Chapter 2

Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Fuels Introduction

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Chapter 2

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1. Introduction

1.1. Background

As with global trends, the introduction of electrified vehicles (xEVs) (hybrid electric vehicles, [HEV]; plug-in hybrid electric vehicles [PHEV], and battery electric vehicles, [BEV]) are now under discussion in Asian countries as well. The main focus of governments on electric vehicle (EV) policy is the following:

Industrialisation: by promoting new and advanced technology, to improve competitiveness of domestic automotive industry and related industries, governments requires localisation.

Reduction of oil consumption: to reduce or conserve oil consumption, thus, to reduce import of oil. The increased use of domestic resources of biofuels and/or natural gas is also promoted in some countries to replace oil.

CO_2 emissions reduction: to reduce CO_2 emissions through vehicle electrification. Air quality improvement (reduction of tail-pipe emissions) is also promoted.

However, we still are not sure that the introduction of xEVs is effective as from the governments' points of view in the aspects below:

Impact on economy: the cost of introducing xEVs as a social burden must be considered because they require new infrastructure (charging stations, etc.), and also prices will be higher for xEVs compared to internal combustion engine (ICE) vehicles.

Reduction of oil consumption: the reduction of oil consumption is possible only if wide spread introduction is achieved, and even the use of alternative fuels such as biofuels and natural gas will be decreased in the case of BEVs as it is not equipped with ICE.

CO_2 emissions reduction: as for well-to-wheel (WtW) CO_2 emissions, BEV is not always the lowest as CO_2 is also emitted at the power generation stage as far as the source of electricity is dependent on fossil energy.

1.2. Objective and Scope

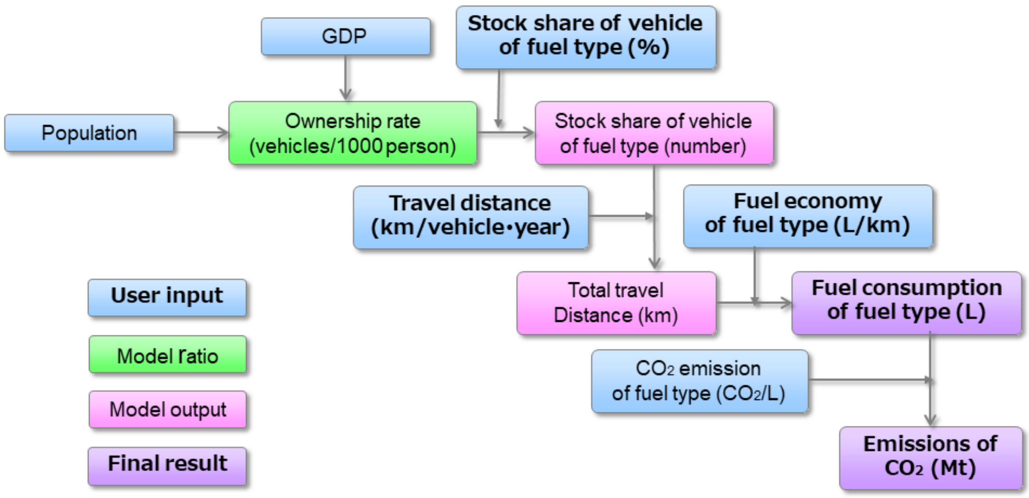
The objective of this study is to propose the most appropriate measure for mobility electrification, based on the investigation of effectiveness of xEV mix scenarios together with the use of alternative fuels. The study covered three countries of India, Thailand, and Indonesia as the governments of these countries have already announced concrete EV policies or roadmaps to some extent,[1] thus enabling us to carry out a scenario study as we can settle the conditions for simulating trend of energy consumption, CO_2 emissions, the cost of xEV introduction, amongst others.

The working group studied the existing policies related to energy and EV, fuel supply, and demand status of road transportation, not only petroleum products (gasoline and diesel fuel) but also alternative fuels such as biofuels and natural gas. The status of current mobility electrification in each country is also considered to have a Business as Usual (BAU) projection as a reference. The combination of measures to effectively contribute to the governments' objectives have been investigated and proposed.

