

Article

Estimating the Long-Term Effects of National and International Sustainable Transport Policies on Energy Consumption and Emissions of Road Transport Sector of Pakistan

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Abstract: Energy/fuel consumption and associated emissions are major concerns of transport sector. During the fiscal year (FY) of 2018, Pakistan's transport sector consumed 22 million tons of oil equivalent (TOE) energy from burning of fossil fuels and emitted 52.8 million metric tons (MMT) of CO₂, which accounted for 30% of country's overall carbon emissions. Different scenarios, such as business as usual (BAU), International Energy Agency Vision 2030 (IEA V30), International Energy Agency Vision 2050 (IEA V50), China Pakistan Economic Corridor (CPEC) and newly developed Pakistan National Electric Vehicle Policy (NEVP), are analyzed for Pakistan's transport sector and results are forecasted for the next 17 years. The results show that effective electric vehicle (EV) adoption can cause significant reductions in energy/fuel consumption as well as atmospheric emissions. The distinctive outputs are important parameters in analyzing future energy demands, emissions and introducing effective sustainable energy policies for the transport sector of developing countries.

Keywords: transport sector; energy/fuel consumption; emissions; sustainable energy; developing countries; Pakistan electric vehicle policy



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1. Introduction

Climate degradation and global warming are major issues that humanity is facing at present. The 25–30% of total CO₂ emissions for a country are caused by transport sector [1]. Under BAU scenarios, major catastrophic changes are expected in the form of global temperature rises that lead to increases in air and water temperatures, prolonged droughts, more intense wildfire seasons, increased in air velocity, more rain, flooding and elevated sea levels [2]. Many developing countries, as well as Pakistan, are signatory members of the Conference of Parties (COP). To avoid catastrophic climate impacts and achieve quick decarbonization, limiting and reducing the combustion of fossil fuels from the transport sector of any country can play a key role in mitigating emissions from greenhouse gases (GHGs) and other harmful emissions via effective sustainable energy policies. Pakistan Intended Nationally Determined Contribution (INDC) has aimed to reduce emissions from GHGs and all other harmful emissions by 30% of the existing values in the coming 10 years [3].

The transport sector of Pakistan is responsible for 30% of the country's total carbon emissions, and the percentage is increasing each year as the number of vehicles on the

roads increases. CO₂ emissions will possibly reach 277.9 MMT in 2035 in Pakistan [4]. Pakistan's transport sector is one of fastest growing sectors, while urbanization and migration towards cities are two of the major factors contributing towards the greater number of vehicles on roads and increased carbon emissions [5–7]. The number of registered vehicles in Pakistan is increasing at the rate of 14%. During FY 2018, more than 23.58 million vehicles were registered, 9.67% more than FY 2017 and 200% more than 2010 [1,8]. The number of cars produced by local manufacturers is increasing every year; according to the Pakistan Automobile Manufacturer Association (PAMA), 2,079,773 motor vehicles were manufactured locally and imported in 2018 [9]. Pakistan has a great market for imported hybrid vehicles such as Honda Vezel, Toyota Prius, Toyota Aqua, Honda Fit and many other imported hybrid vehicles. A few electric vehicles are also seen on the roads, such as Tesla Model S, Audi e-Tron, BMW, Nissan Leaf and Plug-in Hybrid Toyota Prius, but no accurate data are available for the exact number of electric vehicles in Pakistan. The stats suggest that Pakistan is not only a growing market for automobile manufacturers but also needs great attention from policy makers to devise policies and frameworks that help to reduce fossil fuel consumption and mitigate emissions. A very important socio-economic aspect should be mentioned here: Pakistan is heavily reliant on imported fossil fuels and needs to revise its future policies to reduce its fossil fuel reliance. A reduction in fossil fuel reliance could save millions of dollars, which are spent on the import of petroleum products (e.g., gasoline, high-speed diesel (HSD), high-octane blending component (HOBC), liquid petroleum gas (LPG) and liquefied natural gas (LNG)) and promises a cleaner environment by reducing emissions. Pakistan's transport sector consumes 65.027% of total petroleum products, both imported and produced locally. During the FY 2018, Pakistan's transport fuel mix comprised 50% HSD, 40% motor spirit (MS), 9% compressed natural gas (CNG), 1% HOBC, and 0.1% light diesel oil [10]. Pakistan imported 4.928 million tons of MS, 3.845 million tons of HSD and 0.086 million tons of HOBC during FY 2018, which cost 3066.28 million USD, 2126.70 million USD and 59.85 million USD, respectively [10]. These expenditures are a regular burden on Pakistan's economy. Table 1 presents all types of fossil fuels consumed in Pakistan and their annual compound growth rate (ACGR). A policy framework was indispensable for promoting zero-emissions vehicles in Pakistan and, in late 2019, Pakistan's government introduced the National Electric Vehicle Policy (NEVP). The major targets of Pakistan's NEVP are to replace 30–40% of the existing IC engine vehicles' market share with EV in the coming ten years and make 90% of the road transport sector emission-free by 2040. Table 2 shows all the targets and incentives offered by the government of Pakistan by the NEVP to promote electric mobility in the country.

To make the transport sector clean and sustainable, many developed and undeveloped countries have devised policies (both customer and manufacturer oriented) to reduce reliance on fossil fuels and reduce the harmful emissions produced as a result of the combustion of these fuels in Internal Combustion (IC) engines. Table 3 represents a very brief comparison of the efficiencies and effectiveness of the different incentives offered to promote EVs in several European countries. Recent improvements in IC engines, the development of hybrid vehicles, better quality fuels and emission standards have contributed to making the transport sector cleaner, but EVs are a major breakthrough in green and sustainable transport. A literature survey has explained that the adoption of EVs can guarantee reductions in overall CO₂ and other harmful emissions, as well as reducing the heavy reliance on fossil fuels.

Table 1. All fossil fuels consumed in Pakistan 2011–2018.

Source	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018	Unit (TOE)
								ACGR
Aviation Fuel	489,454	481,611	501,906	427,992	477,992	499,677	473,929	−0.3%
Motor Spirit	2,893,980	3,505,959	4,057,635	4,984,851	6,076,351	7,004,423	7,847,016	17.5%
HOBC	8682	9632	11,641	21,618	40,878	93,157	129,380	68.1%
E-10	15,138	9402	2720	0	0	0	0	
Kerosene	354	185	78	74	59	38	41	−25.9%
HSD	6,367,407	6,360,708	6,308,838	6,593,609	7,181,583	7,834,580	8,537,787	6.1%
LDO	620	96	0	0	715	0	0	-
Furnace Oil	2140	377	651	669	1509	2558	426	2.5%
Electricity *	81	0	0	0	0	0	0	
CNG	2,784,591	2,345,331	2,050,646	1,556,505	1,508,246	1,573,536	1,648,649	−6.8%
Total	12,562,447	12,713,301	12,934,115	13,585,318	15,287,333	17,007,969	18,637,229	8%
Annual Growth Rate	4.52%	1.20%	1.74%	5.03%	12.53%	11.26%	9.58%	-

* Includes traction for railway.

Table 2. The Pakistan National Electric Vehicles Policy (NEVP) scenario.

Policy Targets 2030 and 2040	<p>Passenger Vehicles: Electric Sedans and SUVs achieve 30% new sales market share by the end of 2030 and 90% new sales by the end of 2040</p> <p>2 and 3 Wheeler Vehicles: 50% and 90% new sales by the end of 2030 and 2040 respectively</p> <p>Buses: 50% and 90% new sales by the end of 2030 and 2040 respectively</p> <p>Trucks: 30% and 90% new sales by the end of 2030 and 2040 respectively</p>
Federal Govt. Tax Incentives	<p>For new EV registration, only 1% GST as compared with existing 17%</p> <p>For investors, import duty is only 1% on charging equipment</p> <p>For charging stations of EV lower electricity tariffs are provided</p> <p>All the investments of greenfield are applied to manufacturers of EV and those who help to convert their existing setups in the format to be manufactured by the manufacturer of EV</p>
Charging Infrastructure Density and Private Investment Opportunities	<p>One fast DC charging station per 3 KM in major cities and dense urban localities</p> <p>DC charging stations on all existing motorways every 15–30 KM</p> <p>Govt. will ensure uninterrupted power supply on all charging stations on motorways</p>
Manufacturer and Other Incentives	<p>State Bank of Pakistan (SBP) will offer lower financing at lower rates to EV manufacturers</p> <p>SBP will set up low markups for leasing EV for public</p>

