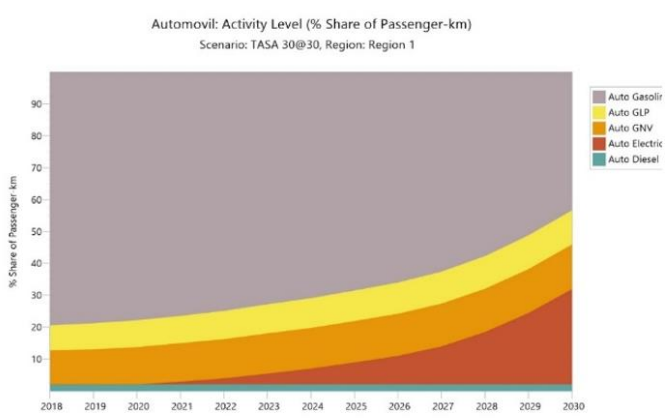

Fig. 17 Level of participation by type of fuel (EV30@30 scenario), projected to 2030

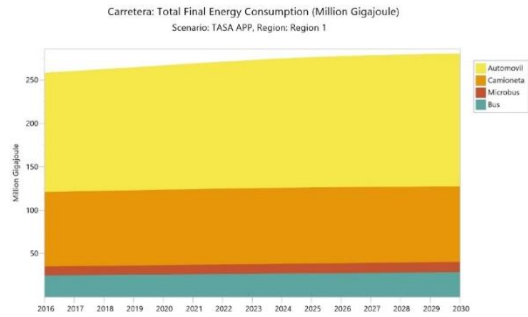

Fig. 18 Total final energy in road transport, (AAP scenario), projected to 2030.

TABLE V
ENERGY EFFICIENCY, EMISSION AND ENERGY FOR EACH SCENARIO.

Year	*BAU (Without VE's)*		*Scenario: WORLD RATE*		*Scenario: AAP RATE*		*Scenario: NGV RATE*		*Scenario: EV30@30*	
	EMISION Gg CO_2	*ENERGY 10^6 GJ*	*EMISION Gg CO_2*	*ENERGY 10^6 GJ*	*EMISION Gg CO_2*	*ENERGY 10^6 GJ*	*EMISION Gg CO_2*	*ENERGY 10^6 GJ*	*EMISION Gg CO_2*	*ENERGY 10^6 GJ*
2021	94003	144.8	94001	144.8	93978	144.8	93546	144.2	93047	143.6
2022	94961	146.3	94935	146.3	94912	146.3	93289	144.2	93089	144.0
2023	95983	147.9	95938	147.9	95713	147.6	92021	142.9	92625	143.7
2024	97011	149.6	96933	149.5	96432	148.9	91648	142.8	92151	143.4
2025	97993	151.2	97862	151.0	97041	150.0	91524	143.0	91152	142.5
2026	98993	152.7	98789	152.5	97518	150.9	91561	143.3	90138	141.5
2027	100090	154.5	99780	154.1	97868	151.7	91701	143.9	88098	139.3
2028	101110	156.1	100622	155.5	98103	152.3	92267	144.9	84497	135.1
2029	102203	157.8	101537	157.0	98324	152.9	92379	145.4	79289	128.8
2030	103238	159.5	102307	158.3	98331	153.3	92902.3	146.4	72422	120.5

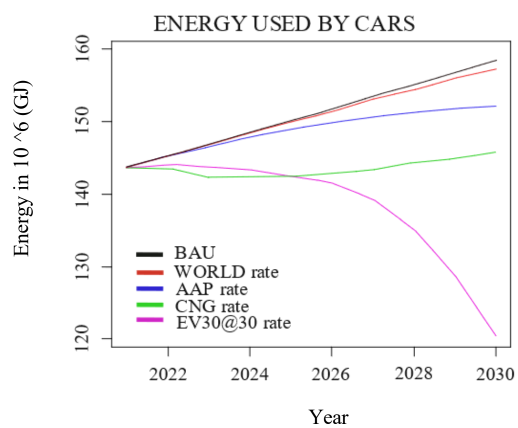

Fig. 19 Energy demand by cars for each scenario, projected to 2030

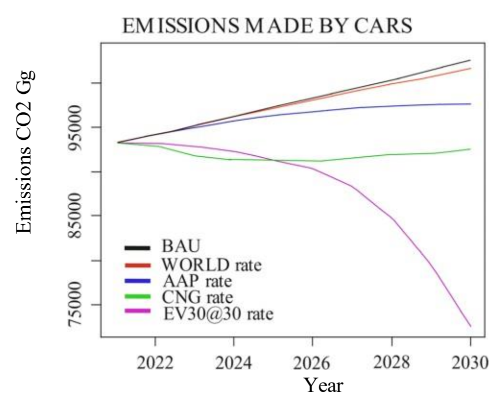

Fig. 20 Emissions made by cars, for each scenario, projected to 2030.