1.3. Methodology

The energy consumption trend of road transportation during 2015–2030 (or target year of each country) was simulated by using an Energy Mix Model. The simulation model of each country was developed by Toyota Motor Corporation (in corporation with Mizuho Information & Research Institute, Inc.) based on the International Energy Agency/Sustainable Mobility Project (IEA/SMP) Model, and the calculation flow of energy consumption is shown in Figure 2.1. CO_2 emissions of road transportation is also possible to estimate by using well-to-tank (WtT) and tank-to-wheel (TtW) CO_2 emissions factor of each type of fuel. The IEA/SMP Model handles all the transportation energy globally, however, we modified and established fit for the road transportation and country base Energy Mix Model.

Figure 2.1. Calculation Flow of Energy Consumption by Energy Mix Model



GDP = gross domestic product, km = kilometre, L = litre, Mt = metric ton.
Each country's specific data such as vehicle registration number, actual fuel economy in each market condition, and mileage travelled annually by vehicle and/or fuel type to be used for simulation were provided by the participating country's research organisation and/or members based on the statistical data and literature. The information on energy policy, alternative fuels policy including biofuels, EV policy, power development plan, amongst others, were also collected and examined by each country member.

[1] Sources: Ministry of Road Transport & Highways, India; Ministry of Industry and Ministry of Energy & Mineral Resources, Indonesia; Ministry of Energy and other agencies, Thailand.

The steps of investigation were:

1) Energy and EV related policies and basic information survey of the country
2) Identification of the government's xEV introduction target (how many, by when) to settle the conditions for scenario simulation based on the information collected
3) Scenario proposal of xEV mix simulation by considering all the types of xEVs to find out reasonable and most effective xEV mix
4) Evaluation of the effectiveness of xEV mix scenarios in terms of reduction of oil consumption and CO_2 emissions while using biofuels and natural gas. The total cost of xEV introduction including infrastructure cost was also compared to judge and propose the most appropriate solutions as policy recommendations.

For cost calculation, we adopted the following assumption to see the social burden up to 2030 (or target year of each country) either paid by the private sector or the government:

- Higher vehicle costs for xEVs compared to ICE vehicles (compared to ICE vehicles, HEVs 126%, PHEVs 146%, and BEVs 200% including home charger)
- Infrastructure cost required depending on the progress of specific vehicle introduction (fast charging station of US$58,500 per 10 units for BEV/PHEV and CNG stations of US$1.8 million per 1,000 units for CNG vehicles)
- The total fuel cost used by all the vehicles in the market, including newly introduced vehicles

Through the activity in FY2018–19, we conducted scenario studies for three countries of India, Thailand and Indonesia, and evaluated the effectiveness of xEV mix scenarios together with the use of alternative fuels. We also summarised appropriate measures for mobility electrification in each country as policy recommendations based on the investigation results.

As our objective or output of the activity is a proposal of a reasonable and effective EV policy in practice, we decided to first review the investigation results in FY2018–19 and worked on revising and adding a scenario study in FY2019–20. Then, we organised policy dialogue opportunities in the three countries with updated policy recommendations to clearly convey our ideas to the policymakers and/or relevant stakeholders. In preparing updated policy recommendations to be presented at the policy dialogue, we also considered levelling between the three countries as a unified manner of summary based on the guidelines after intensive discussion.