According to the International Energy Agency (IEA) Global EV Outlook Report 2019, the global EV fleet is expanding rapidly, with more than 2 million EVs sold in 2018. This is double the number of EVs that were registered in 2017. The global EV fleet has exceeded 5.1 million in 2018 and it is estimated that global EV sales will reach 23 million in 2030. In term of EV sales, China remained the world leader this year, with 1.1 million units sold in 2018, and the total EV fleet is now 2.3 million units. At present, half of the global EV units can be traced to China. A total 1.2 million and 1.1 million EVs were recorded in Europe and the USA, respectively, in 2018. Norway was the world leader in terms of the highest percentage of the EV market share, with 46% of new electric car sales in 2018. The second largest market share was in Iceland, with 17% of the EV market share, and Sweden is in third place, with 8% of the EV market share in the country [12]. EV ownership costs are reducing with the development of lithium-ion battery technology and charging infrastructure advancements. Due to the intense competition and latest research, EV ownership is reducing at a good pace. It is expected that 228 million EVs will be on the

roads by 2030 (EV30 Scenario), with the Nordic region being the most active region in terms of the implication of EV policies since 2010. The incentives and efforts made by the Chinese government made China the biggest EV market in 2019. Comprehensive research is being carried out on the electrification of busses and trucks, and a future roadmap for electric trucks and busses is also being developed. In 2018, the stock of electric buses increased to 460,000 units and the number of electric two/three wheelers reached 300 million. Most of these numbers can be traced to the People's Republic of China (PRC) [12–14].

Table 3. Policy options to support the adoption of electric vehicles in the urban environment [11].

Policy Measures	Average Score	Effectiveness	Efficiency	Feasibility
Plugs and sockets lobby based on the standards implemented country-wide	4.27	4.14	4.50	4.17
Build-up of Infrastructure and Support	4.17	4.33	4.17	4.00
Leadership in political aspects	4.03	4.33	4.17	3.60
Initiatives of Car-sharing with EVs	4.00	4.00	3.75	4.25
Provide information to business and citizens	3.83	3.83	3.83	3.83
EV-readiness as a requirement for new property developments	3.74	4.00	3.83	3.40
Enable roaming between regions (billing)	3.63	3.86	3.71	3.33
Reserve on-street parking spaces for EVs	3.61	4.00	3.67	3.17
Toll/congestion fees relaxation for EVs	3.33	4.00	3.40	2.60
Permission to EVs for drive on bus/taxi lanes	3.20	3.80	3.60	2.20

A study was conducted to analyze the effectiveness of the different incentives offered by the Norwegian government, such as the availability of more charging stations in urban areas, exemptions from toll taxes, and permission to drive in bus lanes. Of all the incentives, the number of charging stations per area in a city proved to be the biggest driving force in the adoption of EVs [15]. Another study on the effectiveness of different incentives offered by the government of Norway to promote EVs in all age groups and all types of users, based on age, education and gender, has shown that exemptions from purchase tax and value-added tax are critical considerations for EV owners [16]. However, power generation efficiency improvements, advancements in battery technology and battery cost reductions can optimize BEV costs and contribute towards the adoption of EV in any country. They can also significantly reduce greenhouse gas emissions [17]. China implemented the New Electric Vehicles (NEV) policy in 2009 to introduce EVs to the country and offered great subsidies, which resulted in an increased number of EVs on the roads [18]. Recently, China developed and implemented the Dual Credit Policy 2018 (NEV and Corporate Average Fuel Consumption) to further support the manufacturing and adoption of EVs in the country [19,20]. This is a close and elaborate example for Pakistan. Similarly, India devised and implemented new sustainable transport policies in 2018, which resulted in an increased number of EVs (the majority of vehicles are two- and three-wheelers) on the roads. There is great potential for EVs in Pakistan, as major European, Chinese and American automobile manufacturers are interested in doing business in the automotive sector of Pakistan. In recent years, there many small-to-medium two-wheeler and three-wheeler EV manufacturing startups have been seen in Pakistan. There are more than 2 million motorbikes of 70–150 CC capacity in Pakistan, and a few new local companies are developing conversion kits to replace motorbike IC engines with an electrical drive system (electric motor, battery and electronic kit) on existing chassis.

The growth in EVs in any country is closely dependent on the development of sustainable and renewable energy projects in the country. When compared to all other sectors, the power generation sector can easily be made renewable and emission-free. Reductions

in energy consumption and emissions via EV adoption are more obvious when major electricity supplies come from renewable energy sources, and less when supplies come from conventional fossil-fuel-fired power plants. The success and adoption of EVs in the country is also directly proportional to the saturation of the charging infrastructure (DC fast chargers are more appreciated among EV users). Many researchers have studied and analyzed the effects of charging infrastructure on the implementation of EV [21–25]. Pakistan had faced electricity shortages in recent years, which were one of the major hurdles in EV policy development. Pakistan's current energy generation capacity is 131,275 GWh, while current electricity consumption is 106,927 GWh. The National Electric Power Regulatory Authority (NEPRA) reported that the shares of fossil fuels, hydro-power, renewable and nuclear power are 57, 31, 4 and 8%, respectively [1]. Electric vehicles powered by fossil fuels are not a completely ecological solution; however, this is a better option than directly using fossil-fuel-based vehicles. Moreover, in the near future, electric vehicles will be powered by energy taken from renewable energy resources with improvements in their technology. Many new electricity generation projects, including renewable energy projects, are in the phase of completion, and many others are being worked upon [25]. The national electricity transmission and dispatch network is also being improved to increase overall transmission system efficiency. With all these projects and considerations, Pakistan will be self-sufficient in terms of electrical power generation in coming years, and there will be enough electricity available to successfully implement EV policies in the country [26–32]. Therefore, a future roadmap is needed under all scenarios to forecast the effect of EV introduction in Pakistan.

2. Methods

The research work in this study was initiated by the fuel consumption of the transport sector in Pakistan. The data were taken from three sources (HDIP, OGRA and Pakistan Energy Year Book). The data were then unbundled and individual trends were generated to obtain a better visualization of energy/fuel consumption. Emission data, specifically carbon emissions from all sectors of Pakistan, were acquired from IEA, World Bank Data Archives and other local and federal government resources and analyzed for future forecasting. Data on the number of registered cars until 2018 were obtained from the Ministry of Finance of Government of Pakistan (G.o.P), Pakistan Economic Survey 2017–2018 Report; this was one of the most important parameters for energy and emissions analysis and forecasting. All these trends were needed as baseline data for program development and forecasting. It is worth noting that forecasting quality is directly related to the accuracy of the base year data and any other data that are used in a forecasting suite. Long Range Energy Alternative Planning (LEAP) is a comprehensive software tool for accurate energy policy analysis, climate change mitigation assessment and forecasting. LEAP is used by educational institutions, energy analysis agencies and government organizations in more than 190 countries. The data associated with Pakistan's transport sector were analyzed in LEAP. Figure 1 shows a tree of demand for the transport sector i.e., with all the fuel sources that were currently being used by Pakistan's transport sector (i.e., gasoline, diesel and CNG). Environmental loadings were applied to specific fuel types using appropriate emissions standards, and results were calculated and verified through existing actual data. Five different scenarios (business-as-usual scenario (BAU), IEA V30 @2030 scenario, IEA V50 scenario, CPEC-2030 scenario and Pakistan New Electric Vehicles Policy scenario) were made and analyzed for Pakistan's transport sector in LEAP. Different effects on energy consumption and emissions were analyzed for the coming 17 years and all scenarios were also simultaneously compared.

