**Government of Nepal**
Ministry of Forests and Environment
**Department of Environment**

# A
# Final Report on study of
# Fuel Economy and Exhaust Emissions Measurement in LDVs
# and
# Policy Development and Awareness Program

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30 June 2021

# Executive Summary


Transport sector occupies a large share of anthropogenic greenhouse gas emissions that impact environment and economy in the case of oil-importing countries. In Nepal, the unmanaged transport sector and fuel energy related GHG emissions are one of the leading causes of deteriorating air quality. Besides, Nepal is fully dependent on the import of fuels and vehicles, mostly from India. Nepal has not developed its roadmap for fuel quality standards and as such, follows emissions standards and fuel quality standards of India. Owing to the variation in geographical and physical conditions in Nepal, these standards are adaptable but might not be suitable. In this context, it has become very imperative to develop its fuel economy (FE) standards or undertake fiscal policy measures to improve FE and reduce fuel-related emissions. Environment-friendly Vehicle and Transport Policy, 2014, was formulated to promote environment-friendly vehicles in Nepal. It sets the target to achieve more than 20% of vehicle fleets to be environment-friendly vehicles by 2020, provided tax exemption to purchase electric vehicles. The air quality management action plan for Kathmandu valley, 2017 was formulated to promote zero-emission vehicles in private as well as in public transport. Frequent changes in fiscal policies have been a bottleneck in introducing cleaner electrical vehicles in the Light Duty Vehicles (LDV) markets of Nepal. The recent budget speech of Government of Nepal (GoN) for the fiscal year 2021/22 bodes well for promoting electric vehicles by reducing the customs duty on electric vehicles and attaining 100% of electric vehicles in new sales of LDVs by 2030.

Global Fuel Economy Initiative (GFEI) is working across the world to reduce overall petroleum consumption and decrease greenhouse gas (GHG) emissions from LDVs. The GFEI target is to reach 4.4 Lge/100 km of fuel economy and a drop in $CO_2$ emissions to 90 g/km in 2030 respectively. On the basis of rated data on fuel economy and tailpipe exhaust emissions of LDVs of the Original Equipment Manufacturers (OEMs), a baseline study on fuel economy and exhaust $CO_2$ emissions of LDVs was carried out in 2019 by Clean Energy Nepal (CEN) from the registered LDVs from 2005-2016. The weighted average rated fuel economy and $CO_2$ emissions were estimated using data of approximately 60 thousand LDVs that were registered during the analysis period. It shows the gradual improvement of rated fuel economy from 6.98 Lge/100km in 2005 to 5.89 Lge/100km in 2016 and $CO_2$ emissions reduction from 159 g/km to 137 g/km respectively (CEN, 2019).

This study is carried out under the support from the Department of Environment, Ministry of Forests and Environment (MoFE), by the Center for Energy Studies (CES), IOE/TU, to find out the evidence-based specific fuel economy and exhaust emissions of a sample of LDVs on the roads for determining norms for fuel economy and the tailpipe emissions of the LDVs in Nepal. The vehicles were tested in the authorized automobile dealers' and government-owned workshops. Different equipment such as flue gas analyzers, fuel meters were used for the tests.

The weighted average fuel economy of LDVs from the sampled experimental tests is found to be 9.4 Lge/100km which is 58% lower than the rated fuel economy of 5.9 Lge/100km of new LDVs. The average $CO_2$ emissions of the sampled vehicles are found to be 275 g/km compared to rated emissions of 146 g/km. The actual exhaust emissions are 88% higher than the manufacturers' rated emissions of new vehicles. By the way, the empirical study also indicated that fuel economy could improve by 10% and exhaust emissions could be decreased by 24% if the vehicles are timely serviced and maintained.

A scenario analysis was also conducted with the Business as usual (BAU) and electric mobility scenarios using IEA's Fuel Economy Policy Implementation tool (FEPIT). Considering 100% new car/jeep sales to be electric by 2030, the share of electric vehicles will be increased to 56% of the total number of LDVs in 2030 from less than 1% share in 2020. The results show that the weighted average fuel economy of LDVs will be 4.7 Lge/100km in 2030 which is near to the GFEI's target of 4.4 Lge/100 km in 2030. Meanwhile, the weighted average $CO_2$ emissions will be reduced from 275 g/km in 2020 to 108 g/km compared to the GFEI target of 90 g/km in 2030. Besides, the total fuel costs savings in focusing on electrification in the LDVs can be estimated to be NRs. 43 billion with the increase in domestic sales of electricity by NRs. 5.4 billion in the decade from 2021- 2030.

Considering all these benefits of electrification in the LDVs transport segment, the recent fiscal policy in reducing the customs duties for electric vehicles, and introducing new feebate fiscal systems, if possible, Nepal can almost meet the GFEI's fuel economy and exhaust emissions targets by 2030. There is no doubt that Nepal must go strongly for electrification with the conducive policies in the transport sector, development of required infrastructure for electric transport, and of course relevant fiscal policies for promoting electrification in the transport sector in the country.

## Abbreviations

| | |
|---|---|
| cc | Centimeter cube |
| CO | Carbon monoxide |
| $CO_2$ | Carbon Dioxide |
| DoE | Department of Environment |
| DoTM | Department of Transportation Management |
| FE | Fuel Economy |
| FEPIT | Fuel Economy Policies Implementation Tool |
| GFEI | Global Fuel Economy Initiative |
| GHG | Greenhouse Gases |
| GPS | Global Positioning System |
| $H_2$ | Hydrogen |
| HC | Hydrocarbons |
| IEA | International Energy Agency |
| km | kilometer |
| kt | kilotons |
| LDV | Light Duty Vehicle |
| Lge | Liters of gasoline equivalent |
| lt | Liter |
| N2O | Nitrous oxide |
| NOC | Nepal Oil Corporation |
| NOx | Nitrogen Oxides |
| $O_2$ | Oxygen |
| PJ | Petajoule |
| OBD | On-Board Diagnostics |
| OEM | Original Equipment Manufacturers |
| PM2.5 | Particulate Matter 2.5 |
| ppm | part per million |
| $SO_2$ | Sulphur Dioxide |

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# 1 Introduction

## 1.1 Background

Transport sector occupies a large share of anthropogenic greenhouse gas emissions that impact environment, and economy in the case of oil-importing countries. Therefore, enforceable, and robust policies are needed to reduce non-renewable fuel dependency and mitigate transport-based emissions. In Nepal, the unmanaged transport sector and energy related GHG emissions are one of the leading causes of deteriorating air quality. The total GHG emissions from the transport sector were 2.74 million metric tons in 2015, which accounted for 26% of the total energy related GHG emissions in the country (ICIMOD, 2017). Nepal is fully dependent on the import of fuels and vehicles, mostly from India. Nepal has not developed its roadmap for fuel quality standards and as such, follows emissions standards and fuel quality standards of India. Owing to the variation in geographical and physical conditions in Nepal, these standards are adaptable but might not be suitable. In this context, it has become very imperative to develop its fuel economy standards or undertake fiscal policy measures to improve FE and reduce fuel-related emissions.

According to the National Survey of Energy Consumption and Supply Situation in Nepal, energy consumption in the transport sector in 2015/16 was 836 ktoe, and an annual growth rate is 7% (MoF, 2016). Petroleum products such as petrol, diesel, aviation fuel, and LPG are the sources of fuels in this sector. Nepal imports 100% petroleum products and more than two-thirds of them are consumed in the transport sector alone (Malla, 2014), and the remaining are consumed in other sectors (household, industry, commerce and services, and agriculture). According to Nepal Oil Corporation (NOC), Nepal imported 2.3 million kiloliters of petroleum products in 2017/18. Energy consumption in the transport sector is influenced by energy intensity, vehicle efficiency, and modes of transport (Gupta and Singh, 2016, Qipeng et al., 2013, Zhang et al., 2011). In 2019, the transport sector consumed 65 PJ (2 million Lge) of energy and out of which 5% was consumed in LDVs (UNDP, 2021).

The deteriorating air quality of Nepal is mainly due to the unmanaged transport sector. GHGs, $CO_2$, CO, $NO_x$, HC, $PM_{2.5}$ are major air pollutants from the transport sector. In 2019, road transport emitted 4,732 kt of $CO_2$, 227 kt of CO, 1.5 $N_2O$, 8.7 kt of $SO_2$, and 34 kt $PM_{2.5}$ in the country (UNDP, 2021). The emissions from LDVs were estimated to be 923 kt of $CO_2$, 6.2 kt of CO, 0.13 $N_2O$, 1.8 kt of $SO_2$, and 0.3 kt PM2.5 in 2019 in the country. Moreover, Kathmandu valley alone emitted 9.6kt of $PM_{2.5}$ and 1.6kt of BC in 2015 (Ghimire and Shrestha, 2014). Meanwhile, in 2015, the particulate emissions $PM_{2.5}$ account for 3% of total emissions from the transport sector while that for black carbon is 17%, mainly due to emissions from diesel vehicles (ICIMOD, 2017).

Nepal Transport Policy 2001 was formulated to develop sustainable, reliable, safer transport in the country with an emphasis on renewable energy sources and pollution-free transport system. In 2010, Nepal Oil Corporation, a state-owned trading enterprise that imports, stores, and distributes various petroleum products started supplying EURO III standard fuel to reduce emissions and improve fuel economy. It banned the import of vehicles emitting carbon dioxide beyond the given limit. In a bid to reduce emissions from vehicles, the government also proposed ethanol mix fuel substitution, but so far it is not implemented. Environment-friendly Vehicle and Transport Policy, 2014, was formulated to promote environment-friendly vehicles in Nepal. It sets the target to achieve more than 20% of vehicle fleets to be environment-friendly vehicles by 2020, provided tax exemption to purchase electric vehicles. As a result, the use of electric vehicles is gradually increasing in Nepal. The air quality management action plan for Kathmandu valley, 2017 was formulated to promote zero-emission vehicles from private as well as public transport. To further promote electric mobility in the country, the national action plan for electric mobility, 2018 was formulated. However, due to weak institutional capacity and the absence of effective implementation and monitoring units, the air quality of the country is degrading despite such policies. The recent budget speech of GoN for the fiscal year 2021/22 also focuses on promoting electric vehicles by increasing the sales of 100% electric LDVs by 2030.

## 1.2 GFEI Fuel Efficiency Targets

GFEI is working across the world to reduce overall petroleum consumption and decrease greenhouse gas (GHG) emissions from LDVs. The initiative has set the target to improve the fuel efficiency of all new LDVs by 50% by 2030 and all vehicles by 2050 preferably known as the "50 by 50" campaign compared to the 2005 baseline levels (IEA, 2019). The GFEI target is to double the efficiency of all new vehicles from 8.8 Lge/100 km in 2005 to 4.4 Lge/100 km in 2030 and the corresponding drop in $CO_2$ emissions from an average of 180 g/km in 2005 to 90 g/km in 2030, which would require an improvement rate of 1.7% per annum. It would save over 1 Gt of $CO_2$ a year by 2025 and over 2 Gt/yr by 2050 and results in savings in annual oil import bills alone worth over US$ 300 billion in 2025 and US$ 600 billion in 2050 (GFEI, 2018).

## 1.3 Fuel economy in developing and developed countries

Fuel consumption trend in developed countries shows a decreasing trend compared to that of other developing countries due to the shift in electric mobility as well as fuel-efficient technologies (GEFI, 2013). Norway is at the forefront in the fuel economy trend, with 47% of the total LDVs share coming from Electric Vehicles (EVs). As a result, the average fuel economy in Norway in 2018 is very low at 3.9 Lge/100 km, exceeding the global GFEI target for 2030 by more than 10% (Scheffer, 2019).

The fuel economy of India enhanced to 5.6 Lge/100 km in 2017 with the introduction of a large share of small and fuel-efficient cars (IEA, 2019). The annual average fuel economy and $CO_2$ emissions of ICE cars (first registration) in Sri Lanka is 6.6 Lge/100 km and 160 g/km of $CO_2$ respectively in 2015. To reach the GFEI target, the country is in the process of developing and managing the fuel economy in cars to mitigate the adverse effects on the economy and the environment (Sugathapala, 2015). The average fuel economy in Bangladesh has improved from 8.98 Lge/100 km in 2005 to 6.9 Lge/100 km in 2017 with an improvement of 23.16 % in fuel economy and a 24.5 % reduction in $CO_2$ emissions (GFEI, 2019). The country has a restriction on the import of vehicles older than 5 years and as such, is on promotion of imports of energy-efficient vehicles.

## 1.4 Fuel economy and exhaust CO2 emission baseline in Nepal

The baseline study on fuel economy and exhaust $CO_2$ emission of LDVs was carried out in 2019 by Clean Energy Nepal (CEN) from the registered LDVs from 2005-2016. The weighted average rated fuel economy and $CO_2$ emissions were estimated using data of approximately 60 thousand LDVs that were registered during the analysis period. It shows the gradual improvement of rated fuel economy from 6.98 Lge/100km in 2005 to 5.89 Lge/100km in 2016 and $CO_2$ emission reduction from 159 g/km to 137 g/km respectively (CEN, 2019). Since Nepal depends completely on imported automobiles, the reduction comes mainly from the manufacturers' fuel efficient technology improvement.