The guidelines for policy recommendations were as follows:

1) Combination of vehicle electrification (xEV mix) and alternative fuels utilisation, such as biofuels is the most effective in reducing oil consumption and/or CO_2 emissions
2) Comment on biofuels use: xEV mix (incl. HEV) consideration for vehicle electrification has a positive effect on promoting the use of biofuels
3) Use of CNG as an alternative fuel for heavy duty vehicles in combination with the electrification of light duty vehicles is a reasonable solution for reducing oil

consumption and/or CO_2 emissions by replacing diesel fuel

4) Effect of BEV introduction on oil consumption and/or CO_2 emissions reduction is limited they are a new vehicle type

5) WtW basis CO_2 emissions of BEV are not always lower than HEV (or even compared to ICE vehicles) depending on the CO_2 emissions of power generation, and reducing the CO_2 emissions of power generation is an issue

6) Cost of implementation is much lower with a combination of xEV mix and alternative fuels utilisation due to higher costs of BEV introduction with charging infrastructure construction, and cost effectiveness of oil consumption and/or CO_2 emissions reduction

2. xEV Mix Scenario Study for India

2.1. Government Policies

India’s Integrated Energy Policy (2005) recommendations suggested the following: coal will remain India's primary energy source until 2032; focus on control over aggregate and technical losses of state power utilities; captive regimes to facilitate private generation; reduce costs of power; rationalise fuel prices to promote efficient fuel choices and facilitate proper substitution; lower energy intensity of gross domestic product (GDP) growth (by 25%) through higher energy efficiency and demand side management; augment existing resources by exploration or more recovery rates; give attention to hydro and nuclear projects; increase the role of renewables; approach energy security from the supply risk, market risk, and technical risk; climate change concerns to be met; focus on energy efficiency in all sectors, emphasis on mass transport and renewable energy including biofuels and fuel plantations, accelerated development of nuclear and hydro-electricity, and technology missions for clean coal technologies (Planning Commission India, 2006).

The Draft National Energy Policy (2017) focuses on providing access at affordable prices, improved security and independence, greater sustainability, and economic growth. It aims at universal electrification with 24x7 electricity by 2022, share of manufacturing to go up to 25% from the present level of 16% of GDP by 2022, reduction of oil imports by 10% from 2014–15 levels by 2022, and the share of non-fossil fuel-based capacity in the electricity mix is aimed at above 40% by 2030 (Government of India, 2017). As part of India’s Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change, India has set a target of reducing emissions intensity by 33%–35% by 2030 from 2005 levels.

The Government of India has several policies pushing alternative fuels and EV in the transport sector. The Draft National Energy Policy plans to promote CNG vehicles by city gas distribution (CGD) projects, pricing liquid transport fuels on market-driven principles, promoting hybrid and electric vehicles, and recognising fuel and electric charging stations as public utilities in determining land rates. The Auto Fuel Vision and Policy (2014) recommends a mix of automotive fuels and promotes the use of alternative fuels that include CNG, LPG, biofuels (dimethyl ether and ethanol), EV, hybrid vehicles, hydrogen fuel, auto LPG, and ethanol blended petrol. The Draft National Auto Policy aims to provide a consistent policy for the automotive industry to achieve its green mobility targets, adopt emissions standards beyond the Bharat New Vehicle Safety Assessment Program and harmonise with global standards by 2028, fix penalties and incentives along with the extension of corporate average fuel efficiency norms till 2025, harmonise automotive standards over the next 5 years in line with the United Nations Economic Commission for Europe World Forum for Harmonization of Vehicle Regulations (WP-29), scale-up of indigenous research and development with commercially viable innovations, harmonise Automotive Industry Standards and Bureau of Indian standards on safety critical parts over the next 3 years, and fast track the adoption of the Bharat New Vehicle Safety Assessment Program (PIB, 2018). This policy also plans to mandate the minimum share of green vehicles to be purchased by central and state government agencies and municipal corporations, which includes 25% of all vehicles from 2023 and 75% of all vehicles from 2030 bought by central and state governments; 50% of all vehicles from 2023, and 100% of all vehicles from 2030 bought by municipal corporations in metropolitan areas (DHI, 2018).