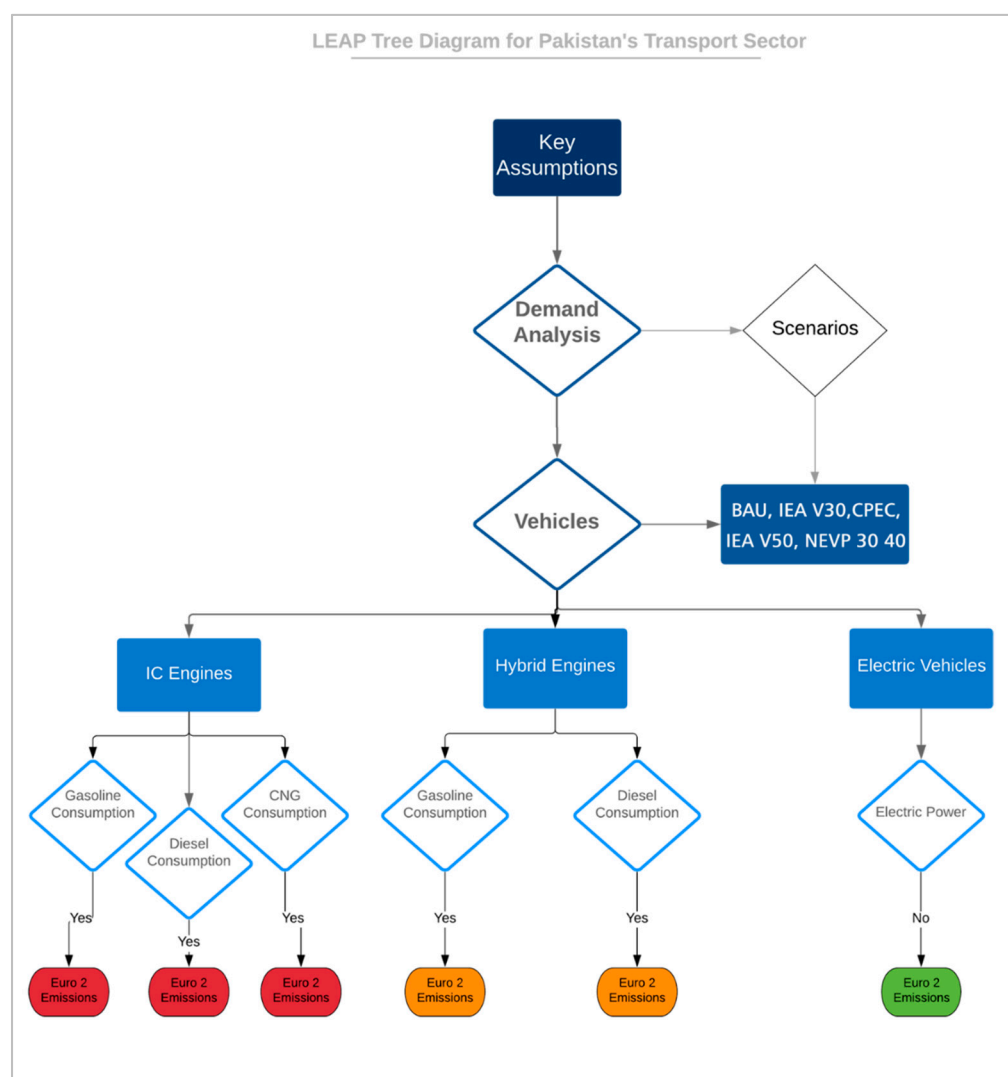


Figure 1. LEAP tree diagram for Pakistan transport sector's energy demand and emissions.

A. Sadri researched long-range general procedures for energy-environment planning for developing countries using LEAP. An analysis was made of the use of gasoline for light-duty vehicles based on GDP and historic population data. The analyzed data were collected from Iran (a developing country) and different scenarios, such as the business-as-usual scenario, GDP-growth scenario, public-transport-improvement scenario and utilization-of-electric-vehicles scenario, were analyzed [33]. Sungjun Hong worked on national greenhouse gas reductions associated with the transport sector in Korea using LEAP. South Korea set targets to reduce greenhouse emissions by 30% by 2020, by implementing certain sets of policies in transport and other sectors. The transport sector was allocated maximum GHG reduction targets of 34.3%; the study analyzed the effectiveness of these policies under the shadow of energy consumption and emissions. Five different scenarios (BAU, improved fuel efficiency, green car distribution, public transport shift and model shift reinforcement) were studied to analyze energy and emission rates [34]. Ling-Yun He worked on policy measures to reduce harmful emissions such as GHG that were associated with China's road transport sector. Five different scenarios, using LEAP, comprising electric and hybrid vehicles, were incorporated and analyzed. The results suggested that implementing both high-efficiency electric vehicles and hybrid vehicles to obtain optimized results, target to save energy and reduce emissions can be fulfilled with the promotion of EV in subsectors, such as two-wheelers, public transport and light trucks [35]. Nnaemeka Vincent Emodi studied a scenario-based model for energy and emissions for Nigeria using LEAP. Energy

consumption and emissions were analyzed using aggressive, moderate and low-energy policies [36]. Musharrat Azam studied energy consumption and emission projection for the road transport sector of Malaysia using LEAP. The study comprised estimations of CO₂, CO, NO_x, SO_x and volatile organic matter emissions from 2012 to 2040 [37].

To date, EV deployment has mostly been driven by policy. The EV policies of different countries, such as China, the US, and Norway, were thoroughly studied to obtain a better understanding and visualization of policy measures, which resulted in the improved adoption of EV in these countries. General EV trends all over the world were also studied. An extensive literature survey was carried out to conduct this research work and the results will assist in EV adoption in the country, as well as further finetuning the New Pakistan EV policy.

3. Overview of Pakistan's Transport Sector Energy and Emissions

3.1. Pakistan Transport Sector's Energy Consumption

Over the years, Pakistan's transport sector energy consumption has increased significantly, and the current annual compound growth rate (ACGR) is 8%. During FY 2018, Pakistan's transport sector consumed about 18.6 million tons of oil equivalent (MTOE) energy and emitted 40.8 MMT of CO₂. This energy consumption is 9.7% higher than the previous year due to an increase in energy consumption by the industry and transport sector. With improvements and the installation of new road infrastructure, gasoline and diesel consumption in FY 2018 increased, with annual compound growth rates of 17.5% and 6.1%, respectively. Pakistan relies heavily on imported fuels, as there are not enough fossil fuel extraction localities and oil refineries to cater to the country's demand for gasoline, high speed diesel and other fossil fuels. Pakistan spends billions of dollars every year to fulfill its energy demands. Recent developments under CPEC projects, increasing population, increasing number of vehicles and the expansion of motorways have contributed to the rapid increment of energy usage in recent years. Figure 2 shows the overall energy consumption for Pakistan's transport sector from 2003 to 2018.

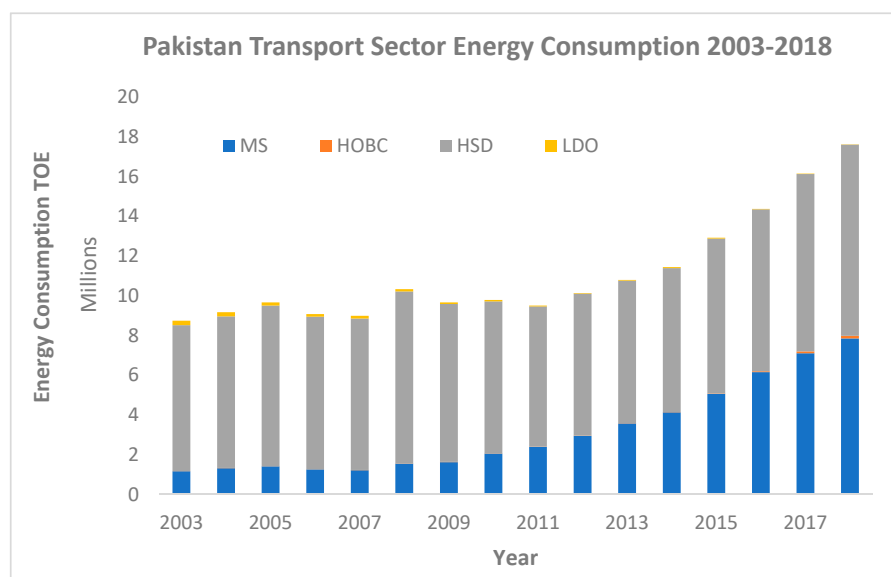


Figure 2. Pakistan's transport sector's energy consumption 2003–2018.

3.2. MS HSD HOBC LDO and CNG Consumption

The majority of small-to-medium-scale IC engine vehicles in Pakistan are gasoline-powered, while heavy-duty buses and trucks are HSD-powered. CNG consumption in Pakistan's transport sector started to decrease after its summit in 2012, and is continuously falling due to the intermittent supply and prices. LDO consumption decreased due to the introduction of new diesel engines in agriculture and other industrial applications that

now rely on HSD. High-octane blending component (HOBC) demand increased due to the addition of more efficient and environment friendly engines in automobiles, such as Euro 3 and Euro 4 engines. This was due to the severe knocking issue faced by imported Japanese domestic models (JDM) vehicles, European vehicles and some of the latest models of locally manufactured vehicles as a result of RON 87 gasoline. The oil and gas regulatory authorities in Pakistan set standards for gasoline, setting 92 RON as the lowest quality fuel to avoid knocking issues in IC engines and maintain smooth combustion in gasoline engines. The annual compound growth rates (ACGR) of gasoline, HOBC, HSD and CNG are 17.5%, 68.1%, 6.1%, −6.8%, respectively. Figure 3A–D and E show MS, HSD, LDO, HOBC and CNG consumption from 2003 to 2018.