## 1.5 Supporting transport policy documents

Over time, several plans, policies, and programs were formulated to improve the transport sector of Nepal. The key features of major transport policy, plans, and programs are tabulated in Table 1.

*Table 1 Policies and regulations related to the transport sector in Nepal*

| S.N. | Transport Sector Policies and Legislations | Provisions mentioned in the policies |
|---|---|---|
| 1 | National Transport Policy 2001 | - Aims to make the transport sector environment friendly.<br>- Special attention to be provided in improving 'the comfort, reliability, safety, frequency, availability, and affordability of public transport to reduce the harmful emissions from mobile sources.<br>- Provisions of custom and tax incentives to encourage nonpolluting vehicles. |
| 2 | Transport Management Act 2049 and Vehicles and Transport Management Rules 2054 | - Refuses to issue route permit to vehicles emitting pollution |
| 3 | National Sustainable Transport Strategy (NSTS) (2015-2040) (Draft) | - Increase climate and disaster resiliency of transport infrastructure<br>- Maintain the standard of vehicle or engine condition<br>- Minimize local pollution and noise effects<br>- Promote electric vehicles<br>- Minimize CO2 emissions from transport |
| 4 | Environmental Act 1996 and Regulation 1997 | - Creating pollution is the punishable act<br>- Provision of Environmental Protection Fund for utilization in pollution prevention and control activities<br>- Use of economic incentives and disincentives to prevent and control pollution<br>- Polluters to have pollution control certificate (concerned authorities to issue within 6 months of this acts in place, and hence not in use yet) |
| 5 | National Climate Change Policy 2011 | - strengthening, climate change mitigation and adaption<br>- promotion of use of clean energy, |
| 6 | National Low Carbon Economic Development Strategy (Draft) | - Decrease the dependence on fossil fuels by the optimal development of hydropower and other renewable energies, and build energy capacity.<br>- To develop climate change resilient infrastructure through the development, use, and promotion of the technologies that emit low carbon. |
| 7 | National Pollution Control Strategy and Action Plan (Draft) | - Mainstreaming pollution prevention measures into all development efforts<br>- Making polluters pay<br>- Addressing transboundary pollution issues<br>- Redefine emission standards for vehicle and industries based on a baseline assessment of monitoring parameters<br>- Update motor vehicle inspection and emission testing system (MVIETS)<br>- Strengthen vehicle emission enforcement capabilities with gradual improvement in the implementation of MVIETS for all vehicles<br>- Develop and implement a policy to discourage to ply the EURO1, EURO 2 vehicles and encourage importing only the EURO 3 and 4 standard vehicles. |

| S.N. | Transport Sector Policies and Legislations | Provisions mentioned in the policies |
|---|---|---|
| | | - Provide the emission test equipment to private motor workshops to ensure that the vehicle that goes under maintenance has thoroughly done maintenance and has passed the emission test.<br>- Introduce metro, trolley-buses and low emission vehicles<br>- Conduct regular clean-up activity of the road and roadside areas and prohibit littering habit of people<br>- Capacitate the private sector technical human resources in emission testing<br>- Introduce age limit regulations based on emission testing results and comply with regulations |
| 8 | Climate change policy, 2076 (2019) | - It states that policy related to reliable, sustainable, and low carbon technology in transport will be developed for climate-resilient economic development.<br>- It also mentions that transport vehicles that have exceeded certain years of running period and that are high-polluting will gradually be phased out based on certain standards.<br>- The use of electrical vehicles will be encouraged. |
| 9 | Kathmandu Vally Air Quality Management Action Plan, 2020 | - Reduce transport related emissions<br>- Euro – 4 standards for all vehicles within 1 year<br>- Develop in-used vehicle emissions standard within 1 year<br>- Provision of green sticker based on in-vehicle emissions test<br>- Installation of mechanical tail pipe to reduce exhaust particulate emission from all diesel vehicles within 2 years<br>- Establish at least 5 vehicle emission test centres within 1 year<br>- Establish at least 5 vehicle fitness centres within 1 year for vehicle inspection<br>- Develop fuel economy norms within 2 years<br>- Promote electric vehicles<br>- Ensure fuel quality and avoid adulteration |

## 1.6 Vehicle registration status in Nepal

Road Transport covers most of the transport in Nepal and passenger vehicles dominate the road transport. Vehicle registration status in Nepal in the fiscal year 2018/2019 shows that 79% of the total registered vehicles are motorcycles, 7% cars/jeeps/vans, 4% tractors and trucks, 1% pickups, 2% buses, and remaining others (tempos, rickshaws, heavy equipment minibuses, and microbuses) (DOTM, 2019). The annual vehicle registration has been increasing at the rate of 14% per annum in the last decade. In 2018, total registered vehicles reached 3.22 million, and 90% of them are passenger vehicles and only 10% are freight vehicles. Private vehicles take over most of the passenger vehicles with 96% and only 4% registered as public.

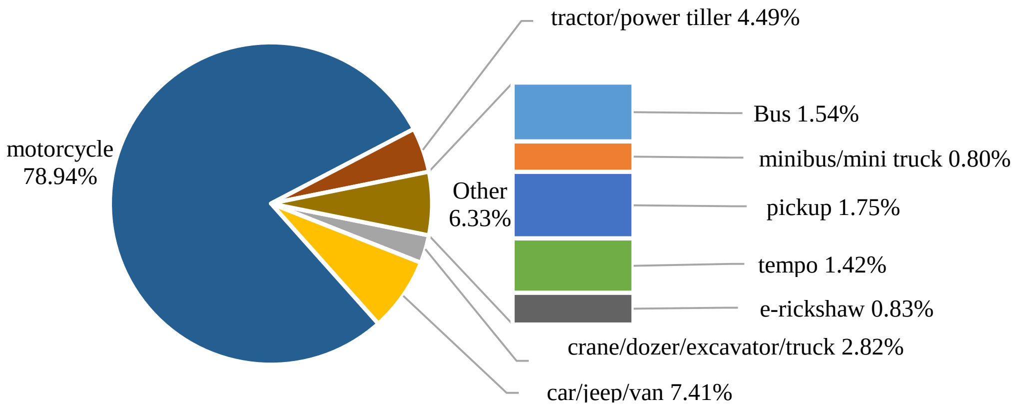



*Figure 1 Vehicle registration status in Nepal in 2018*

## 1.7 Registration status of Light-Duty Vehicles (LDV) in Nepal

LDVs mainly comprise cars, jeeps, vans, pickups, and microbuses having gross vehicle weight less than 3,500 kg. The registration status of LDV (Figure 2) shows a tremendous increase in vehicles with an annual growth rate of 16% during the last decade. The average share of LDVs is 8% of total vehicle registration, and approximately 62% of the registered LDVs are cars followed by jeep 16%, pickup 14%, van 8%, and microbus 1% respectively. The annual car registration is increasing at the rate of 12% in Nepal, and almost 93% of them are petrol vehicles and the rest diesel vehicles (DOTM 2018; CEN 2019). It is found that 43% of the LDVs registered to have an engine capacity range between 1001-1500 CC in Nepal (CEN 2019).

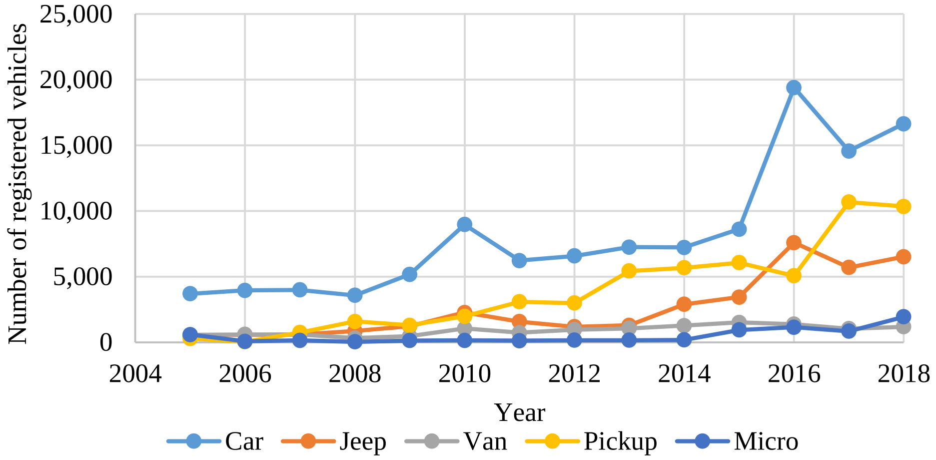



*Figure 2 Registration status in Nepal in 2018*

## 1.8 Objectives:

The primary objective of the study is to empirically determine the specific fuel consumptions and emissions in LDVs and henceforth recommend appropriate policy formulation along with awareness programs. The process would comprise of following specific objectives:

a) Estimation of actual fuel economy of LDVs as per details from the LDVs Original Equipment Manufacturers (OEMs)
b) Estimation of actual exhaust emissions of a sample of major brands of LDVs plying on the roads
c) Develop targets and norms for fuel economy
d) Develop targets and norms for exhaust emissions
e) Analysis of economic and environmental implications of norms and policies
f) Organize awareness campaign to stakeholders

## 1.9 Scope of Study:

The study was sub-grouped into three main activities based on outcomes of each group (Figure 3):

1. Experiment-based fuel economy and emission factor estimation
2. Evidence-based policy recommendation
3. User-based awareness creation

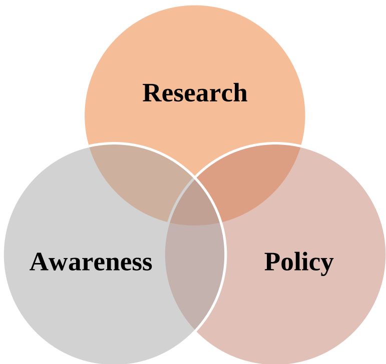



*Figure 3 Main Activities of the study*

### 1.9.1 Evidence-based fuel economy and emission factor estimation

Currently, fuel economy and exhaust emission of LDVs are based on the manufacturers' published claims. It is very well perceived that these values are not accurate, mainly due to differences in actual conditions. Thus, it is essential to have information on the actual variation in fuel economy and exhaust emissions on a contextual basis to know the impact of the use of each vehicle type and fuel.

The economy and the exhaust emissions of vehicles have been improving globally in the neighboring country. Since many of the vehicles in Nepal are imported via India, there is a strong influence of these vehicles on the fuel economy and the emissions of the vehicles running in Nepal, which are in an improving trend (CEN, 2019).

However, this study only takes account of the auto manufacturers' claims for the emissions and fuel economy. However, there may arise questions whether the actual fuel economy and the exhaust emissions comply with the values of the rated fuel economy or not. These facts can be studied through conducting a physical test of vehicles at various technical and running conditions here in a geographically and infrastructurally challenged place like Kathmandu.

The fuel economy and the exhaust emissions are influenced by various factors such as:

- Vehicle type/size
- Vehicle age and accumulated distance travelled
- Fuels used
- Tire type maintenance
- Maintenance condition of new vehicles
- Traffic conditions and driving cycles
- Road conditions
- Ambient weather conditions

Among these, in the context of Nepal, the major affecting factors for the variation in a rated fuel economy and emissions are the road conditions, traffic conditions, driving cycles, driving behavior, fuel quality, and the maintenance condition of the vehicles.

### 1.9.2 Fact-based policy development

The policies should target a specific and realistic objective. In absence of real-time data and empirical evidence, the policies so formulated might not attain the required targets. Fuel economy programs and GHG emission targets, either mandatory or voluntary, have proven to be among the most cost-effective tools in controlling oil demand and GHG emissions from vehicles. The overall effectiveness of standards can be significantly enhanced if combined with fiscal incentives and consumer information. Taxes on vehicle purchase, registration, use, and motor fuels, as well as road and parking pricing policies, are important determinants of vehicle energy use and emissions.

In the year 2019/20, the government had tried to impose a new registration tax system based on engine capacity. Vehicles with an engine capacity lower than 2,000 cc and higher than 2,000 cc are imposed with the tax based on their vehicle prices, which has not come into effect. The recent act of government in 2021 to promote electric vehicles by curtailing customs duty and other taxes is expected to increase number of electric vehicles in near future.