The alternative fuel policies include the National Electric Mobility Mission Plan 2020 that aims at achieving a target of 6–7 million sales of xEVs by 2020. The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme intends to provide incentives and subsidies for manufacturing hybrid and electric vehicles. The scheme provides demand incentives in the form of reduced upfront purchase price for vehicles of all segments including electric buses, electric four-wheeler passenger cars, and electric three-wheelers. It aims to achieve the target of ensuring 30% of vehicles plying to be electric. The scheme has an outlay of INR85.96 billion for demand incentives and INR10 billion[2] for charging station infrastructure with one slow charging unit for every electric bus and one fast charging station for 10 electric buses is to be introduced.

The EV policies in India have been introduced by several states including Delhi, Andhra Pradesh, Telangana, Karnataka, Kerala, Maharashtra, Uttar Pradesh, and Uttarakhand. The policies focus on increasing their EV share by providing incentives, subsidies, and tax waivers to manufacturers, service providers, and buyers. The policies are pushing EV in the private and public transport sector and in all government related agencies. The state governments are providing support to develop charging and/or swapping station infrastructure through incentives, subsidies, and assistance in required land allocation.

The National Biofuel Policy 2018 aims to achieve 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel by 2030. The policy takes measures to support biofuel generation and implementation by ensuring feedstock availability, financing, pricing of biofuels, distribution, and marketing. The implementation of specific biofuel programmes such as the Ethanol Blended Petrol Programme, the Second Generation (2G) Ethanol Programme, and the Biodiesel Blending Programme and Advanced Biofuels to support and increase the production of biofuels.

[2] US$1 = INR75.64, as of 29 May 2020 (https://fbil.org.in/securities?op=referencerate&mq=o/).

2.2. Parameters and Figures used for Scenario Simulation

The base model developed in this study is built on the sustainable mobility project (IEA/SMP) model. The mode of transport comprises cars, taxis, buses, omni-buses, HCV, light commercial vehicles, two-wheelers, and three-wheelers. The fuels considered include gasoline, diesel fuel, CNG, biodiesel, ethanol, electricity, amongst others. The model time horizon is from the present to 2030.

Table 2.1. Model Parameters Based on Vehicle Type for Base Year (2015)

Vehicle Type	Stock Number (in million)	Fuel Economy (km/L)
Cars and jeeps	27.900	12.24
Two-wheelers	110.176	53.46
Three-wheelers	6.392	28.56
Buses	1.405	4.08
Omni-buses	0.372	4.08
HCV	5.903	4.16
LCV	4.613	11.09
Taxis	1.600	18.36
Total	158.362	-

HCV = heavy commercial vehicle, km/L = kilometre per litre, LCV = light commercial vehicle.
Source: Authors.

Table 2.2. Model Parameters Based on Fuel Type for Base Year (2015)

Fuel Type	CO_2 Emissions Factor – TtW* ($kgCO_2/L$)	CO_2 Emission Factor – WtT** ($kgCO_2/L$)
Gasoline	2.36	0.21
Diesel	2.64	0.28
Ethanol	0.00	1.20
Biodiesel	0.00	1.79
CNG	1.86	0.47
LPG	1.86	0.47
Electricity*	0.00	9.25

* For electricity values for WtT are for year 2015 in future it changes with the change in fuel mix of power generation in India.
CNG = Compressed Natural Gas, LPG = liquefied petroleum gas, TtW = tank-to-wheel; WtT = well-to-tank.
Source: Authors.

Fuel Prices

The assumptions for fuel prices are given in Table 2.3. The prices of gasoline and diesel fuel in India vary across each state primarily due to the variation of state taxes levied on them. Therefore, the average sale price of gasoline and diesel fuel in the major metropolitan cities of Delhi, Kolkata, Mumbai, and Chennai for the year 2015–16 is assumed constant over the modelling period. The cost of CNG is considered for the year 2015–16 year from Indraprastha Gas Limited, which is amongst the leading natural gas distribution companies in the country operating mainly in the capital city New Delhi. Ethanol and biodiesel are blended with gasoline and diesel fuel, and sold by the same retailer, thus their price is considered the same as that of gasoline and diesel fuel. The electricity cost varies from state to state due to the different distribution utilities and varied prices for different consumer categories. Therefore, the cost of electricity considered is an average of the billing rate of electricity distribution unities for Delhi for the year 2015–16 for non-domestic consumers, which stands at INR10.66/kWh.