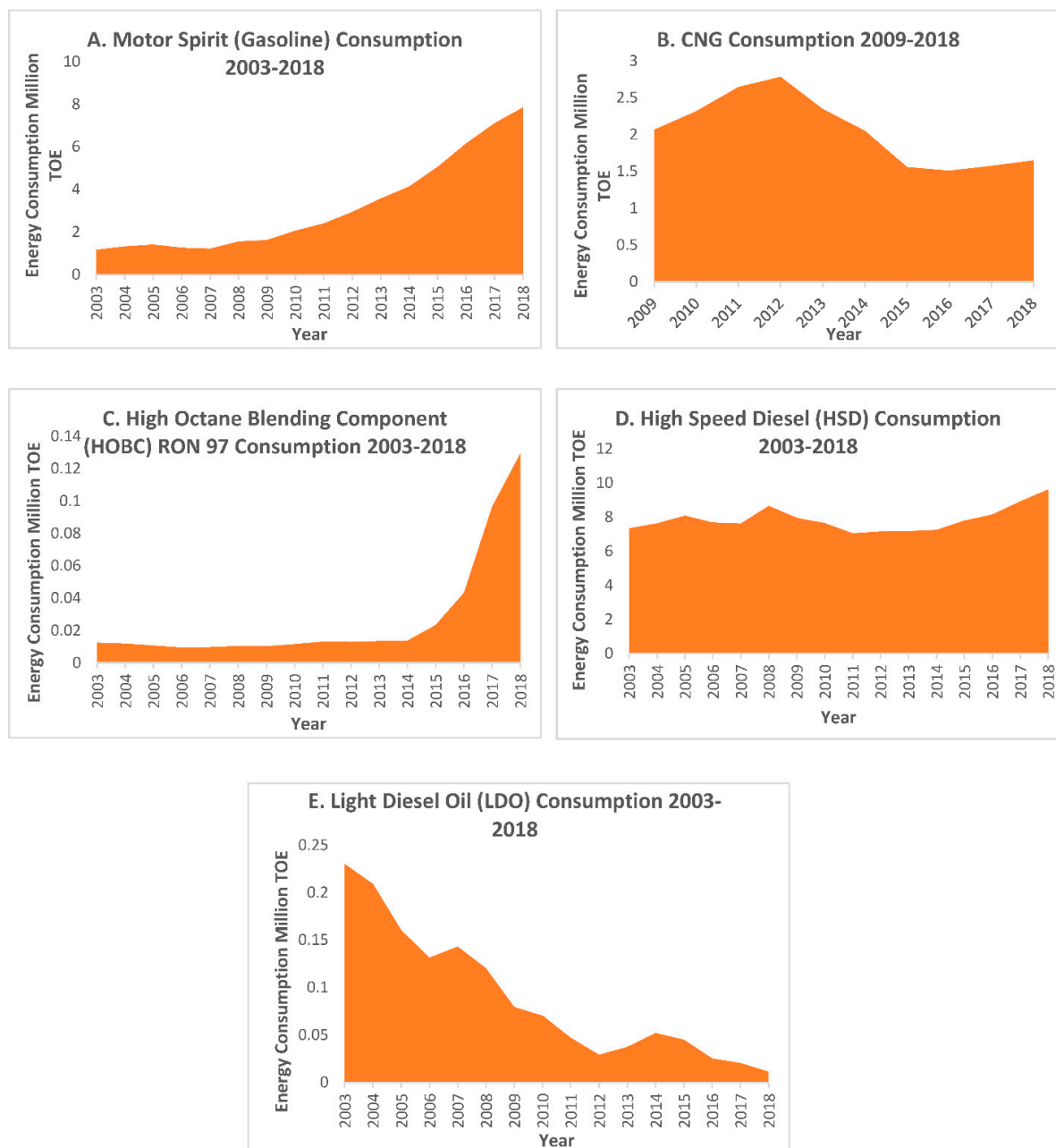


Figure 3. (A) Motor spirit consumption from 2003 to 2018, (B) CNG consumption 2003–2018, (C) high-octane blending component consumption 2003–2018, (D) high-speed diesel consumption 2003–2018 and (E) light diesel oil consumption 2003–2018.

3.3. Pakistan Transport Sector Fuel Mix

Pakistan is an agricultural economy-based country and most of its freight is transported through the road network and railways, while intra-country freight is transported by airways. The percentage share of HSD is highest among all the fuels. During FY 2018, 962,2731 tons of HSD, 7,847,016 tons of gasoline, 11,000 tons of light diesel oil (LDO), 129,380 tons of HOBC and 1,648,649 tons of oil equivalent energy were obtained from CNG. These numbers are expected to increase every year at an approximate rate of 14%, as the number of vehicles are continuously increasing at the same pace. Figure 4 shows a pie chart of the fuel mix in Pakistan's transport sector.

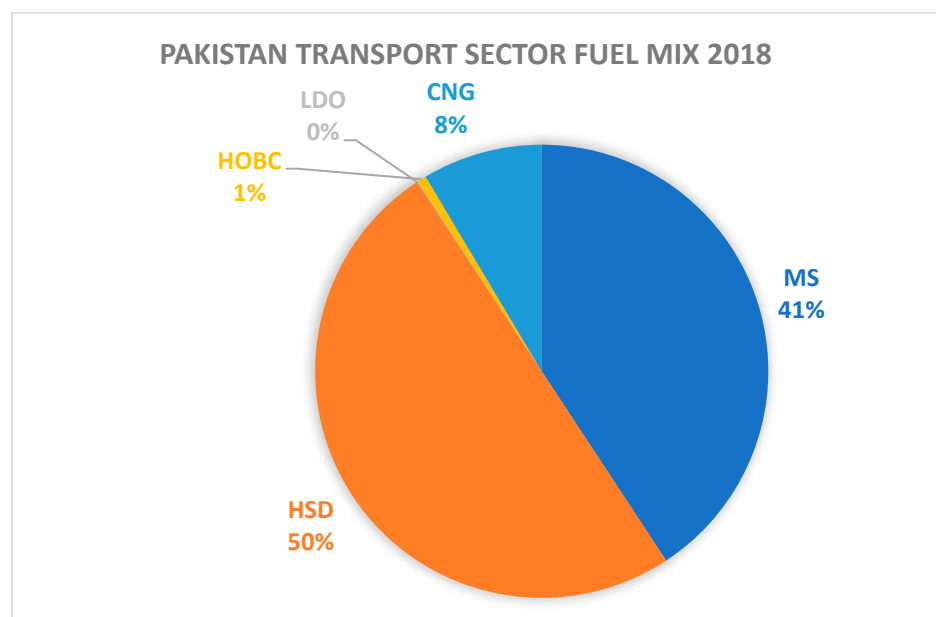


Figure 4. Pakistan transport sector's fuel mix 2018.

3.4. Pakistan's Current Vehicle Fleet

There are over 23.59 million registered vehicles in Pakistan, and this number is increasing every year at a mean rate of 14%. Most cars, motorbikes and tractors on the roads are locally manufactured/assembled, while buses and heavy-transport vehicles are imported in a greater number. Automotive industry is fastly growing than other manufacturing industries in Pakistan. The major shareholders are Japanese brands such as Honda, Toyota and Suzuki Motor. Hyundai and Kia, and some Chinese automobile manufacturing companies are also securing a market share. In recent years, JDM vehicles have significantly increased on the roads. European luxury cars and SUV manufacturers such as Audi, BMW, Porsche and Mercedes Benz have started business in Pakistan in recent years. All the two- and three-wheeler vehicles are designed and manufactured by local companies. The automotive manufacturing sector has long contributed to the economic growth in Pakistan. Figure 5 shows a statistical chart of the number of vehicles that were registered from 2006 to 2019. During FY 2018, 207,630 cars, 1,781,959 motorbikes, 676.3 trucks and busses, 765.4 jeeps, 504.05 tractors and 253.62 pickup trucks were locally assembled, while 65,723 vehicles were imported. This suggests that Pakistan has a fast-growing automotive sector and there is plenty of room for electric vehicles. None of the major vehicle manufacturers in the country are producing electric vehicles; A fleet consisting of small existing electric and hybrid vehicle is imported in the country majorly for travelling purposes. A few small-to-medium startups have manufactured electric two- and three-wheelers. A few new startups have also started to produce conversion kits for 70–125 CC motor bikes, which replace the IC engine on the motor bike with electric motor and battery, as there are over 10 million registered motorbikes in the country. The public response to the adoption of EV is not up to the mark because the newly developed NEVP is in a nascent stage and there is less awareness

regarding EV adoption and its usefulness. Figure 6 shows a stack bar chart of vehicles that were locally produced from 2007 to 2018.