### 1.9.3 User-based awareness creation

The awareness among the general public regarding fuel economy and emissions is very low. In the transport sector, the marketers/suppliers only provide data based on rated fuel economy of the manufacturers. These data are useful only for comparison between two vehicles but do not give real estimates on contextual operating conditions. In addition to these, although manufacturers provide rated emissions, the consumers are very less known to these facts and the dealers hardly mention them during their sales and marketing campaigns, and hence, consumers are ignorant of these facts while making purchasing decisions. From a policy point of view, consumers are also not aware of the current tax system- which already impose fixed-rate pollution taxes. Thus, if people are made more aware of the "polluters pay" scheme in petroleum and vehicles taxation, in addition to the direct and indirect impact of fuel economy and emissions on the livelihood and nation as a whole – they could be socially responsible for making correct choices in purchasing their vehicles.

The nexus of these three activities is very essential for the effective implementation of target-based but environment-friendly policy. Leave any one of these activities alone, the consequence will not have a desired impact on reaching the stipulated targets. For instance, if there is no research-based and scientifically evidence-based information, the effect of policy would be immeasurable, and the stakeholders will be prone to make inappropriate choices. While, in the absence of policy, it is evident that there would be no control over stakeholders' activity nor research development. Meanwhile, in a lack of public awareness regarding the actual data and policies, the stakeholders are prone to make decisions based on ad-hoc information, usually based on the auto dealer's claims. Thus, formulation of scientific research and evidence-based norms and policies with effective dissemination of such information would urge a pragmatic change in consumer behavior and would encourage consumers to the adoption of new cleaner fuel-efficient vehicles.

# 2 Methodology

The methodology consists of two approaches for the first two areas of study The first one is the experimental approach for estimation of fuel economy and emissions based on empirical data collected during the study. Secondly, for policy development, an exploratory approach to evaluate the implications of policies and strategies regarding fuel economy and emissions is taken. The detailed methodology is discussed in the following sections.

The stakeholder's awareness is one of the objectives of this study. At first, preliminary results were shared among the personnel from the Department of Environment for feedback on the methods and outputs of the results. Detail discussions with the policymakers were carried out at the next level for policy inputs to develop future targets for improving fuel economy and exhaust emissions of LDVs in Nepal. Finally, the study insights were disseminated among the stakeholders to aware of the disparity in rated fuel economy and exhaust emissions and actual fuel economy and exhaust emissions of LDVs in Nepal and to explore the underlying problems of disparity in Nepal.

The three main phases of the study/task are depicted in Figure 4.

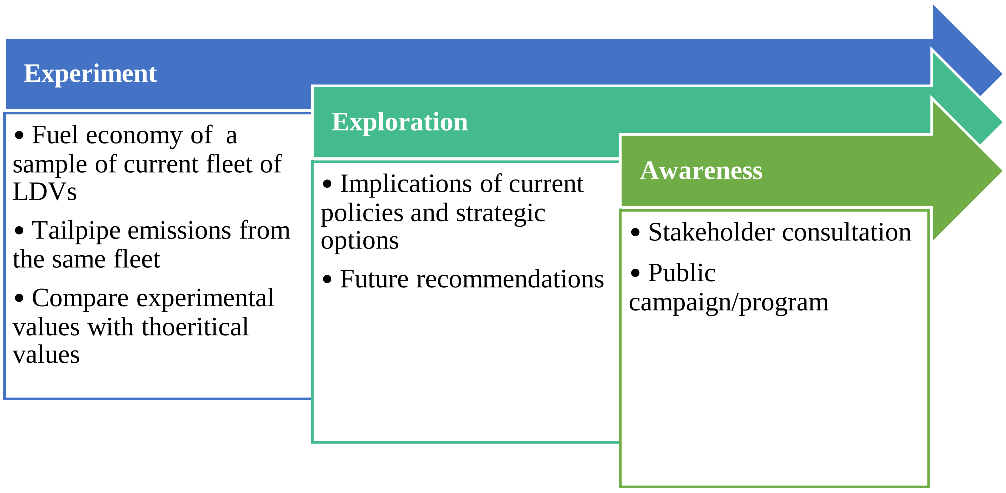



*Figure 4 Phases of the study*

## 2.1 Light-Duty Vehicles (LDVs)

LDVs mainly comprise cars, jeeps, vans, pickups, and microbuses having gross vehicle weight less than 3,500 kg. The main categories of LDVs registered in Nepal are-

- Car
- Jeep
- Van
- Microbus
- Pickup
- EVs in the LDV segment

Furthermore, the LDVs can be categorized by the types of fuel they use. Pick and microbus are almost all diesel-powered vehicles, wherein cars, jeep, and vans could be either be powered by petrol engines or diesel engines, with most cars and vans being petrol engines while most of the jeeps being diesel ones. The average share of LDVs is 8% of total vehicle registration, and approximately 62% of the registered LDVs are cars followed by jeeps 16%, pickups 14%, vans 8%, and microbuses 1% respectively (DoTM, 2018).

## 2.2 Sample approximation

Since the characteristics of mechanical equipment are not prone to deviate widely from vehicle to vehicle, a well sizable number of samples, even though a smaller size, can reflect the specific characteristics of the vehicles. In addition, the performance indicators of a vehicle are also determined by driving conditions such as speed, acceleration, road conditions, terrain as well as weather. However, the measurements were to be carried out with the least variability for driving conditions as possible. This also reduces demand for a larger sample size. Within these circumstances, the smallest representative sample size could be taken, but it needs to represent each category of vehicle types. The experiment was carried out for 41 LDVs, stratified by body type/seat capacity and/or range of engine capacity as shown in Figure 5. The sample was taken proportionately as per vehicle population as well as considering that each category of vehicle is included in the sample. Apart from the conventional petrol and diesel LDVs, around 3 units of Electric Vehicles under LDVs were analyzed for electricity consumption and other performance indicators.

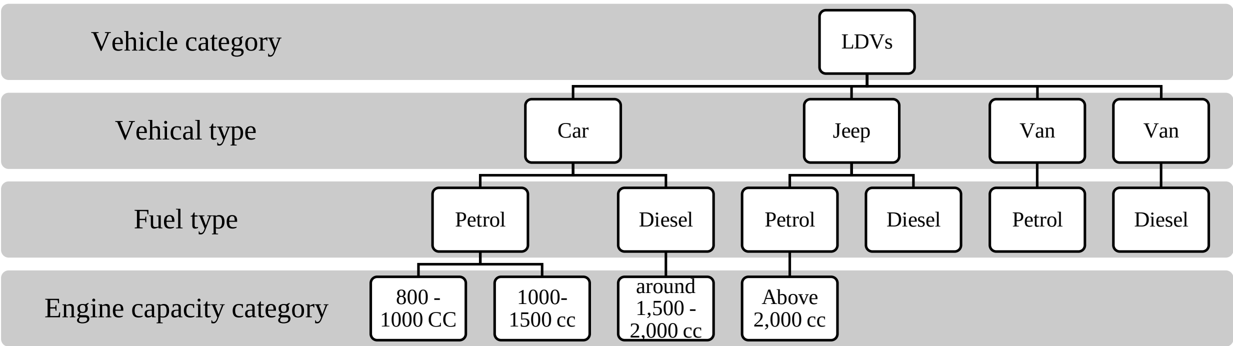



*Figure 5 LDVs stratification*

The sample size is calculated using the formula given by Krejcie and Morgan (1970). The sample size is determined at a 90% confidence interval within a 10% margin of error. The required sample size is calculated to be 43. The total registered LDVs (Car/Jeep/Van) until 2018 was 237,658 (DOTM, 2018).

$$n = \frac{z^2.p.q.N}{e^2(N-1) + z^2.p.q}$$

Where,

p = population proportion assumed to be 0.2

$z^2$ = Chi square for the specified confidence level (90%) = 2.71

N = Population size

e = Marginal error = 0.10

n = required sample size = 43

The sample of vehicles is categorized as per the vehicle type which is further classified into fuel type. In each category, the sample vehicles are further selected based on their engine capacity. The historical data of the light-duty vehicles registered in the Department of Transport Management (DOTM) from 2005-2016 was taken to estimate the weighted average of LDVs in each category. The registration data shows that 68% of LDVs were petrol-based and the remaining were diesel-based. It was found that 60% of registered vehicles were cars, 19% were jeeps, 7% were Vans, and 14% were pickups. Approximately 57% of the registered cars were petrol-based, of which 60% lies in between 1000-1500 CC engine capacity category. The registration data shows that 34% of total LDVs were petrol-based cars with an engine capacity of 1000-1500 CC and 17% were petrol cars with less than 1000 CC capacity. Meanwhile, there were 14% diesel-based LDVs and most of them have engine capacity higher than 2000 CC. In the case of a van, almost all registered vehicles were petrol-based with engine capacity less than 1500 CC and for pick-up, all the registered vehicles were diesel-based with most of them having engine capacity higher than 2000 CC. Based on the available data from DOTM, the number of sample vehicles in each category were estimated for fuel economy and exhaust emission tests. The number of vehicles tested in each category is as shown in Table 2.

*Table 2 Vehicle sample to be tested in each category*

| | **Diesel** | | | | | | |
|---|---|---|---|---|---|---|---|
| **CC** | **upto-1000** | **1001-1500** | **1501-2000** | **2001-2500** | **2501-2900** | **2901 and above** | **Total** |
| Car/Jeep | - | 2 | 2 | 8 | 1 | 1 | 14 |
| Van | - | - | - | - | - | - | - |
| Pickup | - | - | 1 | 1 | 1 | 2 | 5 |
| | **Petrol** | | | | | | |
| **CC** | **upto-1000** | **1001-1500** | **1501-2000** | **2001-2500** | **2501-2900** | **2901 and above** | **Total** |
| Car/Jeep | 8 | 11 | 2 | - | - | - | 21 |
| Van | 1 | - | - | - | - | - | 1 |
| Total | 9 | 13 | 5 | 9 | 2 | 3 | 41 |

## 2.3 Fuel Economy Estimation

The rated fuel economy of the vehicle was estimated based on the manufacturer's rated fuel economy. The following information was retrieved from each sample vehicle before testing

- Vehicles make and model,
- Model production year,
- Year of first registration,
- Fuel type,
- Engine size,
- Servicing time

- Total kilometer driven
- Registration number
- Rated fuel economy per model (from specifications)

The experimental analysis of the sample vehicles was carried out in the authorized workshops/ training centers. The On-Board Diagnostics (OBD) system was used as a vehicle scanner for the preliminary test of the vehicles. The vehicle warm-up was done before testing. Data for idle and cruising speed at 2500-3000 rpm were noted during the experiment.

The road test was carried out at an ambient temperature and the commercially available fuel was used for testing. A fuel flow meter was used that measures the total kilometer travelled in each test, fuel consumed during the test distance, and the speed of vehicles. Most of the recent vehicles have an inbuilt display dashboard that gives instant fuel consumption as well as the average fuel economy of the vehicle. The estimated fuel economy is reported in liter gasoline equivalent per 100km (Lge/100km).

The weighted average fuel economy of the vehicles-both experimental and rated is estimated using the following equation:

$$Average\ annual\ fuel\ economy = \frac{Total\ vehicles\ of\ first\ registration\ during\ the\ year}{\sum_{i=1}^{n} \frac{Number\ of\ vehicles\ in\ Model\ i}{Fuel\ economy\ of\ vehicles\ in\ Model\ i}}$$

## 2.4 Exhaust emission estimation

A flue gas analyzer is used to calculate different types of exhaust emissions. The major pollutants measured by the gas analyzer are Nitrogen Dioxide ($NO_2$) (ppm), Oxygen ($O_2$) (%), Carbon Monoxide (CO) (%) and Carbon Dioxide ($CO_2$) (%), Nitric Oxide (NO) (ppm) and Nitrogen Oxides (NOx) (ppm). The equipment is provided with the gas probe where sample gas is taken through by a diaphragm suction pump inside the equipment. The cone attached to the probe is placed roughly at the center of the flue. The gas-cooled, dried, and cleaned of humidity and impurities/particulates by a condensate trap and filter positioned along with the rubber hose that connects the probe to the analyzer. The gas is then analyzed by electrochemical gas sensors. The electrochemical cell guarantees high precision results in a time interval of up to about 60 minutes during which the instrument can be considered very stable. During the zero-calibrating phase, the instrument aspirates clean air from the environment and detects the sensors' drifts from zero (20.9% for the $O_2$ cell), then compares them with the programmed values and compensates them. The sensors are pre-calibrated for measuring carbon monoxide CO (compensated in hydrogen $H_2$), nitrogen oxide (NO), nitrogen dioxide ($NO_2$).

Three measurements of exhaust emission were taken for each vehicle during both idling and cruising speed and the average data were noted for each vehicle. The experimental data were compared with the rate of exhaust emission.