Table 2.3. Fuel Cost Assumptions

Fuel Type	Price
Gasoline	64.87 INR/L
Diesel fuel	53.48 INR/L
CNG	38.00 INR/kg
Electricity	10.66 INR/kWh

CNG = compressed natural gas, kWh = kilowatt hour, L = litre.
Source: Authors.

Infrastructure and Vehicle Cost Assumptions

An average of 5,000 vehicles is considered for every petrol and/or diesel pumping station. The average cost for setting up a new pump is taken as INR6 million as reported by ESSAR Oil where the cost is exclusive of land cost. The investment required for a CNG station is twice as much as that of the petrol and/or diesel pumping stations. The CNG station cost is assumed accordingly. For every fast charging station, an average of 10 BEV has been considered. The cost of introducing one fast charging station is taken to be US$58,500.

The vehicles categories are classified as buses, cars, taxis, two-wheelers, and three-wheelers, HCV, and LCV. The costs for HEV and BEV are considered at 126% and 200% as that of the corresponding conventional vehicles respectively, based on the review of the literature and discussions with stakeholders.

2.3 Scenarios

The model illustrates six scenarios: Business as Usual (BAU) scenario, Alternative Fuels Scenario (AFS), Aggressive Electrification Scenario (AES), Moderate Electrification Scenario (MES), Moderate Electrification cum Hybrid Promotion Scenario (HPS), and Aggressive Electrification condition and Only Electrification Scenario (OES).

Business as Usual (BAU) Scenario

In this scenario, the status quo is maintained and is characterised by the continuation of the existing trends. Already existing government policy measures are not fully attained, thus limiting their effectiveness in attaining India's Nationally Determined Contribution (NDC) objectives for decarbonisation of the transport sector. Ambitions in the transport sector fall short of the NDC targets set for 2030. There will be a continuation of the trends in motorisation, with increasing road transport shares, relatively less reliance on public transport, and growing demand for petroleum-based fossil fuels.

Table 2.4. BAU Scenario Conditions

Vehicle/Fuel type	-	2010	2015	2020	2025	2030
Electric two-wheelers	share	0.1%	0.2%	0.4%	0.6%	0.8%
Electric taxis	share	-	-	-	-	-
Electric passenger cars	share	-	-	-	-	-
Hybrid passenger cars	share	-	-	-	-	-
CNG three-wheelers	share	2.5%	4.5%	5%	6%	7%
CNG buses	share	1%	1.3%	1.5%	1.8%	2%
CNG taxis	share	2.5%	4.4%	5%	6%	7%
CNG passenger cars	share	2%	2%	2%	2%	2%
Fuel efficiency improvement	per annum	0.1%				
Ethanol utilisation	blend ratio	2%	3.8%	4%	4%	4%
Biodiesel utilisation	blend ratio	-	-	-	-	-

- stands for negligible.
BAU = Business as Usual, CNG = compressed natural gas.
Source: Authors.

Alternative Fuels Scenario (AFS)

This scenario is characterised by policy impetus for increasing the share of CNG-fuelled vehicles coupled with the attainment of increased target for ethanol blending with petrol and biodiesel blending with diesel. There is a concerted focus to accelerate the pace of CGD infrastructure development followed by a commensurate rise in the number of CNG dispensing stations leading to increased CNG availability. Furthermore, the government has also accorded top priority in allocating domestic gas to meet CNG requirements of all CGD entities, thus improving both availability and affordability of CNG. The barriers in the uptake of CNG fuelled vehicles are removed partly due to these policy interventions causing the new sales of CNG-fuelled vehicles to increase across all vehicle categories, that is, three-wheelers, buses, taxis, and passenger cars, thereby increasing the share of CNG-fuelled vehicles in the overall vehicle fleet.