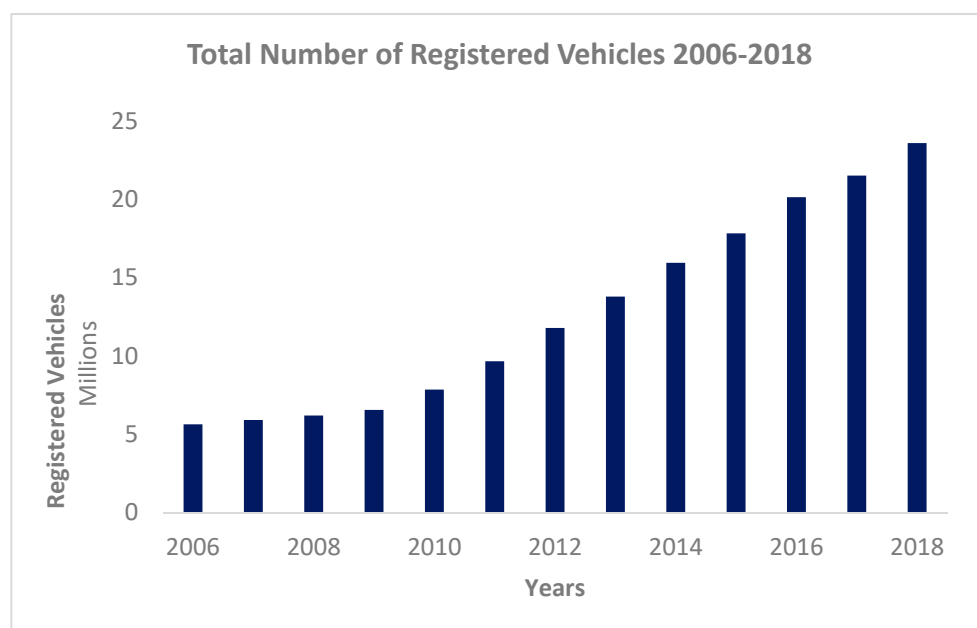


Figure 5. Number of registered vehicles in Pakistan from 2006 to 2018.

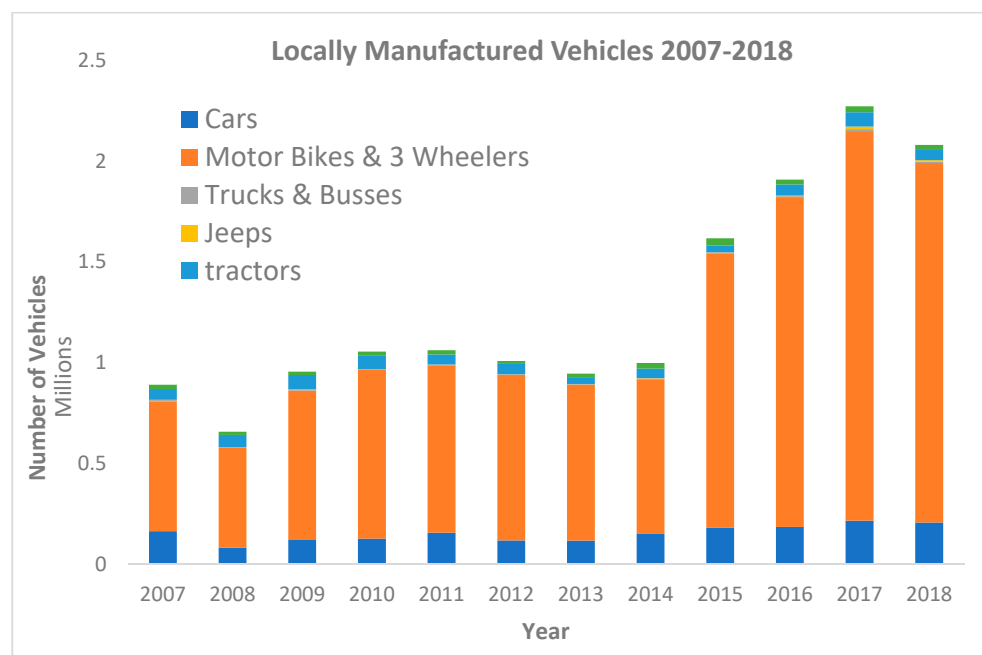


Figure 6. Locally manufactured vehicles in Pakistan 2007–2018.

3.5. CO₂ Emissions from Fuel Combustion

The IEA CO₂ emissions from fuel consumption OECD/IEA, 2019 proposed that Pakistan produced approximately 180 MMT of CO₂ from the combustion of fossil fuels. At present, Pakistan's transport sector is responsible for approximately 30% of the total annual carbon emissions. Developed countries have a general trend of 18–20% of total carbon emissions associated with the transport sector. During 2018, in Pakistan, 48.9 MMT of CO₂ was produced during electricity and heat production, 2.5 MMT from industrial applications, 50.5 MMT from production and conduction industries, 55.6 MMT from transport sector and

25.6 MMT from other sectors. Figure 7 presents a pie chart showing the sectorial emission contributions as a result of the combustion of fossil fuels in Pakistan. Recent trends have shown a continuous increment in CO₂ emissions in the last 10 years. Pakistan has great potential for clean energy and mitigating GHG emissions. Many new green energy projects, such as solar (PV and CSP), hydel energy, wind energy, tidal energy and energy from biogas, have started to add their shares to the national grid and many of these are being expanded and extended. This shift towards green energy will pave the way for EV in the country. Figure 8 shows the CO₂ emitted from fuel combustion in Pakistan from 1970 to 2019.

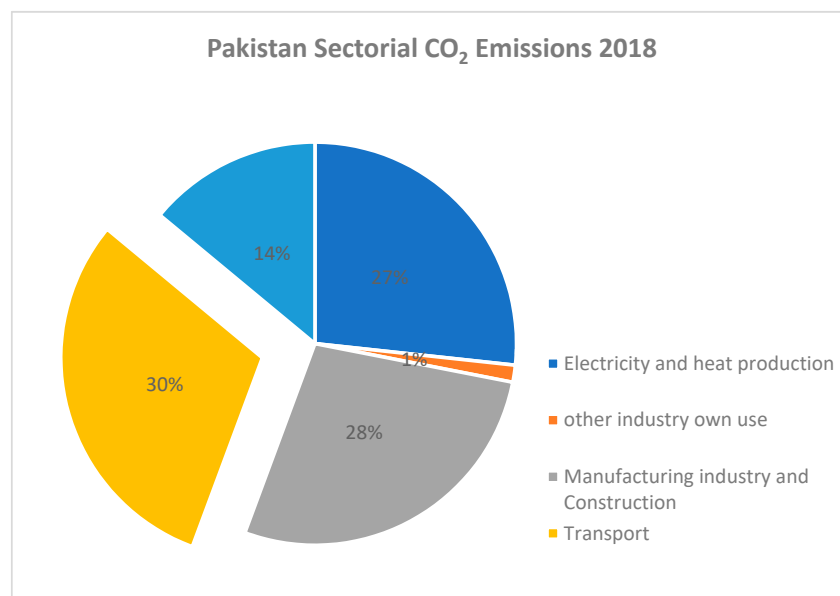


Figure 7. Pakistan sectorial CO₂ emissions 2018.

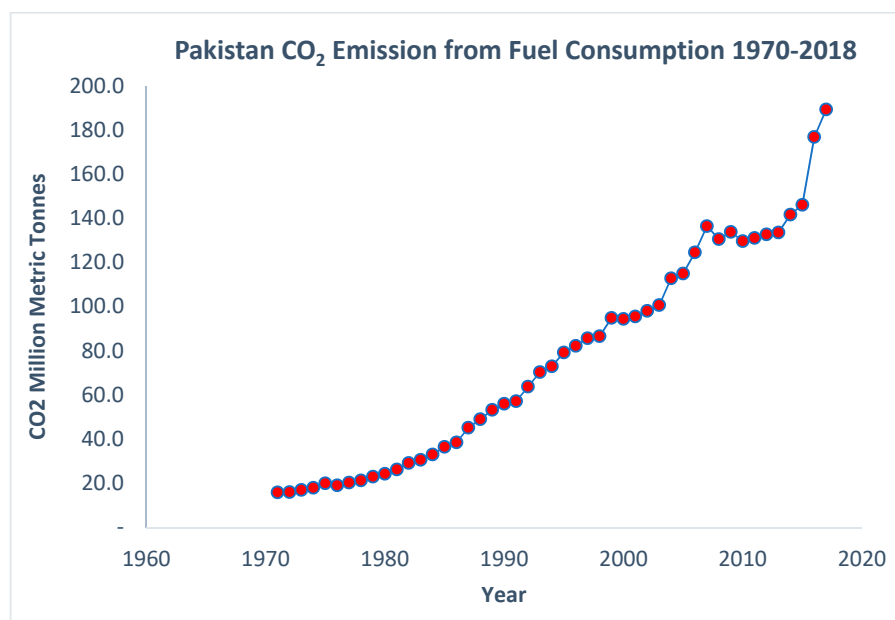


Figure 8. Pakistan CO₂ emissions from fuel consumption 1970–2018.