Emissions standards for light-duty vehicles are usually reported in g/km. The coefficient for general conversion from emission gas concentration (ppm) to specific fuel consumption (g/km) is given by Pilusa et al. (2012).

$$CO\ (g\ km) = 9.66\ x\ 10\text{-}3\ X\ CO\ (ppm)\ \text{..........Eq1}$$

$$NOx\ (g\ km) = 28.56\ x\ 10\text{-}3\ X\ NOx\ (ppm)\ \text{..........Eq2}$$

For Diesel vehicles

$$CO2\ (g/km) = 166.3\ x\ 10\text{-}3\ X\ CO2\ (vol\ \%)\ \text{..........Eq3}$$

For Petrol Vehicle, $CO_2$ (g/km) is derived using following formula

$$FC = 100 * D / \{(0.1154)*[(0.866*HC)+(0.429*CO)+(0.273*CO_2)]\}\ \text{..........Eq4}$$

Where,

$CO_2$ = emission of carbon dioxide in g/km

FC = the fuel consumption in km per liter (in the case of petrol – obtained from experimental values)

HC = the measured emission of hydrocarbons in g/km (for petrol 1.85)

CO = the measured emission of carbon monoxide in g/km – obtained from the experimental value

D = the density of the test fuel. In the case of gaseous fuels, this is the density at 15° C (0.76 kg/lt)

The average annual emission is calculated using the following equation:

$$Average\ annual\ emissions = \frac{\sum_{i=1}^{n}(Number\ of\ vehicles\ in\ Model\ i\ x\ Emission\ of\ Model\ i)}{Total\ vehicles\ of\ first\ registration\ during\ the\ year}$$

## 2.5 Test validation

The observed fuel economy and emissions of each sample vehicle were averaged over the test distance (g/km, l/km). Three tests run for each sample vehicle were carried out. Due to differences in road conditions and driving patterns there arises the uncertainty in the absolute value of observations. So, an uncertainty analysis was carried out at a 95% confidence interval.

# 3 Experimental Results

## 3.1 Average fuel economy of LDVs

The weighted average fuel economy of LDVs from the sampled experimental tests is found to be 9.4 Lge/100km. The actual fuel economy is found to be 58% lower than the rated fuel economy of the same type of vehicles (5.9 Lge/100km). The engine capacity-wise fuel economy is as shown in Table 3. It shows that lower the engine capacity vehicle has better the fuel economy, and it increases with the increasing engine capacity. The high fuel consumption of vehicles with engine capacity 15001-2000cc is comparatively higher due to other factors like driving patterns, vehicle conditions, and the fuel quality of the sample vehicles. In contrast, the fuel economy of electric vehicles is found to be 2.1 Lge/100km which is 78% better than the fuel economy of petroleum vehicles in fuel equivalence. There could be substantial savings in petroleum consumptions by switching to electric vehicles.

*Table 3 Experimental and rated fuel economy of sampled vehicles*

| Engine Capacity (CC) | Experimental Lge/100km | Rated Lge/100km |
|---|---|---|
| Upto 1000 | 7.1 | 4.7 |
| 1001-1500 | 8.1 | 5.4 |
| 1501-2000 | 13.0 | 6.2 |
| 2001-2500 | 10.9 | 7.3 |
| 2501-2900 | 12.2 | 8.5 |
| 2901 and above | 17.4 | 9.8 |
| Weighted average | 9.4 | 5.9 |
| Electric Vehicles | 1.8 | |

The fuel economy of the sampled petrol vehicles is as shown in Figure 6. It shows that the actual fuel economy of petrol-operated vehicles is 37% lower than the manufacturer's rated fuel economy indicating higher fuel consumption. The weighted average fuel economy of 22 sampled petrol vehicles was found to be 11.8 km/lt (7.9 Lge/100km), meanwhile, the rated average fuel economy of the same vehicles was obtained to be 18.7 km/lt (5.2 Lge/100km).

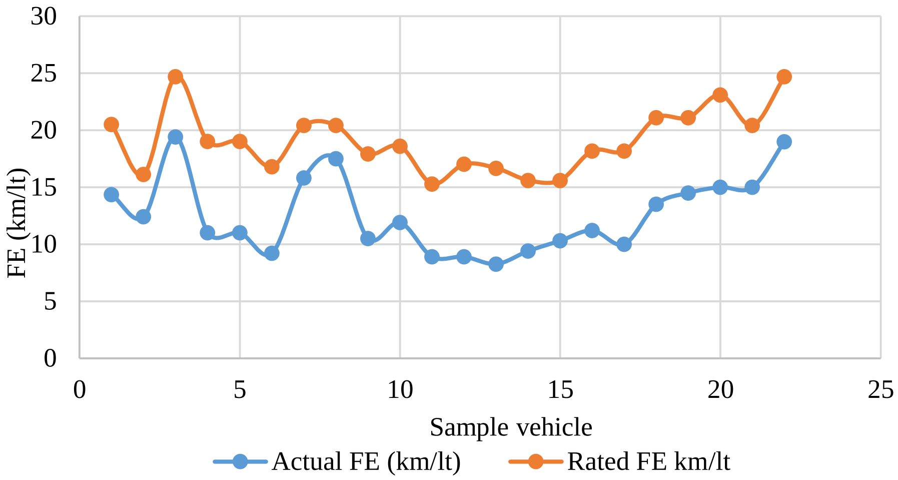



*Figure 6 Fuel Economy of sample petrol vehicles*

The fuel economy of the sampled diesel vehicles is as shown in Figure 7. It shows that the actual fuel economy of diesel-operated vehicles is 39% lower than the manufacturer's rated fuel economy indicating higher fuel consumption. The weighted average fuel economy of 19 sampled diesel vehicles is found to be 9.5 km/lt (11.2 Lge/100km), meanwhile, the rated average fuel economy of the same vehicles is obtained to be 15.7 km/lt (7.1 Lge/100km).

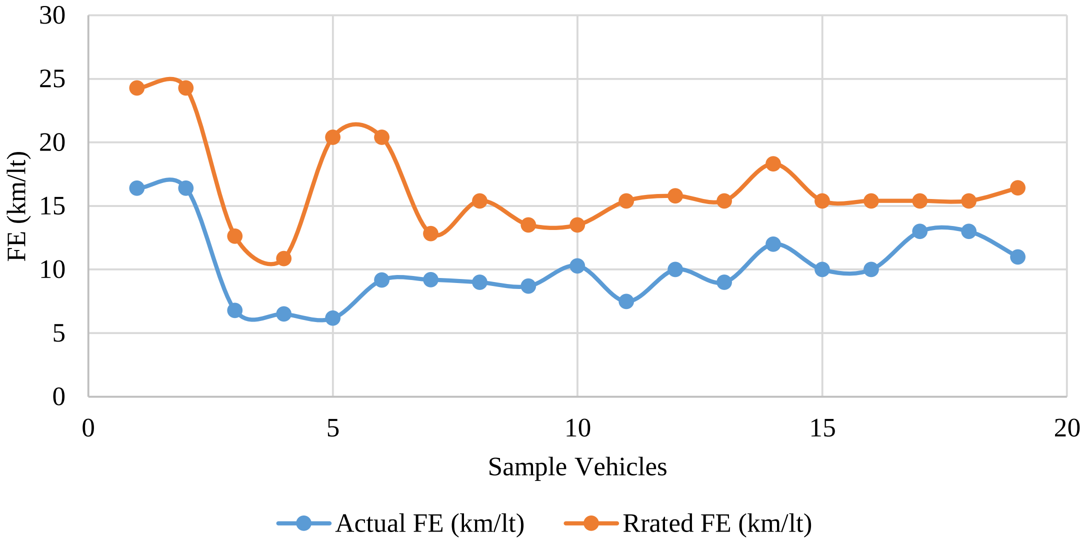



*Figure 7 Fuel Economy of sample diesel vehicles*

The trend data of the sampled vehicles shows that the weighted average fuel economy is improving at the rate of 1.04% from 2010 through 2021 (Figure 8). Meanwhile, the manufacturer's fuel economy trend shows an improvement of 1.89% per annum during 2005-2016 (CEN, 2019).

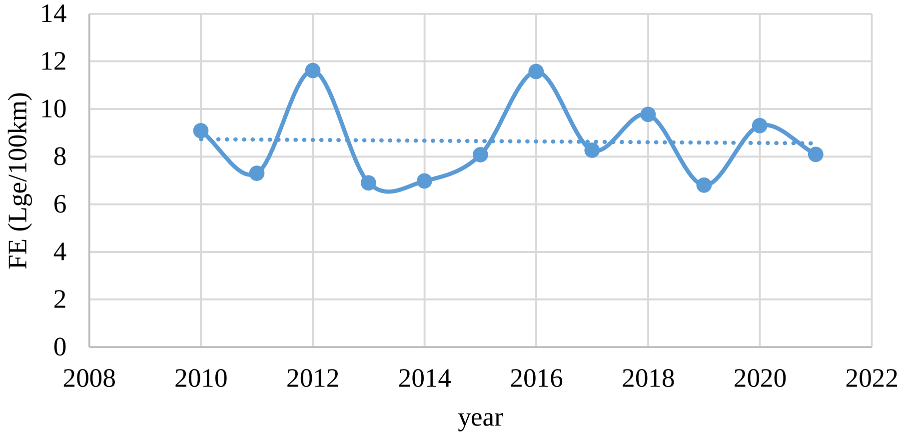



*Figure 8 Weighted average fuel economy trend from the experiment*

## 3.2 Average $CO_2$ emissions of LDVs

The average $CO_2$ emissions of the sampled vehicles were found to be 275 g/km during the experiment. Meanwhile, the rated exhaust emissions of the sampled vehicles were 146 g/km as obtained from the manufacturer's specification. The actual exhaust emissions were 88% higher than the rated emissions of new vehicles. $CO_2$ emissions as per the engine capacity are shown in Figure 9. The emissions are comparatively lower in the lower engine capacity vehicles and increases with the increase in engine capacity.

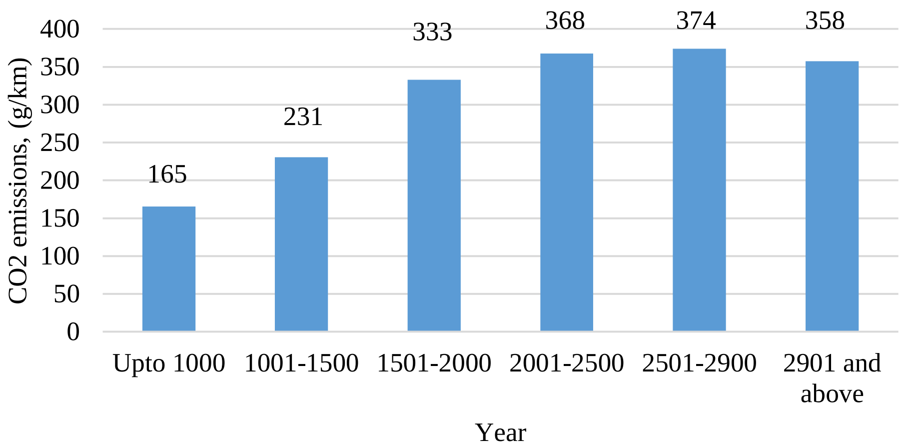



*Figure 9 Average $CO_2$ emissions*

The comparison of experimental exhaust emissions with the rated emissions of petrol vehicles is as shown in Figure 10. The weighted average $CO_2$ emissions of sampled petrol vehicles are found to be 224 g/km which is 77% higher than the manufacturer's $CO_2$ emission (126 g/km). The higher emissions account for the conditions of the vehicles, driving patterns, and fuel quality. The emissions from petrol vehicles were comparatively lower than the values of the diesel-operated vehicles.

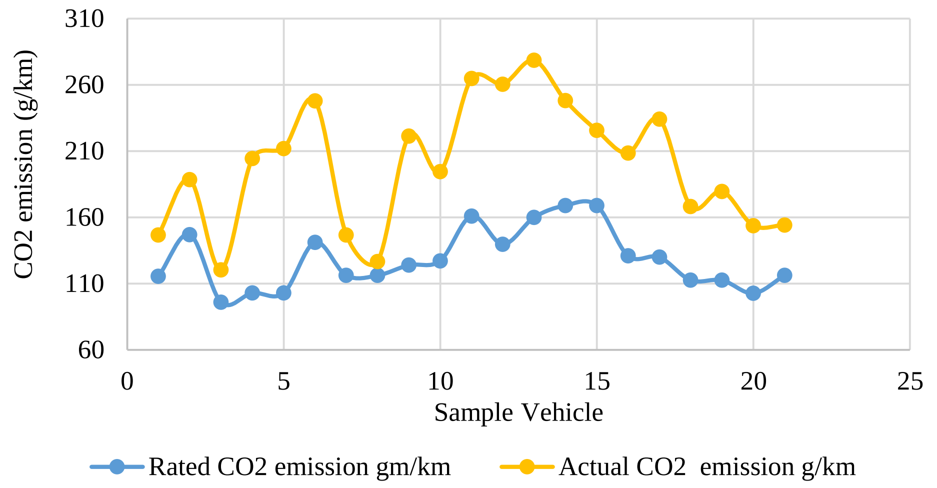



*Figure 10 Average $CO_2$ emission of sample petrol vehicles*

The comparison of experimental exhaust emissions with the rated emissions of diesel vehicles is as shown in Figure 11. The weighted average $CO_2$ emissions of sampled diesel vehicles are found to be 370 g/km which is 119% higher than the manufacturer's $CO_2$ emissions rate (169 g/km). The higher emission accounts for the conditions of the vehicles, driving patterns, and fuel quality.