With regards to alternative fuels, in the AFS, it is assumed that the country will attain the 10% ethanol blending mandate by 2030. The supply of ethanol for blending with petrol will increase with the commissioning of proposed ethanol-based projects based on a variety of feedstock including lignocellulosic biomass, etc. For promoting the use of biodiesel, the Ministry of Petroleum and Natural Gas has permitted the direct sale of biodiesel (B100) to bulk consumers like railways, shipping, state road transport corporations, and so on. A rise in the domestic supply of biodiesel will ensure that progressively by 2030, the biodiesel blending mandate of 5% is met. With regards to the other two decarbonisation strategies, that is, the electrification of road transport and fuel efficiency improvements, the conditions of the BAU scenario persist with limited electrification levels of road transport and relatively slower growth in fuel efficiency.

Table 2.5. AFS Conditions

Vehicle/Fuel type		2010	2015	2020	2025	2030
Electric two-wheelers	Share	0.1%	0.2%	0.4%	0.6%	0.8%
Electric taxis	Share	-	-	-	-	-
Electric passenger cars	Share	-	-	-	-	-
Hybrid Passenger cars	Share	-	-	-	-	-
CNG three-wheelers	Share	2.5%	4.5%	7%	11%	15%
CNG buses	Share	1%	1.3%	3%	6.5%	10%
CNG taxis	Share	2.5%	4.4%	8%	11.5%	15%
CNG passenger cars	Share	2%	2%	4%	7%	10%
Fuel efficiency improvement	per annum	0.1%				
Ethanol utilisation	blend ratio	0%	3.8%	5%	7.5%	10%
Biodiesel utilisation	blend ratio	-	-	0.5%	2%	5%

- stands for negligible.
AFS = Alternative Fuels Scenario, CNG = compressed natural gas.
Source: Authors.

Moderate Electrification Scenario (MES)

In the Moderate Electrification Scenario, the electrification targets as set out by the Government of India's policies are moderately higher when compared to the BAU scenario. This scenario encompasses increased penetration and/or adoption of battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs) for passenger movement by road vis-à-vis the BAU scenario. Further, in sharp contrast to the BAU scenario, wherein there was a limited deployment of electric vehicles in the two-wheeler category, the electrification will be across all categories of road transport vehicles including taxis, passenger cars, three-wheelers, and buses.

There is a moderate policy support for EVs accelerating EV deployment in this scenario. Compared to the BAU scenario, there is an additional effort on part of all stakeholders for all the road transport modes to become more electrified. With regards to the decarbonisation strategy of increased share of CNG-fuelled vehicles and alternative fuels, the conditions of the AFS scenario persist with increased shares of CNG-fuelled vehicles, and alternative fuels whereas with regards to fuel efficiency improvements, the condition of the BAU scenario of relatively slower growth in fuel efficiency holds in this scenario as well.

Table 2.6. MES Conditions

Vehicle/Fuel type		2010	2015	2020	2025	2030
Electric two-wheelers	Share in new sales	-	1%	7.7%	25%	50%
Electric taxis	Share in new sales	-	-	0.7%	5%	15%
Electric passenger cars	Share in new sales	-	-	0.7%	5%	15 %
Electric three-wheelers	Share in new sales	-	-	5%	25%	50%
Electric buses	Number of new buses			500	3,300	10,000
Hybrid passenger cars and Taxis	Share in new sales	-	-	2.5%	5%	7.5%
CNG three-wheelers	share	2.5%	4.5%	7%	11%	15%
CNG buses	share	1%	1.3%	3%	6.5%	10%
CNG taxis	share	2.5%	4.4%	8%	11.5%	15%
CNG passenger cars	share	2%	2%	4%	7%	10%
Fuel efficiency improvement	per annum	0.1%				
Ethanol utilisation	blend ratio	0%	3.8%	5%	7.5%	10%
Biodiesel utilisation	blend ratio	-	-	0.5%	2%	5%

CNG = compressed natural gas, MES = Moderate Electrification Scenario.
Note: Authors.