4. Results and Discussions

4.1. Business as Usual (BAU) Scenario

Transport sector is one of the fastest growing sectors worldwide and contributes 20–25% of the global CO₂ and other harmful emissions. Pakistan's transport sector consumed 18.7 million TOE energy from fossil fuels and emitted about 59.9 MMT of CO₂ and other harmful emissions. Under current socio-economic conditions, the BAU scenario suggests that, if such conditions continue to prevail, the current energy and emissions values will increase in 2035. LEAP results suggest that there will be a 237.4% increase in energy consumption in 2025, and until 2035, Pakistan's transport sector will consume about 152.7 million TOE energy. As Pakistan's transport sector relies more on imported fuels, the BAU scenario results also suggest that Pakistan's expenditures to import fossil fuels will also increase with the same percentage as the energy values if there is no significant change in international oil prices. Under the current conditions, the emissions associated with Pakistan's transport sector will hit 132 MMT in 2025 and 453.6 MMT in just 17 years. Results obtained from the BAU scenario clearly suggest that there is need for quick decarbonization and limiting fossil fuel combustion activities. Figure 9A shows a detailed energy demand forecasting until 2035 and Figure 10A shows an emissions (CO₂, CO, CH₄, NO_x, SO_x and non-methane volatile organic compounds) forecasting until 2035 for the BAU scenario.

4.2. IEA V30 Scenario for Pakistan's Transport Sector

To achieve the emission standards addressed in COP 21, 22, 23, 24 and 25, the International Energy Agency (IEA), in its Global EV Outlook Report, 2019, proposed electrifying 30% of all IC engine vehicles worldwide in the coming ten years. Two-wheelers are excluded from this compulsion. IEA V30@30 campaign has proposed supporting the development of electric vehicle (EV) chargers and tracking progress, as well as spreading awareness to highlight the need of the hour for usage of EVs and importance of EVs in the future prospective majorly focusing on the public sector. This should strengthen automobile manufacturers' interest in the development of EV. Policy research is being scaled up to promote EV use in the country by devising effective policies for charging infrastructure and other incentives to promote electric vehicles in the country. The exchange of intercountry experience for the replication of the best policies is achieved by participating in Global EV Pilot Program. A LEAP demand analysis model is prepared by applying IEA V30 conditions, to electrify 30% of the vehicle fleet, to Pakistan's transport sector, using 2018 conditions as base year conditions and forecasting energy demand and emissions results until 2035. The results show that energy demand in 2025 is 38.7 million TOE, as compared to 44.4 million TOE in the BAU scenario, and 95.5 million TOE, as compared to 152.7 million TOE in the BAU scenario in 2035. CO₂ emissions associated with the IEA V30 scenario are 114.9 MMT and 283.7 in 2025 and 2035, respectively, as compared to 132.0 MMT and 453.6 MMT in the BAU scenario. Figure 9B shows a detailed energy demand forecasting until 2035 and Figure 10B shows emissions (CO₂, CO, CH₄, NO_x, SO_x and non-methane volatile organic compounds) forecasting until 2035 for the IEA V30 scenario.

4.3. IEA V50 Scenario for Pakistan's Transport Sector

The commission presented a vision on 28 November 2018 which focuses on long-term strategy and planning for the achievement of climate-neutral economy depicting modern and competitive milestones by the end of 2050. The strategy depicts how European countries can achieve effective climate neutrality and reduce the effects of immense industrialization, deforestation and air pollution, caused by fossil fuel combustion by promoting research and development in all these sectors to reduce emissions, devising policies towards a carbon-free transition and considering social sensitivities.

The vision presented by the commission fulfils all the requirement to achieve policies set by the EU and Paris Agreement's objective to achieve such a climate which is neutral in the future by keeping the increase in global temperature below than 2 °C or 1.5 °C. IEA V50 suggests reducing global GHG emissions by 80% in 2050 as compared to 1990 GHG levels.

Applying these conditions to Pakistan's transport sector reveals a quick decarbonization potential. Under the IEA V50 Scenario, energy demand in 2025 will be 33.5 million TOE, as compared to 44.44 million TOE in the BAU scenario. Similarly, in 2035, energy demand will be 61.1 million TOE, as compared to 152.7 million TOE in the BAU scenario. After NEVP 2040, IEA V50 scenario has the lowest overall emissions when applied to Pakistan's transport sector. The results reveal that, in 2025, under IEA V50 conditions, CO₂ emissions associated with the transport sector are 99.4 MMT, as compared to 132.0 MMT in the BAU scenario, and 181.4 MMT as compared to 453.6 MMT in the BAU scenario, during 2035. Figure 9C shows a detailed energy demand forecasting until 2035, and Figure 10C shows emissions (CO₂, CO, CH₄, NO_x, SO_x and non-methane volatile organic compounds) forecasting until 2035. A significant reduction in energy demand (in term of fossil fuels) and emissions is achievable under the long-term implementation of such recommendations.

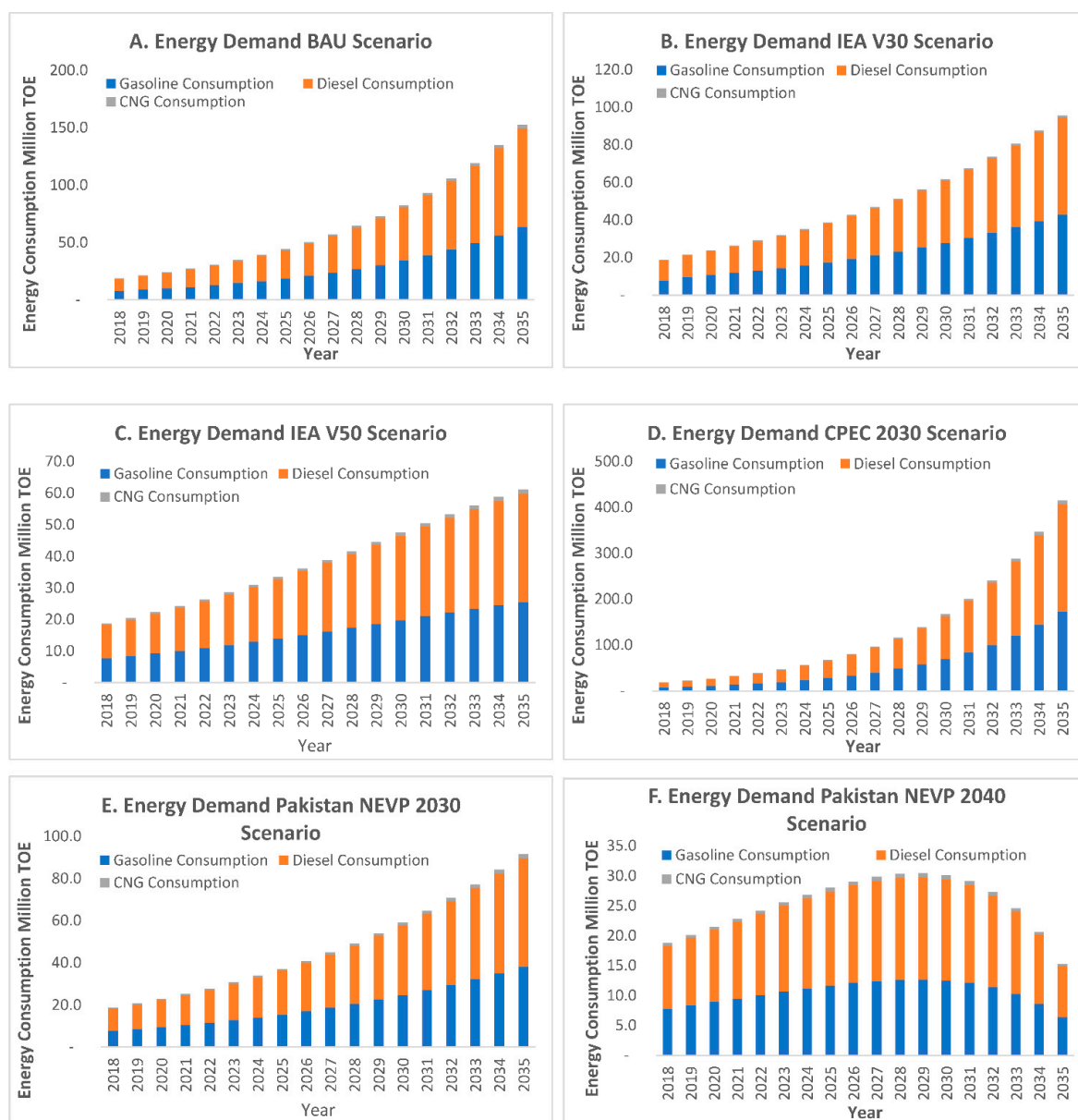


Figure 9. (A) Energy consumption associated with the BAU Scenario, (B) energy consumption associated IEA V30 scenario, (C) energy consumption associated with IEA V50 scenario, (D) energy consumption associated with CPEC 2030 scenario, (E,F) energy consumption associated with Pakistan's NEVP scenarios for 2030 and 2040.