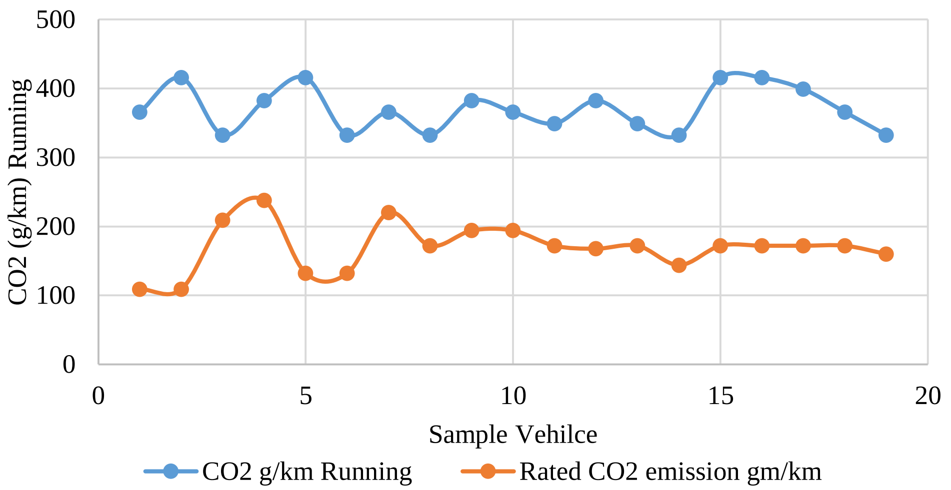



*Figure 11 Average $CO_2$ emission of sample diesel vehicles*

The trend data of the sampled shows that the weighted average $CO_2$ emissions in the diesel LDVs are increasing at the rate of 6% from 2010 through 2020 (Figure 12). Meanwhile, the manufacturer's fuel economy trend shows an improvement of 1.89% per annum during 2005-2016 (CEN, 2019).

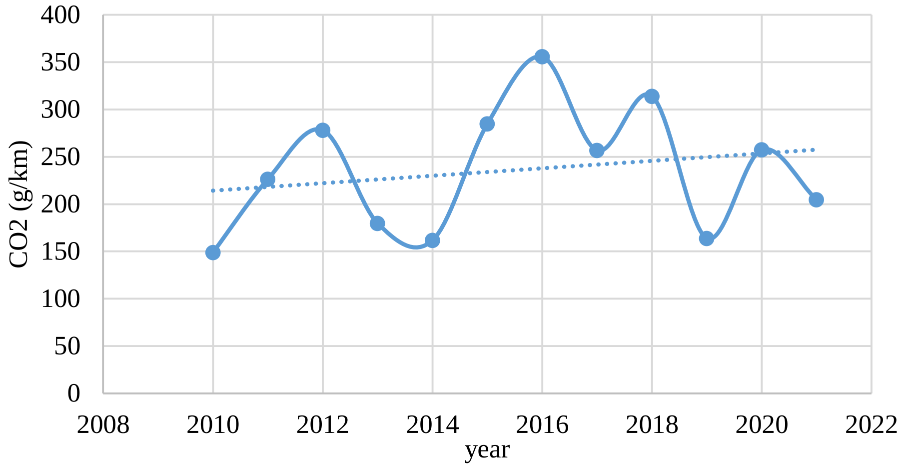



*Figure 12 Weighted average $CO_2$ emission trend from experiment*

## 3.3 Impact of servicing and timely maintenance in fuel economy and exhaust emissions

The effect of the servicing and maintenance on the fuel economy was also analyzed in the study. The pre-servicing and post-servicing fuel economy and exhaust emissions of the sampled vehicles were measured. It was found that the fuel economy of the vehicle could improve up to 10% and $CO_2$ emissions could reduce up to 24% under timely servicing. It shows that the timely maintenance of the vehicles could improve fuel economy and reduce $CO_2$ emissions without the need for a huge investment.

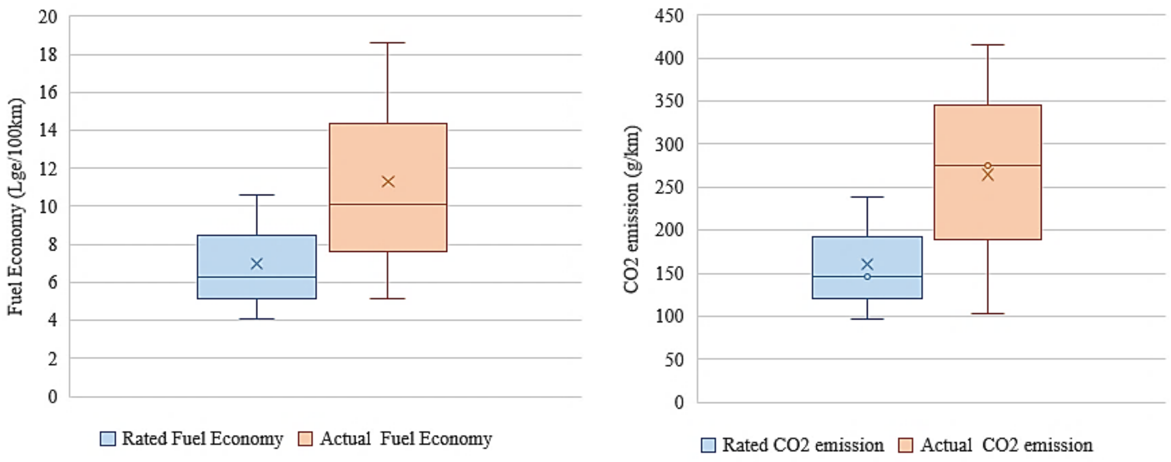
The other exhaust emissions measured during the experiment are CO, $NO_x$, and $PM_{2.5}$. The emissions in both the idle and the running conditions were measured as shown in Table 4. It shows that the actual exhaust emissions of CO were 3.4 times higher in running conditions but is only 35% higher in the idle condition in petrol vehicles compared to the rated values. Meanwhile, diesel vehicles emit 3.6 times higher in idle and 8.8 times higher in running conditions compared to the rated CO emissions. NOx emission in petrol is found to be 71% and 68% higher than the rated values in idle and running conditions in petrol vehicles.

*Table 4 Exhaust emission of the sampled vehicle*

| | **Petrol** | | | **Diesel** | | |
|---|---|---|---|---|---|---|
| | Idle | Running | Rated | Idle | Running | Rated |
| CO (gm/km) | 2.2 | 7.4 | 1-2.3 | 2.6 | 5.6 | 0.5-0.64 |
| NOx (gm/km) | 0.3 | 1.7 | 0.15-0.08 | 6.6 | 4.4 | |
| PM2.5 (µg/m3) | 97.0 | 136.5 | | 105.3 | 512.6 | |

## 3.4 Statistical analysis of the experimental data

The uncertainties in activities, equipment, and measurement conditions could affect the experimental data. In the gas analyzer, three data for each experiment were collected and the average emissions were noted endogenously within the analyzer. For fuel economy, three trips were taken in different routes for approximately 5 km to measure the fuel economy of the vehicle. Then weighted average fuel economy and $CO_2$ emissions are obtained from the experimental data. However, due to variations in engine capacity, fuel type, vehicle conditions, driving pattern of each vehicle, and servicing time, the absolute value of fuel economy of the LDVs may not represent the average fuel economy precisely. So, the descriptive statistical analysis is carried out to estimate the probable variations of the fuel economy from the mean value. The mean value of fuel economy (Lge/100km) of LDVs is estimated to be 10.1 Lge/100km with a standard deviation of 3.2. At a 95% confidence interval, the average fuel economy of LDVs can range between 9 Lge/100km to 11 Lge/100km. Similarly, the mean value of the $CO_2$ emissions is expected to be 275 g/km with a standard deviation of 99 g/km. At a 95% confidence interval, the average $CO_2$ emissions can range between 244 g/km to 307 g/km. It is mainly due to the difference in $CO_2$ emissions from petrol and diesel vehicles. The statistics are presented in Figure 13.




*(a) Fuel Economy* *(b) $CO_2$ Emission*

*Figure 13 Statistics for fuel economy and emission for LDVs*

# 4 Scenario analysis

The Fuel Economy Policies Implementation Tool (FEPIT) is used to estimate the various policy measures on the fuel economy. It is an excel based tool, used mainly to study the magnitude of the impact of the policy measures rather than the exact forecast (GFEI, 2015). It mainly focuses on short-term and medium-term policies. Baseline fuel economy and $CO_2$ emissions are estimated to 2030 using the improvement rate of 1.04% obtained from the experimental data.

## 4.1 Baseline fuel economy and $CO_2$ emissions

The baseline fuel economy of the in-use vehicles is as shown in Figure 14. The historical fuel economy improvement rate of 1.04%, obtained during the experimental data of vehicles from 2010-2021 is used. At this improvement rate, the fuel economy of Nepal in 2030 is estimated to be 8.5 Lge/100km (Figure 15), which is 10% less than the base year value. As per the GFEI fuel economy target of LDVs, the fuel economy should improve to 4.4 Lge/100km by 2030 to meet the global target of fuel efficiency. The projected fuel economy of Nepal would be twice that of the GFEI target at this improvement rate. To achieve the GFEI target, Nepal needs to improve its fuel economy at the rate of 7.7% per annum which could be possible only if there is an aggressive transition to electric vehicles.

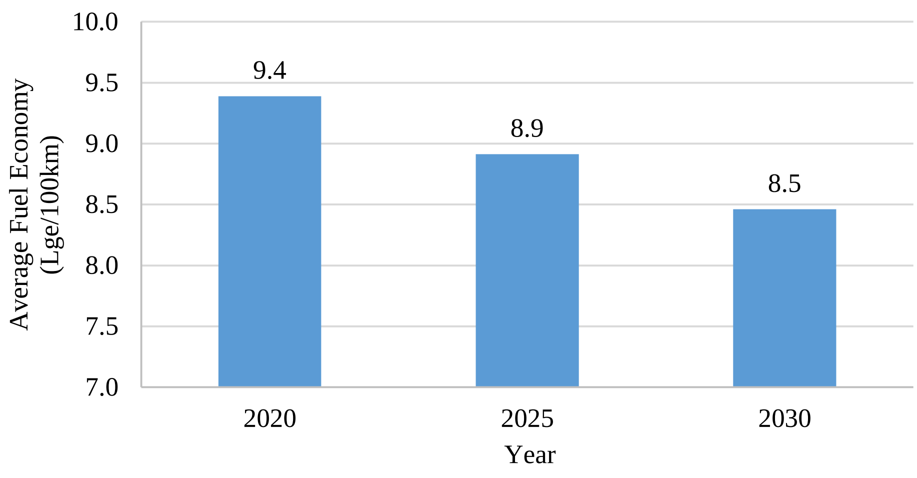



*Figure 14 Average fuel economy in the baseline scenario*

At this historical improvement rate of fuel economy, the $CO_2$ emissions from the exhaust are also estimated to be 248 g/km in 2030 from the base year value of 275 g/km, an improvement of 10% (Figure 15). Meanwhile, the GFEI target for 2030 is 90 g/km of $CO_2$ emissions. The projected emissions of Nepal are almost three times the GFEI targets.

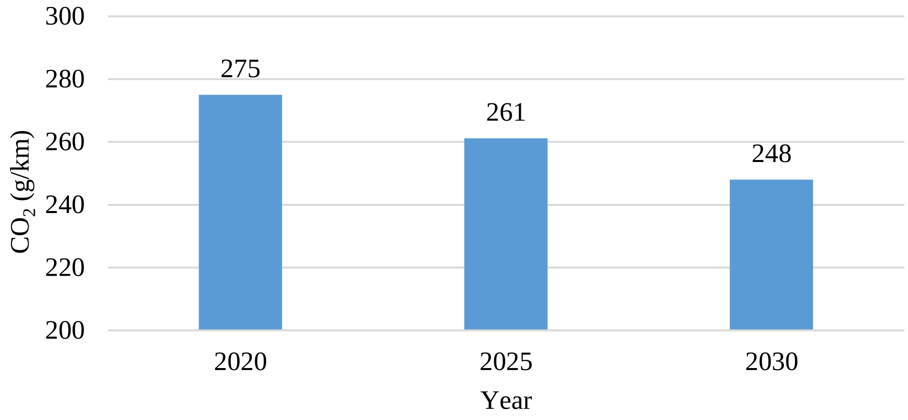



*Figure 15 Average $CO_2$ emission in the baseline scenario*

## 4.2 Policy Interventions

Nepal's government has formulated several policies linked to electric vehicles. As per the second Nationally Determined Contributions (NDC), Nepal committed to increasing the sales of electric vehicles to 25% by 2025 and to 90% by 2030 (NDC, 2020). To support the NDC commitments, the recent fiscal year budget 2078/79 has emphasized increasing the electric vehicles by increasing the sales of all new LDVs to 100% electric by 2030. Lately, LDVs are becoming extremely popular in Nepal with an annual increase of 16% during the last decade (DOTM, 2019).