Aggressive Electrification Scenario (AES)

In this scenario, the electrification targets as set out by the Government of India's policies are exceedingly high when compared to the BAU scenario and encompasses the aggressive penetration and/or adoption of BEVs and HEVs for passenger movement by road vis-à-vis the BAU scenario. Further, the electrification levels will be higher across all categories of road transport vehicles including taxis, passenger cars, three-wheelers, and buses.

There is strong policy support for EVs accelerating EV deployment in this scenario. Compared to the BAU scenario, there is a concerted and focused effort by all stakeholders to create an EV ecosystem such that all the road transport modes become increasingly electrified.

With regards to the decarbonisation strategy of increased share of CNG fuelled vehicles and alternative fuels, the conditions of the AFS persist with increased shares of CNG-fuelled vehicles, and alternative fuels whereas with regards to fuel efficiency improvements, the condition of the BAU scenario of relatively slower growth in fuel efficiency holds in this scenario as well.

Table 2.7. AES Conditions

Vehicle/Fuel type		2010	2015	2020	2025	2030
Electric two-wheelers	Share in new sales	-	1%	7.7%	25%	50%
Electric taxis	Share in new sales	-	-	1%	10%	30%
Electric passenger cars	Share in new sales	-	-	0.7%	5%	15 %
Electric three-wheelers	Share in new sales	-	-	5%	25 %	50 %
Electric buses	Number of new buses	-	-	500	10,000	40,000
Hybrid passenger cars and taxis	Share in new sales	-	-	5%	10%	15%
CNG three-wheelers	share	2.5%	4.5%	7%	11%	15%
CNG buses	share	1%	1.3%	3%	6%	10%
CNG taxis	share	2.5%	4.4%	8%	11%	15%
CNG passenger cars	Share	2%	2%	4%	7%	10%
Fuel efficiency improvement	per annum	0.1%				
Ethanol utilisation	blend ratio	0%	3.8%	5%	7.5%	10%
Biodiesel utilisation	blend ratio	-	-	0.5%	2%	5%

- stands for negligible.
AES = Aggressive Electrification Scenario, CNG = compressed natural gas.
Source: Authors.

Moderate Electrification cum Hybrid Promotion Scenario (HPS)

In HPS, the percentage share of new sales of hybrid electric vehicles is enhanced compared to that in MES. With regards to the decarbonisation strategy of increased share of CNG-fuelled vehicles and alternative fuels, the conditions of the AFS persist with increased shares of CNG-fuelled vehicles, and alternative fuels whereas with regards to fuel efficiency improvements, the condition of the BAU scenario of relatively slower growth in fuel efficiency holds in this scenario as well.

Table 2.8. HPS Conditions

Vehicle/Fuel type		2010	2015	2020	2025	2030
Electric two-wheelers	Share in new sales	-	1%	7.75%	25%	50%
Electric taxis	Share in new sales	-	-	0.7%	5%	15%
Electric passenger cars	Share in new sales	-	-	0.7%	5%	15 %
Electric three-wheelers	Share in new sales	-	-	5%	25%	50%
Electric buses	Number of new buses	-	-	500	3,300	10,000
Hybrid passenger cars and taxis	Share in new sales	-	-	1%	17%	50 %
CNG three-wheelers	share	2.5%	4.5%	7%	11%	15%
CNG buses	share	1%	1.3%	3%	6%	10%
CNG taxis	share	2.5%	4.4%	8%	11%	15%
CNG passenger cars	share	2%	2%	4%	7%	10%
Fuel efficiency improvement	per annum	0.1%				
Ethanol utilisation	blend ratio	0%	3.8%	5%	7.5%	10%
Biodiesel utilisation	blend ratio	-	-	0.5%	2%	5%

- stands for negligible.
CNG = compressed natural gas, HPS = Hybrid Promotion Scenario.
Source: Authors.