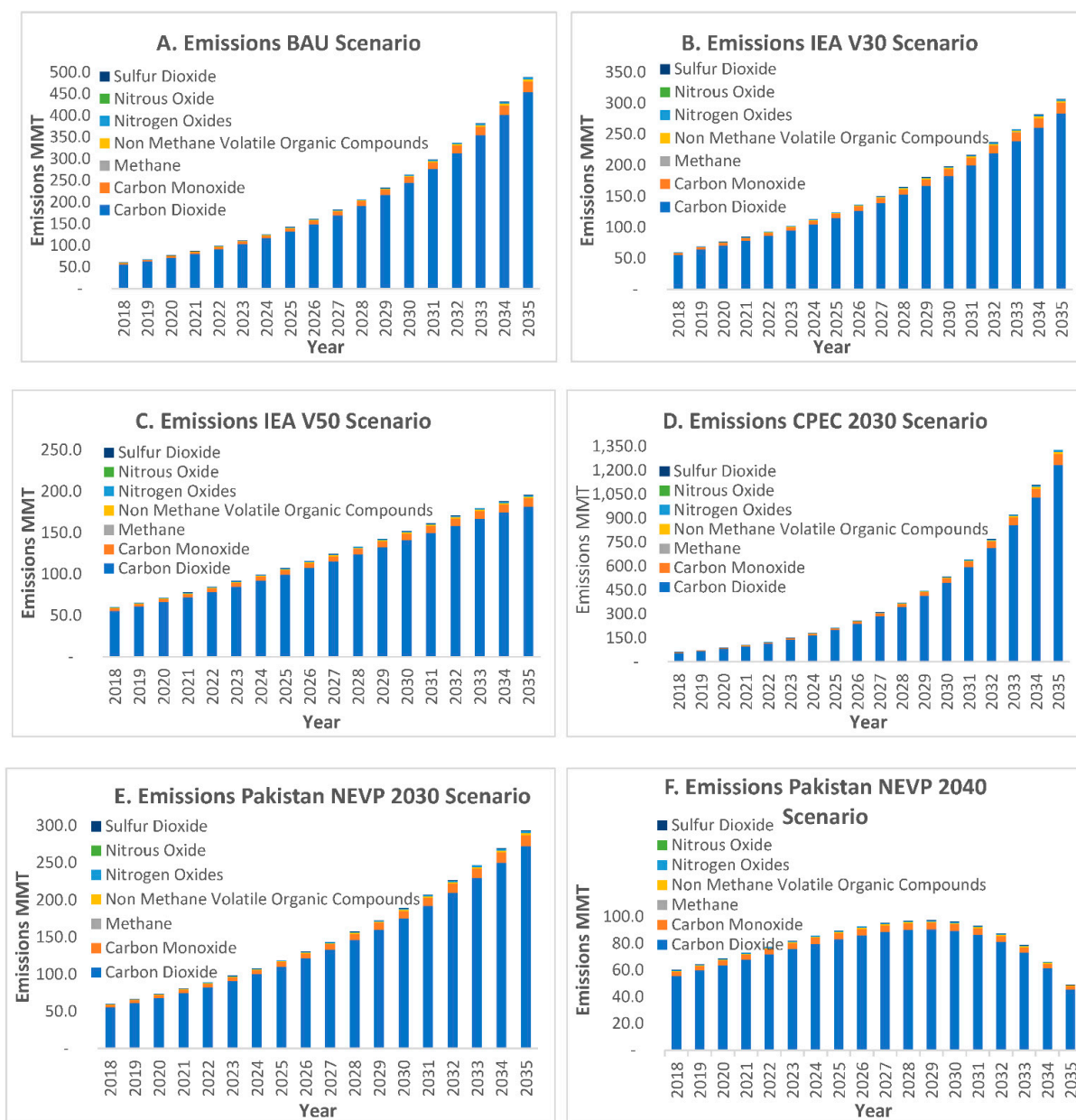


Figure 10. (A) Emissions associated with BAU scenario, (B) emissions associated with IEA V30 scenario, (C) emissions associated with IEA V50 scenario, (D) emissions associated with CPEC 2030 scenario, (E) emissions associated with Pakistan NEVP 2030 scenario and (F) emissions associated with Pakistan NEVP 2040 scenario.

4.4. CPEC 2030 Scenario for Pakistan's Transport Sector

The president Xi Jinping's visited Pakistan in 2015 and a strategical cooperation partnership was made between the two countries which mainly focuses all-weather improvements with new connotations. The cooperation mode set by both countries was "1 + 4", the main focus was on CPEC with improvement in Gwadar, the Energy sector, infrastructure regarding transportations sector and cooperation's of industries. This agreement opened a new chapter for the development and construction of CPEC project. The growth of the countries would be increased by CPEC and it is considered as development belt which has features such as collaboration of China and Pakistan, their mutual advantages and common prosperity.

The CPEC project consists of collaborations between the China and Pakistan for developments (constructions) of infrastructure, flourish the industries by developments, improvements in livelihood by creating opportunities for jobs. The main aims and objectives of the CPEC are to develop a socio-economic projects, prosperity and security of the regions being followed in both the countries. These improvement of the CPEC have basis on comprehensive developments in transportations sector (corridor) and cooperation developments of industries between both the countries acting as the maxi axis, developments in trade and economic aspects of both the countries and exchange of peoples as work forces and exchange of culture between the countries [38]. The results associated with the CPEC scenario have the highest energy demands and emissions. In 2025, under CPEC development conditions, energy demand will be 67.1 million TOE, as compared to 44.4 million TOE in the BAU scenario, and in 2035, CPEC will have a 415.4 million TOE energy demand, as compared to 152.7 million TOE under BAU conditions. CO₂ emissions are also the highest among all scenarios, such as 199.3 MMT in 2025 and 1233.8 MMT in 2035. Figure 9D shows detailed energy demand forecasting until 2035 and Figure 10D shows emissions (CO₂, CO, CH₄, NO_x, SO_x and non-methane volatile organic compounds) forecasting until 2035 for the CPEC 2030 Scenario.

4.5. Pakistan National EV Policy (NEVP) 2030 and 2040 Scenarios

After almost a year, Pakistan's government finally developed its first EV policy in late 2019. According to Pakistan NEVP 2030, Pakistan's government aims for electric vehicles to comprise the following percentages of total new vehicles by 2030; 30% cars, 50% two- and three-wheelers, 50% busses and 30% trucks. Replacing 90% of IC engine vehicle fleet with EVs by 2040 is also proposed. Estimating the long-range effects of Pakistan's EV policy on energy / fuel consumption and emission on the transport sector of Pakistan clearly show that, under such policy measures, there can be significant reductions in energy consumption, as well as associated emissions, in the short and long term. The scenario results have shown energy and emissions curves for NEVP 2030 scenario between the IEA V30 and IEA V50 scenarios, that is, 37.1 million TOE in 2025 as compared to 38.7 million TOE and 44.1 million TOE in IEA V30 and BAU scenarios, respectively. NEVP 2040 has minimal energy demands and emissions (15.3 million TOE) in 2035 compared to the other scenarios. The same trends were observed for CO₂ emissions (110.2 MMT and 83.1 MMT for NEVP 2030 and NEVP 2040, respectively, during 2025, and 272.1 MMT and 45.4 MMT for NEVP 2030 and NEVP 2040, respectively, during 2035). Figure 9E and F show a detailed energy demand forecasting until 2035, and Figure 10E and F show emissions (CO₂, CO, CH₄, NO_x, SO_x and non-methane volatile organic compounds) forecasting until 2035 for Pakistan's NEVP 2030 and 2040 scenarios.