Comparative result of the reduction of CO_2 emissions for light vehicles (cars), taking into consideration the introduction of VEB electric vehicles. The generation of electricity occurs with renewable sources.

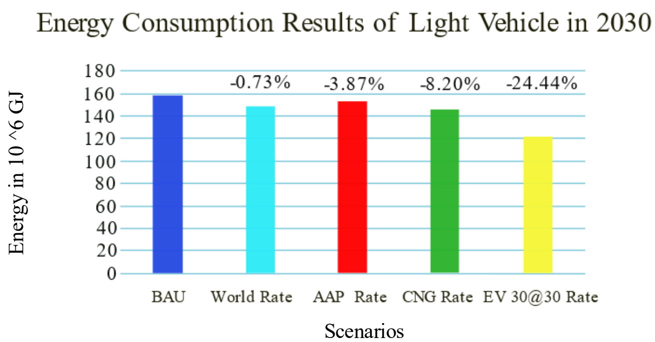

Fig. 21 Result of final energy in car transportation, for each scenario, projected to 2030.

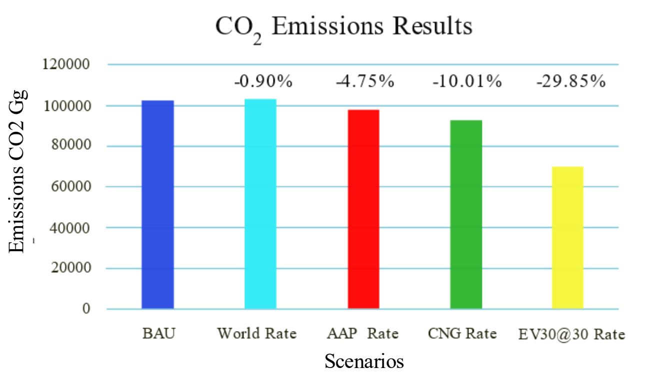

Fig. 22 Comparative result of CO_2 emissions for each scenario, projected to 2030.

V. Conclusions

In the Peruvian energy matrix, the sector with the greatest impact is the transportation sector representing 43% of it. Thus, policies to reduce the demand for fossil fuels on this sector would greatly impact it. Which represents 43%. With the introduction of electric vehicles, there is greater energy efficiency in our vehicle fleet, and there is a reduction in energy consumption, as shown in figure 22, by 2030 with a penetration equal to the world rate this will be reduced by 0.73% regarding the BAU scenario. For a scenario suggested by AAP, this reduction will be 3.87%, for a rate equal to NGV, the reduction will be 8.20%, while for a very optimistic EV30@30 scenario, it will be 24.44%, that is, the greater the penetration, the greater the energy benefits.

An electrical demand generated by the introduction of electric vehicles was also found, for the global rate scenario 64.95 GWh, for the AAP scenario 339.20 GWh, for the NGV rate scenario 712.33 GWh, and finally for the EV30@30 scenario 2120.03 GWh. As shown, Peru can generate electricity from renewable sources. This would be an opportunity to have greater energy diversification in electricity generation, especially with renewable energies, mainly with hydroelectric power as they do in Norway, followed by solar and wind energy.

A decrease in the demand for fossil fuels has also been proven in each scenario, this generates a decrease in energy dependence related to fossil fuels such as diesel and gasoline. For the world rate scenario, there will be a decrease of 0.130 MBP, for the AAP scenario 0.438 MBP, for a NGV rate scenario 0.890 MBP, while for an EV30@30 scenario 2.691 MBP This will cause imports to decrease, since every year it grows if there is no energy transfer.

Acknowledgments

This work was supported by the doctoral program in Energy Engineering from the School of Mechanical Engineering, National University of Engineering, UNI. We thank Dr. Jaime Luyo for his support and advice. Finally, we salute the candidates for the UNI doctoral program.