Scenario analysis is carried out to evaluate the impact of electrification on fuel economy using IEA's Fuel Economy Policy Implementation tool (FEPIT). Considering 100% new car/jeep sales to be electric by 2030, the share of electric LDVs is expected to increase to 56% of the total LDVs in 2030 from less than 1% share in 2020. The average fuel economy of electric vehicles is assumed to be 1.8 Lge/100km obtained from the survey of electric vehicles during this study. At the same fuel economy of the EVs, the weighted average fuel economy is calculated till 2030. The results show that the weighted average fuel economy of LDVs will improve to 4.7 Lge/100km in 2030, which is 44% lower than the baseline value of 9.4 Lge/100km in 2020, as shown in Figure 16. With the assumptions that EVs will grow at the rate of 6.6% per annum between 2020 - 2030, the projected fuel economy is estimated to be 4.7 Lge/100km - still 7% lower than the GFEI target of 4.4 Lge/100km in 2030 (Figure 16). But the difference is not so significant, and it can be reduced by adopting other measures like increasing the share of public transportation, promoting hybrid vehicles, etc.

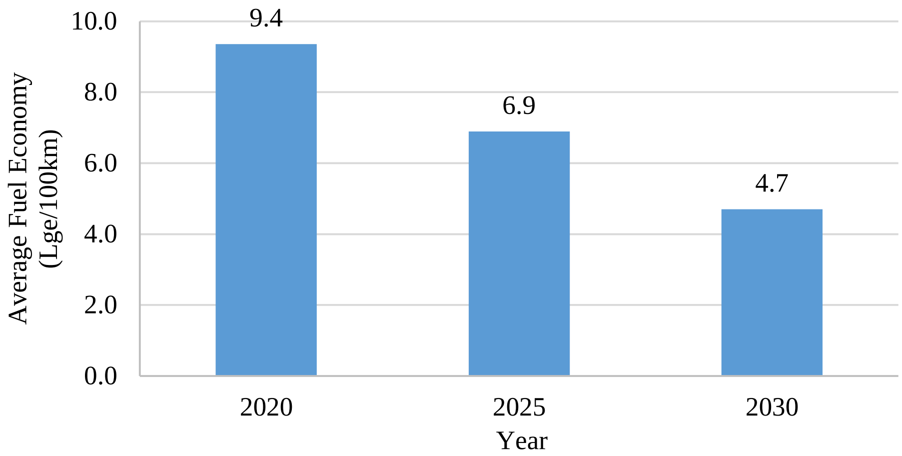



*Figure 16 Average fuel economy in policy intervention scenario*

The impact of electrification in LDVs on $CO_2$ emissions is also analyzed. The result shows that the weighted average $CO_2$ emissions reduce from 275 g/km in 2020 to 108 g/km in 2030 which is near to the GFEI target emissions in 2030. The average $CO_2$ emissions from 2020-2030 are as shown in Figure 17.

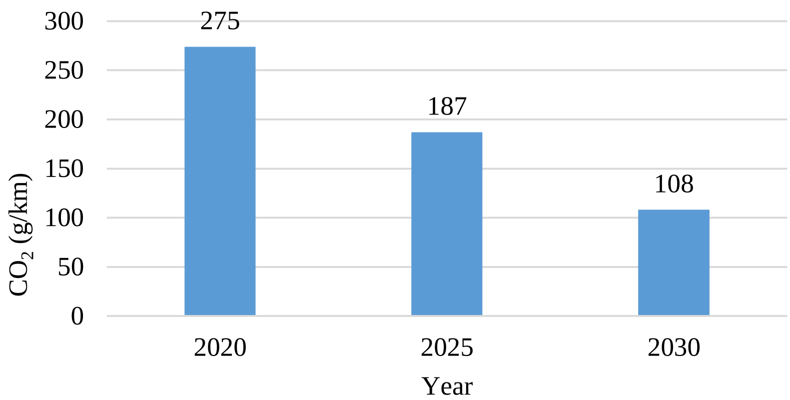



*Figure 17 Average $CO_2$ emission in policy intervention scenario*

## 4.3 Fuel Savings

It is evident from not only the literature but also from the on-road testing of electric vehicles, the intervention of electric vehicles would bring about a reduction in vehicular fuel demand. In Baseline (BL) Scenario, the fuel economy of the LDV's is slowly improving and on the other hand, the number of LDVs is also increasing. Based on both the parameters, it is approximated that the total fuel demand for LDV will be increasing at an average rate of 4.3% per annum (Figure 18). However, taking only passenger LDVs into account, due to increasing fuel economy, the fuel demand could be nearly stagnant within this limited category.

With the policy of electric vehicle intervention, supported by recent financial rebates for an electric vehicle, it can be expected the number of electric vehicles would rise. With the assumption that the policy target is reached, Electric Mobility (EM) Scenario has been developed and compared to the Baseline Scenario.  With the expected penetration of electric vehicles, the total fuel demand for LDVs will be reduced by about 16% in 2030. Considering only passenger vehicles, which can be highly expected to be replaced by electric ones, the total fuel demand for passenger LDVs will decrease by 81% in 2030 (Figure 18).

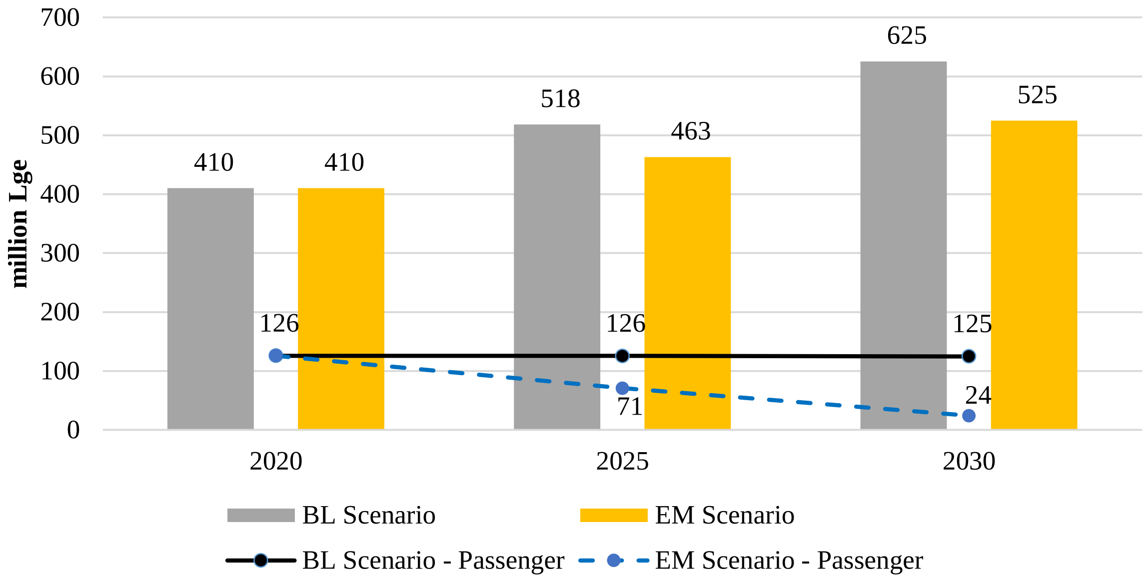



*Figure 18 Total fuel demands for passenger LDVs till 2030*

On the other hand, if the fuel type is taken into consideration, in the BL scenario the demand for petroleum for LDV's would increase at the rate of nearly 4.3% till 2030. Meanwhile, with the GoN's electric vehicle policy intervention as indicated in the budget 2021/22, the growth in petroleum demand will be limited to 2.5% over the next decade. Most of the contribution for this reduction would come from decrease in new sales of gasoline vehicles, resulting a decline of gasoline demand at the rate of nearly 20% per annum in the next decade. Meanwhile, replacing the gasoline fuel, demand for electricity for LDV's could increase with the share of electricity in LDV fuel demand would increase from nearly 0% in 2019 to 2% in 2030 (Figure 19). Although this portion of the share seems insignificant, however, the mileage covered by the EVs is higher than that of an equivalent gasoline engine vehicle due to its higher efficiency, with the added benefit of emissions and costs reductions as well.

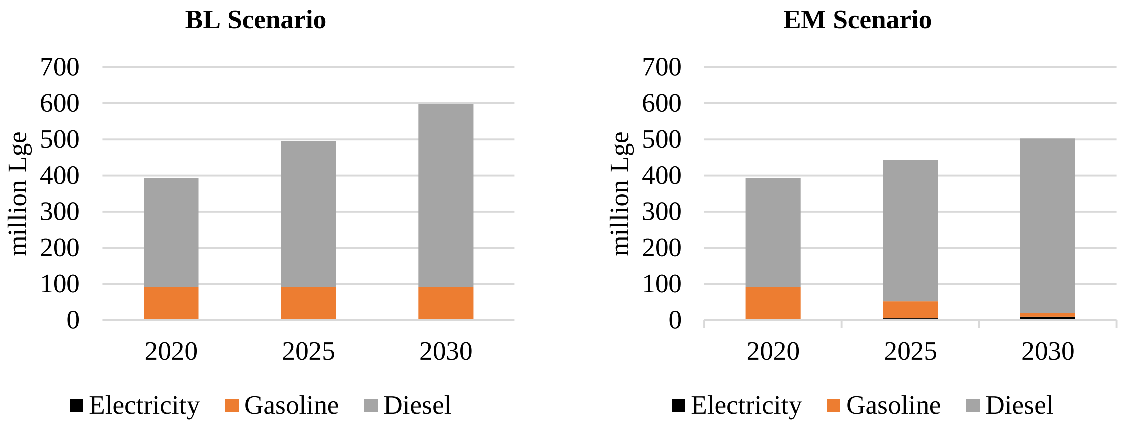
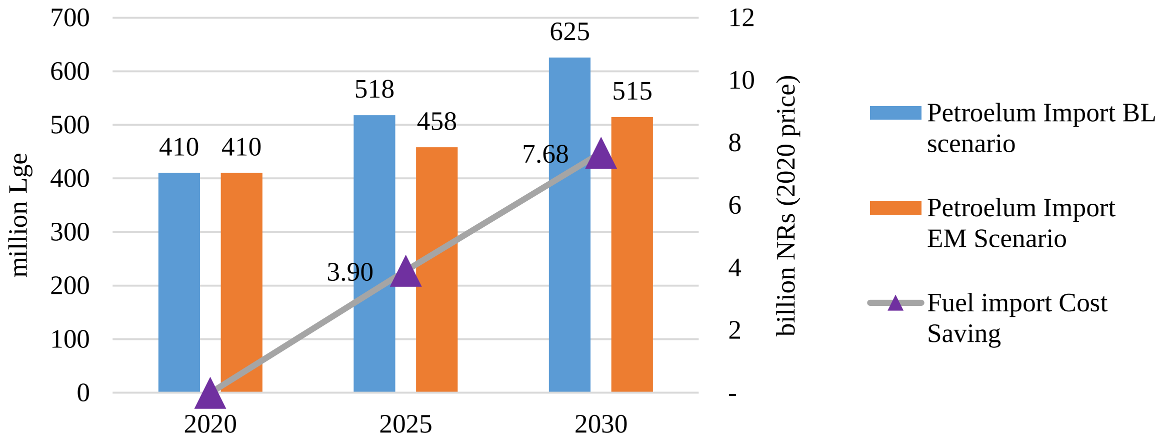



*Figure 19 Fuel demands for LDVs by fuel type till 2030*

## 4.4 Cost savings in fuel

In monetary terms also, electric vehicles contribute from two perspectives – a) reduction of fuel imports and b) increase in domestic demand for electricity. From consumers' point of view, they must pay for both the forms of energy. If they use electricity, consumers can be benefited from cost savings in fuels by nearly NRs. 7.7 billion in 2030 (Figure 20).




**The estimations are based on Raxaul price of petroleum as on June 1st, 2021 from NOC.*

*Figure 20 Fuel costs for LDVs till 2030*

## 4.5 Emissions reduction

One of the direct impacts of the intervention of electric mobility is in the emissions reduction in the LDVs. From Table 5, there are significant reductions in tailpipe emissions. The gaseous emissions like carbon dioxide, carbon monoxide, and sulfur dioxide can be reduced by 60% to 84% respectively. Furthermore, the particulate emissions can also be reduced by 55% in 2030 compared to the baseline value in 2020.