4.6. Comparison of BAU, IEA V30, IEA V50 and CPEC-2030 Scenarios

It can be seen that CPEC-2030 has the highest energy consumption and associated emissions values in the short- as well as long-term (415.4 million TOE energy demand and 1233.8 MMT CO₂ emissions in 2035). The CPEC agreement between Pakistan and PRC included many economic development projects, such as infrastructure and energy projects, which will have a direct impact on transport fleet, transport sector energy consumption and emissions. The second scenario, in descending order, is the BAU scenario, with a forecasted energy need of 152.7 million TOE and 453.6 MMT of CO₂ emissions in 2035. The IEA-recommended V30 scenario is number three on the list (energy demand is 95.5 million TOE and CO₂ emissions are 283.7 MMT in 2035), followed by NEVP 2030, IEA V50 and NEVP 2040 scenarios, with energy demands of 91.6 million TOE, 61.1 million TOE and 15.3 million TOE, respectively, in 2035, and associated CO₂ emissions are 272.1 MMT, 181.4 MMT and 45.4 MMT, respectively, in 2035. Figure 11A shows a detailed comparison of the energy demands in all scenarios, and Figure 11B is presents a detailed comparison of CO₂ emissions in all scenarios in the time-frame from 2018 to 2035.

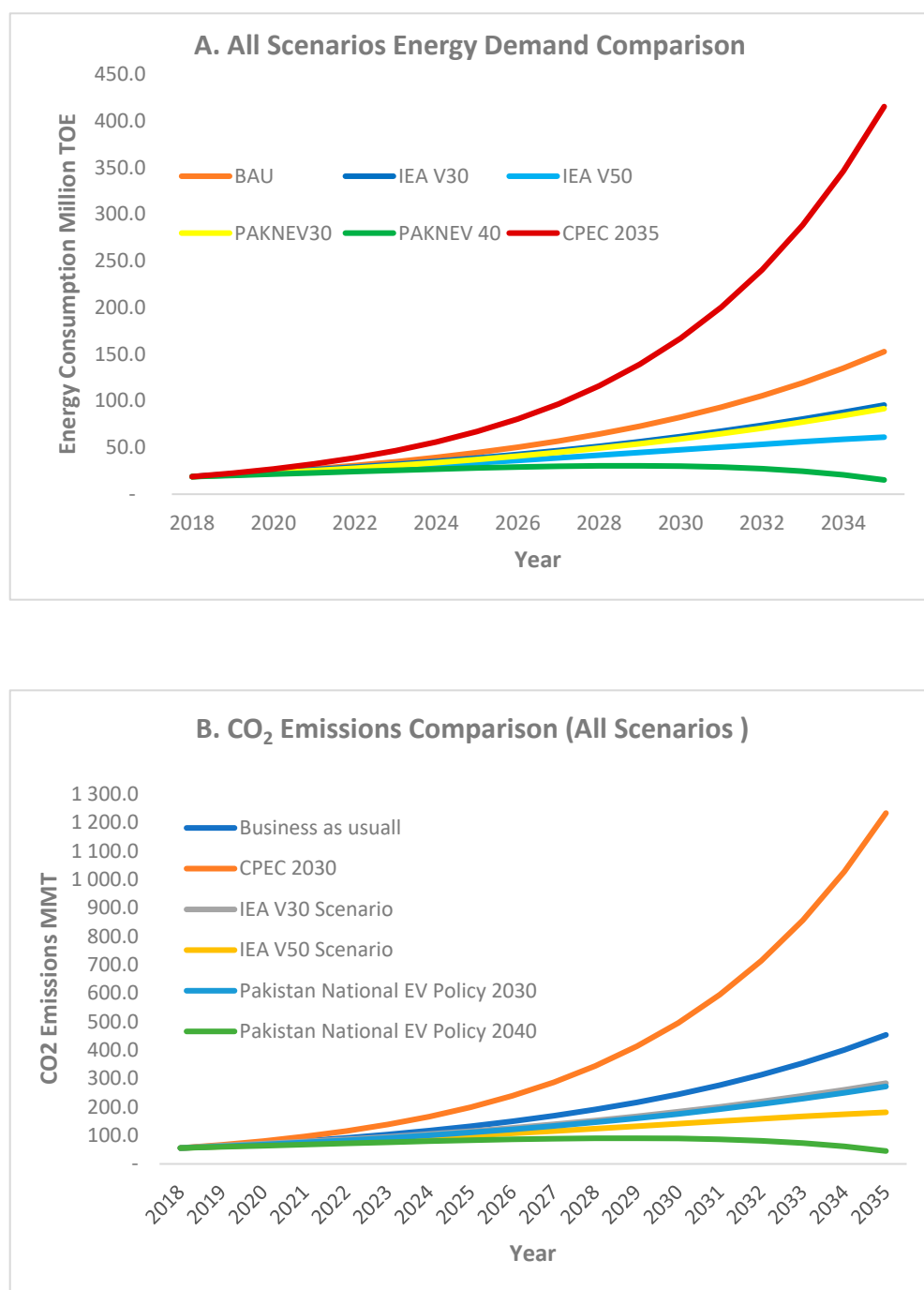


Figure 11. Energy demand comparison (A) and emission comparison (B) of BAU, IEA V30, IEAV50, CPEC2030, Pakistan NEVP 2030 and Pakistan NEVP 2040 scenarios.

5. Conclusions

This study provides a comprehensive outlook of the emissions and energy consumption associated with the transport sector in Pakistan. Time series trends are updated and validated, while Pakistan's energy consumption data in terms of individual fuel consumption (gasoline, HOBC, HSD, LDO, CNG), emissions produced as a result of the combustion of fossil fuels, unbundled number of locally manufactured and registered vehicles in Pakistan, and other related statistics are presented based on actual data provided by Pakistan's federal government departments and different international agencies (e.g., UN, UNFCCC and IEA). A detailed literature survey was conducted, looking at sustainable and clean

transport policies, Pakistan's current energy situation, renewable energy sources, global electric mobility and supportive and regulatory measures to promote zero-emissions mobility. Six different scenarios (BAU, IEA V30, IEA V50, CPEC and Pakistan NEVP 2030 2040) were analyzed in LEAP for energy and emissions forecasting up to 2035. The results have shown that the CPEC-2030 scenario has highest rate of energy consumption and the highest allied emission for Pakistan, while the NEVP 2040 scenario for Pakistan transport sector has the lowest energy needs and allied emissions. The newly developed Pakistan NEVP 2030 has potential to reduce the transport sector's fuel consumption and associated emissions by 50% within a short period of time. The study explains that Pakistan's transport sector has significant potential to increase its energy sustainability and reduce emissions through technology and policies. The study also explains that electric/zero-emissions mobility is indispensable for the clean and sustainable future of the transport sector. This study will be helpful for the researchers and environmental policy-makers in Pakistan. The findings and analysis in this study can be used to improve Pakistan's transport sector to obtain energy suitability and a less toxic environment.

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Nomenclature

EV	Electric Vehicles
COP	Conference of Parties
IPCC	International Panel on Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
IEA	International Energy Agency
Li Ion	Lithium Ion (Batteries)
INDC	Intended Nationally Determined Contribution
GHG	Green House Gases
TOE	Tons of Oil Equivalent (Energy)
MMT	Million Metric Tons
CO ₂	Carbon Dioxide
SO _x	Oxides of Sulphur
NO _x	Oxides of Nitrogen
HC	Hydrocarbons
UBHC	Unburnt Hydrocarbons
CH ₄ (g)	Methane Gas
LEAP	Long-Range Energy Alternate Planning
MS	Motor Spirit
HSD	High-Speed Diesel
HOBC	High-Octane Blending Component
LDO	Light Diesel Oil
BAU	Business as Usual

V30	Vision 2030
V50	Vision 2050
CPEC	China Pakistan Economic Corridor
PRC	People's Republic of China
NEVP	National Electric Vehicle Policy

Abbreviations

Pakistan GDP	\$305 Billion
Pakistan GDP Per-Capita	\$1547.85
Total Energy Consumption	50.12 TOE
Number of Registered Vehicles	22 million
Energy Consumption Share by Transport Sector	33.93%
Pakistan Population	220 million
Pakistan Electricity Supply	123,118 GWh
Pakistan Electricity Demand	95,530 GWh
CO ₂ From Fuel Combustion	200 MMT
Current renewable Energy Share	35% (hydel and non hydel)
Emission Standard used in LEAP for Gasoline, HOBC and HSD CNG	IPCC Tier 1 Default Emission Factor

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