References

[1] IEA/OECD., “CO2 emissions from fuel combustion highlights 2016.,” Paris: International Energy Agency and Organization for Economic Cooperation and Development;
[2] EIA, “Global EV Outlook 2019 to electric mobility,” OECD iea.org, p. 232, 2019.
[3] E. Sector and T. Terrestre, “El Sector Transporte Terrestre, el Uso de la Energía y sus Impactos en el Cambio Climático,” 2014.
[4] DW, “Las capitales y países de América Latina más contaminados,” *16/05/2019*, p. www.dw.com/es/, May 16, 2019.
[5] C. McAndrews and E. Deakin, “Public health sector influence in transportation decision-making: The case of health impact assessment,” *Case Stud Transp Policy*, 2018, doi: 10.1016/j.cstp.2018.02.002.
[6] MINEM, “Balance Nacional de Energía,” pp. 1–208, 2018.
[7] M. Contestabile, M. Alajaji, and B. Almubarak, “Will current electric vehicle policy lead to cost-effective electrification of passenger car transport?,” *Energy Policy*, vol. 110, no. January, pp. 20–30, 2017, doi: 10.1016/j.enpol.2017.07.062.M. Young, *The Technical Writer's Handbook*, Mill Valley, CA: University Science, 1989.
[8] M. Wikström, “Electric vehicles in action,” [en linea].Doctoral thesis. KTH - Royal Institute of Technology School. Stockholm, Sweden. 03/08/2020, 2015. doi: “http://www.ehcar.net/library/these/these052.pdf.”.
[9] K. Kieckhäfer, K. Wachter, and T. S. Spengler, “Analyzing manufacturers' impact on green products' market diffusion – the case of electric vehicles,” *J Clean Prod*, vol. 162, pp. S11–S25, Sep. 2017, doi: 10.1016/j.jclepro.2016.05.021.
[10] I. E. A. IEA, “Global EV Outlook 2021 - Accelerating ambitions despite the pandemic,” *Global EV Outlook 2021*, p. 101, 2021.
[11] A. Z. Miftah, C. K. Hesti, M. A. Raharjo, and A. F. Khairani, “Bandung sustainable urban mobility policy - Angkot contribution on public transport emission,” in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing Ltd, Feb. 2021. doi: 10.1088/1755-1315/673/1/012029.
[12] M. de E. y M. MINEM, “Balance Nacional de Energía 2013,” 2013.
[13] Instituto de Opinión Pública de la PUCP, “Encuesta Lima Cómo Vamos 2018,” vol. IX, p. 102, 2018.

[14] G. Bauer, “The impact of battery electric vehicles on vehicle purchase and driving behavior in Norway,” *Transp Res D Transp Environ*, vol. 58, pp. 239–258, Jan. 2018, doi: 10.1016/j.trd.2017.12.011.

[15] D. A. Hennessy and D. L. Wiesenthal, “The relationship between traffic congestion, driver stress and direct versus indirect coping behaviours,” *Ergonomics*, vol. 40, no. 3, pp. 348–361, 1997, doi: 10.1080/001401397188198.

[16] D. G. C. Rainham and K. E. Smoyer-Tomic, “The role of air pollution in the relationship between a heat stress index and human mortality in Toronto,” *Environ Res*, vol. 93, no. 1, pp. 9–19, 2003, doi: 10.1016/S0013-9351(03)00060-4.

[17] A. Sadri, M. M. Ardehali, and K. Amirnekooei, “General procedure for long-term energy-environmental planning for transportation sector of developing countries with limited data based on LEAP (long-range energy alternative planning) and EnergyPLAN,” *Energy*, vol. 77, pp. 831–843, Dec. 2014, doi: 10.1016/j.energy.2014.09.067.

[18] M. K. Nyasulu, “Scenario Evaluation of Malawi Energy Policy : LEAP System Modelling Projections from 2008 to 2063,” no. April, pp. 1–62, 2018, doi: 10.13140/RG.2.2.10694.11842.

[19] Y. He, Q. Zhang, and Y. Pang, “The development pattern design of Chinese electric vehicles based on the analysis of the critical price of the life cycle cost,” *Energy Policy*, vol. 109, pp. 382–388, 2017, doi: 10.1016/j.enpol.2017.07.015.

[20] M. F. Chavez-Rodriguez *et al.*, “Fuel saving strategies in the Andes: Long-term impacts for Peru, Colombia and Ecuador,” *Energy Strategy Reviews*, vol. 20, pp. 35–48, 2018, doi: 10.1016/j.esr.2017.12.011.