*Table 5 Emissions from LDVs till 2030*

In thousand tons

| | Baseline Scenario | | | Electric mobility Scenario | |
|---|---|---|---|---|---|
| | 2020 | 2025 | 2030 | 2025 | 2030 |
| Carbon Dioxide | 5,563.35 | 5,814.49 | 6,044.14 | 3,452.56 | 1,737.19 |
| Carbon Monoxide | 7.44 | 7.95 | 8.44 | 5.02 | 3.09 |
| Nitrogen Oxides | 4.05 | 5.18 | 6.32 | 4.69 | 5.4 |
| Nitrous Oxide | 0.12 | 0.13 | 0.13 | 0.07 | 0.02 |
| Sulphur Dioxide | 1.95 | 2.61 | 3.26 | 2.50 | 3.05 |
| Particulates PM2.5 | 0.87 | 0.96 | 1.04 | 0.65 | 0.47 |
| Black Carbon | 0.31 | 0.38 | 0.45 | 0.33 | 0.36 |

Electric mobility technology in the LDVs is already proven and many top automotive giants are switching to different modes of EVs – such as hybrid, PEVs, and BEVs and other innovative technology in the LDVs due to growing concern about climate change impacts.

## 4.6 Power plant capacity requirement

Penetration of electric vehicles in policy intervention scenario increases electricity demand in the transport sector from virtually none in the base year. The electricity demand would increase to 92 GWh by 2030 to supply electricity to 56% of LDVs in 2030 (Figure 21). The total power plant capacity requirement would be 20 MW in 2030.

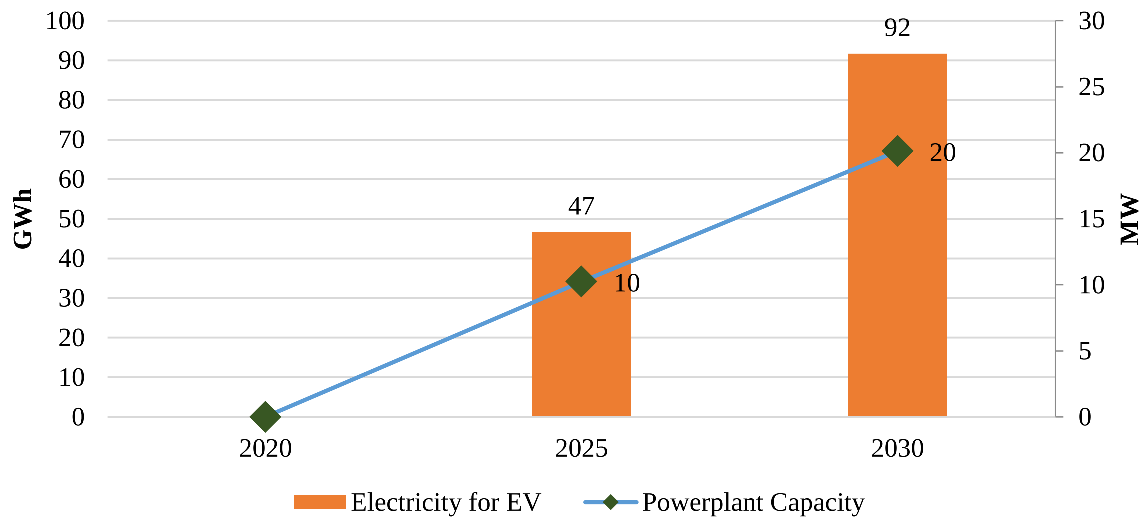



*Figure 21 Electricity Demand and powerplant capacity for Passenger LDVs*

## 4.7 Economic benefits

The scenario analysis shows that the electric mobility scenario has huge economic benefits over the baseline scenario (Table 6). Electric vehicles, which are 80% efficient than petroleum vehicles, can significantly reduce the import of petroleum products used for the transport sector. Cumulative petroleum imports of 650 million Lge used for LDVs can be avoided during 2021-2030 which makes savings of Rs. 43 billion in the national economy. Meanwhile, carbon trading can bring additional economic benefits to the nation. The additional benefits of Rs. 15 billion can be generated from the reduction of $CO_2e$ emissions, even traded at \$5 per ton of $CO_2e$. The cumulative electricity demand will be 518 GWh during 2020-2030, which will be paid by the customers at NEA's tariff of Rs. 10.5 /kWh, generating further Rs. 5.4 billion from electricity sales.

*Table 6 Economic benefits of EV penetration (Cumulative from 2021 to 2030)*

| | **Quantity** | | **2020 Price** | |
|---|---|---|---|---|
| Fuel Cost Saving* | 650 | million Lge | 43 | billion NRs |
| CDM** | 25 | million tons | 15 | billion NRs |
| Electricity Sales*** | 518 | GWh | 5.4 | billion NRs |

## 5 Policy Implications

1. **Electric Mobility**. The growing petroleum consumptions and vehicular emissions directly influence the economy, and environment. To reduce the growing but adverse impact, electric vehicles could provide a long-term solution in the case of Nepal where there is an enormous source of clean electricity. Switching to electric vehicles can thus play an important role in reducing emissions in Nepal. As per GoN's electric vehicle policy intervention in the budget 2021/22, the growth in petroleum demand will be limited to 2.5% over the next decade. There must be accurate plans and policies for the implementation of the budget in the sector of electric vehicles with the engagement of the private sectors.

2. **Fiscal Policy**. Adjustment in vehicle taxation could be another policy implication to improve fuel economy and reduce exhaust emissions. Currently, the tax and duty structure of vehicles is based on engine capacity in Nepal. Adjusting the tax structure based on fuel economy/tailpipe emissions rather than engine capacity might urge people to shift to fuel-efficient and less polluting vehicles as they will be aware of the benefits from fuel economy as well as tax fees. Literature review of fiscal policies in other countries indicate that "feebate" systems can reduce vehicular emissions and side by side can improve fuel economy providing incentives for cleaner technologies like electric vehicles. A recent fiscal policy on 'feebate" systems in New Zealand to be introduced in 2022 seems to be noteworthy and it penalizes super emitters but provides rebate to cleaner technologies like electric vehicles which have zero emissions (Figure 22).

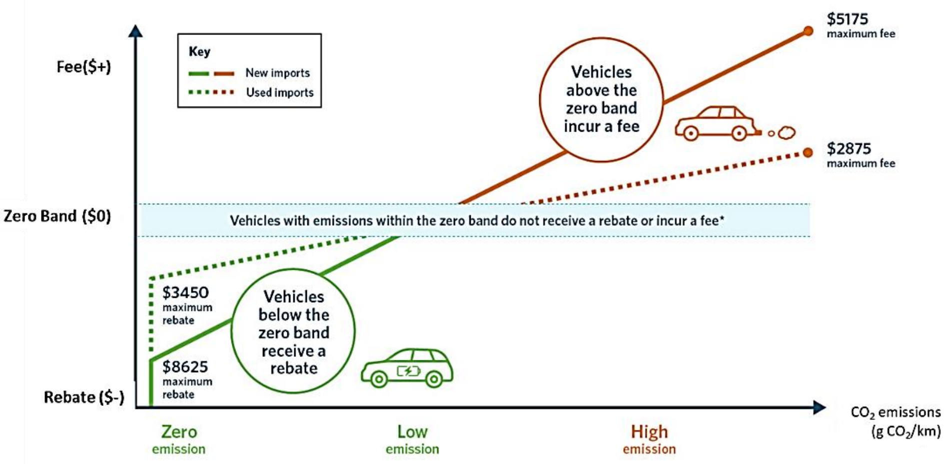



*Figure 22 Feebate System  for cars in New Zeland (New Zeland Herald, 14/06/2021)*[1]

[1] https://www.driven.co.nz/news/nz-s-cheapest-ev-gets-even-more-affordable-following-feebate-announcement/ accessed 20 June 2021.

If feebate systems can be introduced in Nepal like in New Zealand, fuel economy can be improved, and vehicular emissions can be drastically reduced. But there is one big challenge and this kind of feebate system can be realized only if there is a strong vehicle testing system in full operations.

3. **Air Pollution**. Vehicles are the main sources of air pollution in places with heavy traffics so the Air Quality Management Action Plan for Kathmandu Valley 2020 should be strictly implemented. The study findings also show large emissions and lower fuel economy from diesel vehicles. As diesel exhaust is very hazardous for human health and is the main source of fine particles, diesel vehicles with high engine capacity should be avoided to the extent possible.

4. **Fuel Quality**. Another important issue related to emissions is the quality of commercial fuel available in Nepal. Thus, the arrangement to be made to maintain the fuel quality in the market, as well as import fuel quality as per the improving standard of vehicles for their optimum benefit in environmental ground and monitoring of fuel quality, to be initiated by the designated authority NBSM (Nepal Bureau of Standards & Metrology).

5. **Vehicle Testing Laboratory**. To monitor the existing vehicular emissions, a well-equipped and functional vehicle emission testing laboratories should be brought into use in all provinces of Nepal to ease users to test the vehicles. To control the growing transport emissions, the government must enforce strict mandatory vehicle emission tests for all vehicles, including two-wheelers and heavy-duty vehicles. It requires a comprehensive strategy for developing testing labs, including various testing equipment, maintaining emission standards, developing inspection and maintenance programs, developing institutional awareness, and training programs.

6. **Consumer Information**. Consumer information or fuel economy labelling is essential for consumers to decide what type of cars or vehicles they are buying and how much they are emitting $CO_2$ by driving their vehicles. This would help consumers in selecting vehicles having better fuel economy and producing less $CO_2$ emissions. So, the auto-dealers should be enforced to display the manufacturer's fuel economy and $CO_2$ emission information of the vehicles in the showroom. It helps the consumer to compare vehicles based on the fuel economy and emission and not just on the cost and comfort basis.

7. **Vehicle Operations and Road Maintenance**. Driving behavior and road conditions, vehicle conditions are the major cause of disparity in rated fuel economy and actual fuel economy as perceived during this experimental study. So, the regular maintenance of road conditions should be carried out by the government. Meanwhile, consumer awareness through workshops, advertisements, training on the driving patterns and vehicle conditions could improve fuel economy and emissions even at low investment. Similarly, the consumers are to made aware of the fact that timely servicing and maintenance of their vehicles can improve fuel economy and reduce vehicular emissions, thus making them savings and thus improving air quality in the country.

# 6 Conclusions

Almost 75% of GHG emissions in the global atmosphere are caused by energy consumptions by people and reduction of $CO_2$ emissions to net-zero by 2050 is a paramount challenge for all human beings to limit the long-term increase in average global temperature to $1.5^0$ C (IEA, 2021). The transport sector is the major consumer of fossil fuels and in the context of Nepal, consumption of petroleum products in the transport sector in Nepal is increasing at a tremendous rate and thus, jeopardizing the energy security and the country's balance of payment. It is very essential to improve fuel economy and subsequently reduce GHG emissions to reduce adverse impacts of climate change. Rated fuel economy and $CO_2$ emissions of newly registered LDVs as per the published documents from the OEMs were improving as per the baseline study (CEN, 2019) but the experimental study of FE and the CO2 emissions of LDVs were not yet done in Nepal. Hence, it is very noteworthy that the Department of Environment has assigned the CES to conduct this study.

CES conducted an empirical study of Fuel Economy and tailpipe exhaust emissions of a sample of 41 LDVs, representing the whole population as per the data of DoTM in 2018. Three EVs in the LDVs were also tested for fuel economy. The sample is unbiasedly selected from both the petrol and the diesel vehicles of different engine capacities and with different production years. The vehicles were tested in the authorized automobile dealers' and government-owned workshops. Different equipment such as flue gas analyzers, fuel meters were used for the tests. The weighted average fuel economy of LDVs from the sampled experimental tests was found to be 9.4 Lge/100km which is 58% lower than the rated fuel economy of 5.9 Lge/100km of new LDVs. Thus, the average fuel economy of LDVs could range between 9 Lge/100km to 11 Lge/100km at a 95% Confidence Interval (CI). In contrast, the fuel economy of electric vehicles was found to be 2.1 Lge/100km which is 78% better than the fuel economy of petroleum vehicles. On top of it, there will be a substantial savings of petroleum consumptions by switching to electric vehicles with no $CO_2$ emissions as Nepal's electricity is green compared to our neighboring countries.

The average $CO_2$ emissions of the sampled vehicles were found to be 275 g/km compared to rated emissions of 146 g/km. The actual exhaust emissions were 88% higher than the manufacturers' rated emissions of new vehicles. The statistical analysis indicates that the average CO2 emissions of LDVs can range between 244 g/km to 307 g/km at 95% Confidence Interval (CI).