[21] M. F. Chavez-Rodriguez *et al.*, “Fuel saving strategies in the Andes: Long-term impacts for Peru, Colombia and Ecuador,” *Energy Strategy Reviews*, vol. 20, pp. 35–48, Apr. 2018, doi: 10.1016/j.esr.2017.12.011.

[22] S. A. Ates, “Energy efficiency and CO2 mitigation potential of the Turkish iron and steel industry using the LEAP (long-range energy alternatives planning) system,” *Energy*, vol. 90, pp. 417–428, 2015, doi: 10.1016/j.energy.2015.07.059.

[23] A. Sadri, M. M. Ardehali, and K. Amirnekooei, “General procedure for long-term energy-environmental planning for transportation sector of developing countries with limited data based on LEAP (long-range energy alternative planning) and EnergyPLAN,” *Energy*, vol. 77, pp. 831–843, 2014, doi: 10.1016/j.energy.2014.09.067.

[24] Y. Simsek, H. Sahin, Á. Lorca, W. G. Santika, T. Urmee, and R. Escobar, “Comparison of energy scenario alternatives for Chile: Towards low-carbon energy transition by 2030,” *Energy*, vol. 206, p. 118021, 2020, doi: 10.1016/j.energy.2020.118021.

[25] D. Quiroga, E. Sauma, and D. Pozo, “Power system expansion planning under global and local emission mitigation policies,” *Appl Energy*, vol. 239, no. March 2018, pp. 1250–1264, 2019, doi: 10.1016/j.apenergy.2019.02.001.

[26] D. Quiroga, E. Sauma, and D. Pozo, “Power system expansion planning under global and local emission mitigation policies,” *Appl Energy*, vol. 239, pp. 1250–1264, Apr. 2019, doi: 10.1016/j.apenergy.2019.02.001.

[27] J. A. Nieves, A. J. Aristizábal, I. Dyner, O. Báez, and D. H. Ospina, “Energy demand and greenhouse gas emissions analysis in Colombia: A LEAP model application,” *Energy*, vol. 169, pp. 380–397, 2019, doi: 10.1016/j.energy.2018.12.051.

[28] J. Meza-segura and J. Luyo-kuong, “PERÚ RESIDENTIAL DEMAND FORECASTING METHODOLOGY FOR LONG- TERM ENERGY PLANNING IN PERU,” vol. 30, no. December, 2020.

[29] P. L. Castro Verdezoto, J. A. Vidoza, and W. L. R. Gallo, “Analysis and projection of energy consumption in Ecuador: Energy efficiency policies in the transportation sector,” *Energy Policy*, vol. 134, no. August, 2019, doi: 10.1016/j.enpol.2019.110948.

[30] L. Angrisani *et al.*, “Innovations in Electrical and Electronic Engineering,” 2020. [Online]. Available:” http://www.springer.com/series/7818N.“.

[31] Di Sbroiavacca, G. Nadal, F. Lallana, J. Falzon, and K. Calvin, “Emissions reduction scenarios in the Argentinean Energy Sector,” *Energy Econ*, vol. 56, pp. 552–563, 2014, doi: 10.1016/j.eneco.2015.03.021.

[32] P. L. Castro Verdezoto, J. A. Vidoza, and W. L. R. Gallo, “Analysis and projection of energy consumption in Ecuador: Energy efficiency policies in the transportation sector,” *Energy Policy*, vol. 134, Nov. 2019, doi: 10.1016/j.enpol.2019.110948.

[33] C. Bataille *et al.*, “Net-zero deep decarbonization pathways in Latin America: Challenges and opportunities,” *Energy Strategy Reviews*, vol. 30, 2020, doi: 10.1016/j.esr.2020.100510.

[34] J. Quiros-Tortos, L. Victor-Gallardo, and L. Ochoa, “Electric Vehicles in Latin America: Slowly but Surely Toward a Clean Transport,” *IEEE Electrification Magazine*, vol. 7, no. 2, pp. 22–32, 2019, doi: 10.1109/MELE.2019.2908791.

[35] M. de E. y M. MINEM, “Guía de Orientación del Uso Eficiente de la Energía y de Diagnóstico Energético, SECTOR TRANSPORTE,” 2017.

[36] R. Shabbir and S. S. Ahmad, “Monitoring urban transport air pollution and energy demand in Rawalpindi and Islamabad using leap model,” *Energy*, vol. 35, no. 5, pp. 2323–2332, 2010, doi: 10.1016/j.energy.2010.02.025.