Scenario analysis is carried out to evaluate the impact of electrification on fuel economy using IEA's Fuel Economy Policy Implementation tool (FEPIT). Considering 100% new car/jeep sales to be electric by 2030, the share of electric LDVs will be increased to 56% of the total in 2030 from less than 1% share in 2020. At this range of penetration of electric vehicles in 2030, the results show that the weighted average fuel economy of LDVs will be 4.7 Lge/100km in 2030, which is 44% lower than the baseline value of 8.5 Lge/100km in 2030, It indicates that the projected fuel economy can almost meet the

GFEI's target of 4.4 Lge/100km by 2030. Meanwhile, the weighted average $CO_2$ emissions will be reduced from 275 g/km in 2020 to 108 g/km in 2030 which is 20% higher than the GFEI target emissions of 90 g/km in 2030.

Considering only passenger vehicles, which can be highly expected to be replaced by electric ones, it would bring the total fuel demand for passenger LDVs down by 81% in 2030. Most of the contribution for reduction would come from gasoline vehicles, which could be decreasing at the rate of nearly 20% per annum in the next decade. Meanwhile, replacing the gasoline fuel, demand for electricity for LDV's could increase with the share of electricity in LDV fuel demand increasing from nearly 0% in 2019 to 2% in 2030. Increase in demand for electricity seems not so significant because electric vehicles are highly energy-efficient compared to conventional gasoline and diesel vehicles. In today's monetary terms, consumers can be benefitted from the fuel cost savings of nearly NR 7.7 billion in 2030 alone.

Furthermore, there are huge reductions in tailpipe emissions. The gaseous emissions like carbon dioxide, carbon monoxide, and sulfur dioxide can be reduced by 60% to 84% respectively. Furthermore, the particulate emissions can also be reduced by 55% in 2030 compared to the baseline value in 2020. The total fuel costs savings  in focusing electrification in the LDVs only can be estimated to be NR 43 billion with the increase in domestic sales of electricity increased by NR 5.4 billion in the decade from 2021- 2030.

Considering all these benefits of electrification in the LDVs transport segment, the recent fiscal policy in reducing the customs duties for electric vehicles, and introducing new feebate fiscal systems, if possible, Nepal can almost meet the GFEI's fuel economy and exhaust emissions targets by 2030.

## References:


CEN, 2019. Baseline Study on Fuel Economy of Light Duty Vehicles (LDV) in Nepal. Clean Energy Nepal, Kathmandu, Nepal.

DOTM, 2019. Department of Transport Management, Ministry of Physical Infrastructure and Transport, Governement of Nepal

GFEI (2018). Global Fuel Economy Initiative: Delivering Sustainable Developement Goal 7.

GFEI, 2013. How vehicle fuel economy improvements can save 2 trillion dollars and help fund a long term transition to plug-in vehicles, working paper 9. Retrieved from Global Fuel Economy Initiative, London:

GFEI, 2019. Global Fuel Economy Initiative Update. Global Fuel Economy Initiative Global Fuel Economy Initiative

Ghimire, K. P. & Shrestha, S. R. 2014. Estimating Vehicular Emission in Kathmandu Valley, Nepal *International Journal of Environmental Science and Technology,* 3**,** 133-146.

Gupta, M. & Singh, S. 2016. Factorizing the Changes in CO2 Emissions from Indian Road Passenger Transport: A Decomposition Analysis. *Studies in Business and Economics,* 11**,** 67-83.

ICIMOD, 2017. National Action Plan for SLCPs mitigation in Nepal, International Centre for Integrated Mountain Development

IEA, 2019. Fuel Economy in Major Car Markets. International Energy Agency, Paris.

Malla, S. 2014. Assessment of mobility and its impact on energy use and air pollution in Nepal. *Energy,* 69**,** 485-496.

MOF 2016. Economic Survey 2015/16. Ministry of Finance, Government of Nepal, Kathmandu, Nepal.

Qipeng, S., Jiao, J. & Cheng, X. 2013. Energy consumption driving factors and measuring models of regional integrated transport system. *Journal of Transportation Systems Engineering and Information Technology,* 13**,** 1-9.

Scheffer, S. (2019). Fuel economy of cars & vans;Tracking Clean Energy Progress. Retrieved from https://www.iea.org/tcep/transport/fueleconomy/

Sugathapala, T. (2015). Fuel Economy of Light Duty Vehicles in Sri Lanka.

UNDP, 2021. Assessment report on technical and financially feasible long-term vision and long-term strategy for net zero emission for Nepal, United Nation Development Programme.

Zhang, M., Li, H., Zhou, M. & Mu, H. 2011. Decomposition analysis of energy consumption in Chinese transportation sector. *Applied Energy,* 88**,** 2279-2285.

# Annex

## Policy Analysis Workshop

The workshop was organized by the Center for Energy Studies with the Department of Environment on 11th June, 2021 (Jestha-28st, 2078) from 1:00 PM to 2:30 PM through virtual Zoom platform.

Mr. Mukunda Niroula, Director General, Department of Environment, MOFE indicated that the current study results and recommendations, being based on real time data, are in line with current requirements as deemed by the Department of Transport Management and the Department of Environment as well. He also agreed upon necessity of improving fuel quality testing capacity of Nepal Oil Corporation (NOC) and thus suggested to include as direct recommendation to related ministry. With revision in tax structure for electric vehicles, the interest in EV have seemingly increased, proven by increased activity at Custom offices. He also affirmed to recommend the policy based on this study results in forthcoming Government plans.

Mr. Indu Bikram Joshi, Deputy Director General, Department of Environment, MOFE, with reference to economic outcomes of the study, put forward the importance of lifecycle cost analysis of electric vehicles compared to combustion engines. He also suggested, in addition to economic benefits from fuel savings, if the reduction of emissions of GHG gases could be capitalized via Carbon Trading under Clean Development Mechanism (DM). Furthermore, he noted any other reference of fuel economy in running condition in other countries as well. He confirmed the methodology used for measurements with the study team. He raised the concern about the appropriateness of grade of fuel imported – which is of only one grade, and the mix of vehicles currently running – which ranges from old vehicles to new and highly sophisticated vehicles. Finally, he also signified the necessity of branding/labeling system based on study like these to provide informative knowledge to consumers.

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| 3. | Saroja Adikari Baniya | Department of Environment |
| 4. | Sunita Khanal | Department of Environment |
| 5. | Amrit Nakarmi | Center for Energy Studies, IOE, TU |
| 6. | Anita Prajapati | Center for Energy Studies, IOE, TU |
| 7. | Utsav Shree Rajbhandari | Center for Energy Studies, IOE, TU |

## Stakeholder's workshop and feedbacks

The workshop was jointly organized by Clean Energy Nepal and Center for Energy Studies in collaboration with the Department of Environment on $14^{th}$ June, 2021 (Jestha-31st, 2078) from 2:00 PM to 3:30 PM through virtual zoom platform.

Mr. Bhusan Tuladhar, Chairperson of Clean Energy Nepal shared the current scenario of electric vehicles in Nepal. He highlighted the importance of promotion in walking, cycling, public transport and electric vehicles for reducing air pollution and to maintain the budget deficit. He said though the government is planning to reduce budget deficit by exporting sand and gravel but it is not possible without shifting into electrical vehicles as we import petroleum products in huge amount. He added, for fuel economy there should be standards, strategies and road maps and for all of this field-based evidence is essential. So, this study would be very fruitful to work on guiding to make such documents.

Professor Dr. Rejina Maskey Byanju, Head of Department, Central Department of Environmental Science said that this research is very useful, and it helps policy makers to develop new policies and revise the standard. She also explained her similar research related to diesel in collaboration with ICIMOD and shared the experiences of different factors like road structures, fuel quality, engine capacity, age of vehicles altering the study. Also, she suggested to conduct study on running vehicle conditions rather than the idle conditions. She added as Nepal carries high potential for hydroelectricity, the government should give more subsidies on electric vehicles. In Nepal maintenance of vehicles is not addressed by law so she requested the environment department for addressing these issues. She said, advocacy for fuel testing laboratories and preparation of the action plans is required. Likewise, promotion of e-vehicles and restricting ban of vehicles above 20 years can help to achieve the target of reducing GHGs within 5 years and reducing pollution.

Mr. Indu Bikram Joshi, Deputy Director General, Department of Environment, MOFE said the research is part of the action of Air quality management action plan for Kathmandu valley. Such studies help in showing savings to the national and to the individual economy and thus help also in reducing the pollution. He committed to use the similar results and recommendations in coming days in government program, planning and policy making. It is necessary to prepare criteria's for maintaining vehicle emissions which is in government priorities. He further added there is no other alternative than switching to electric vehicles, it is like "*Ramban*" kinds of medicines for pollution. As cycle tracks cannot bring huge substantial changes instantly, brick industry and open burning also need to be stopped for effective results. Department of Environment has already started to work on several environmental issues and within few coming years the positive impacts will be noticed.

Bhupendra Das, one of the participants, raised questions about why CO is not considered in the study as it have huge health impact on human Dr. Nakarmi addressed the question by replying, global fuel economy mainly focuses on $CO_2$ and hence, showed in the presentation accordingly, even though CO was also measured in the experiments . Dr. Nakarmi and Dr. Maskey also talked over about the relationship between emissions and mileage of vehicles.

Mr. Indu Bikram Joshi concluded the program with his remarks. He requested academicians and other stakeholders for further coordination and continuation of such result oriented research in the upcoming days which can aid government in planning and policy making.

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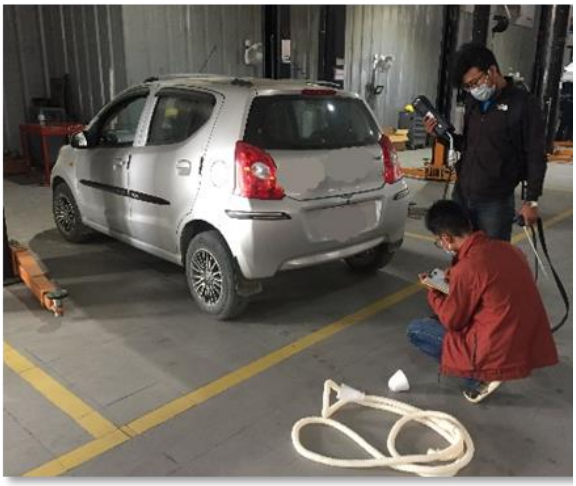
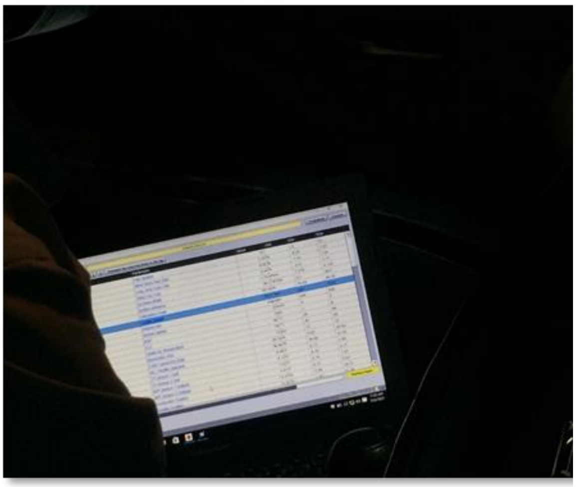
## Photographs



Taking vehicle information

Setting Emission analyzers



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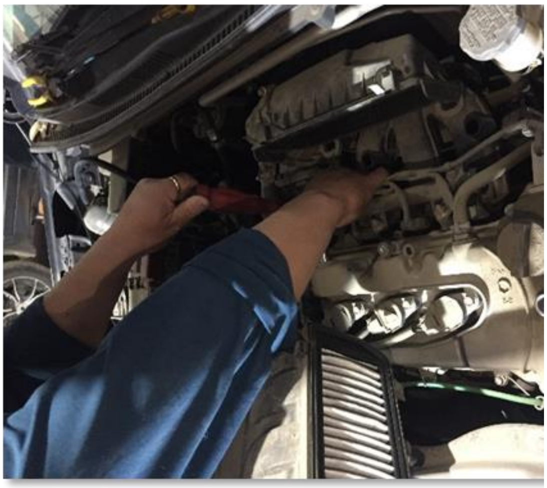


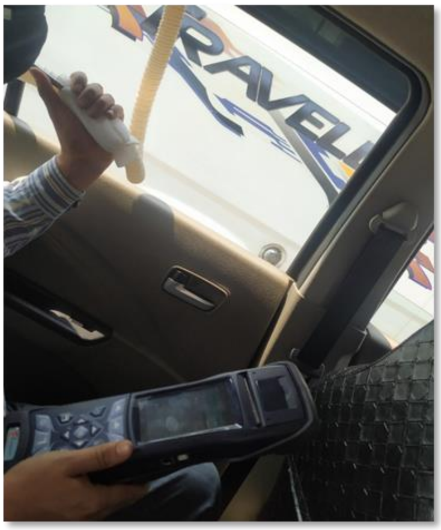
Setting up fuel flowmeter

Setting up fuel flowmeter

Fuel Flowmeter

Idle Emission Measurement

Idle Emission Measurement



Setup for running emission measurement

Running emission measurement



Running fuel measurement

Running emission measurement