Only Electrification Scenario (OES)

This scenario is a hybrid of the BAU cum Aggressive Electrification scenarios as detailed above. The storyline and strategic context including all other conditions of AES hold except that in OES, with regards to the decarbonisation strategy of increased share of CNG-fuelled vehicles and alternative fuels and fuel efficiency improvements, the conditions of the BAU scenario persist with limited shares of CNG-fuelled vehicles and relatively slower growth in fuel efficiency.

Table 2.9. OES Conditions

Vehicle/Fuel type		2010	2015	2020	2025	2030
Electric two-wheelers	Share in new sales	-	1%	7.75%	25%	50%
Electric taxis	Share in new sales	-	-	1%	10%	30%
Electric passenger cars	Share in new sales	-	-	0.7%	5%	15 %
Electric three-wheelers	Share in new sales	-	-	5%	25%	50%
Electric buses	Number of new buses	-	-	500	10,000	40,000
Hybrid passenger cars and taxis	Share in new sales	-	-	5%	10%	15%
CNG three-wheelers	share	2.5%	4.5%	5%	6%	7%
CNG buses	share	1%	1.3%	1.5%	1.8%	2%
CNG taxis	share	2.5%	4.4%	5%	6%	7%
CNG passenger cars	share	2%	2%	2%	2%	2%
Fuel efficiency improvement	per annum	0.1%				
Ethanol utilisation	blend ratio	2%	3.8%	4%	4%	4%
Biodiesel utilisation	blend ratio	-	-	-	-	-

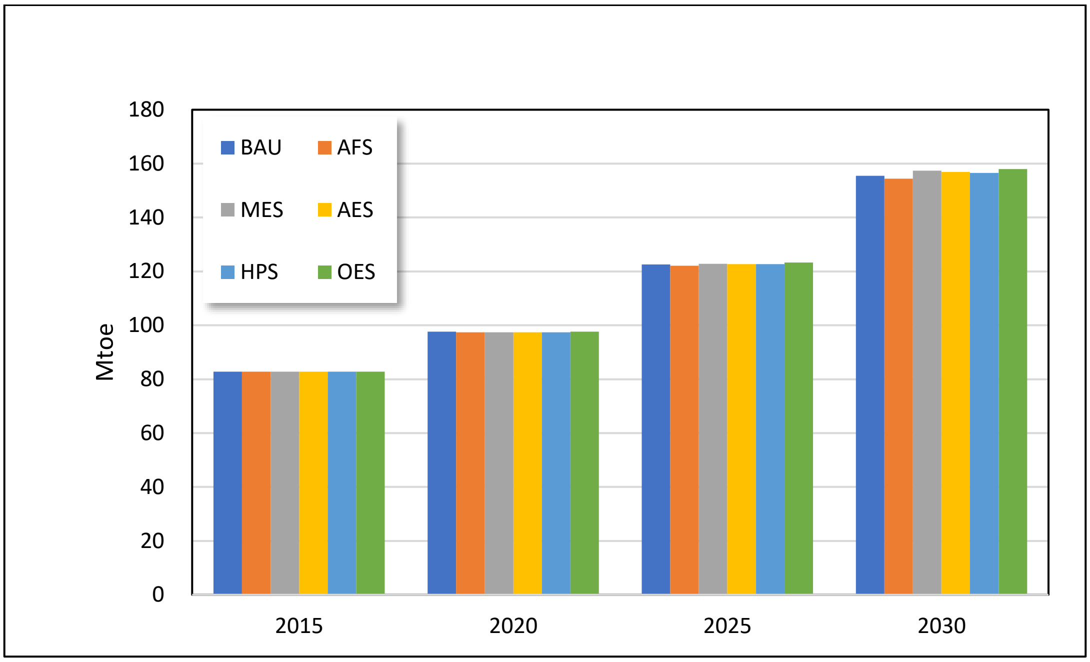
- stands for negligible.
CNG = compressed natural gas, OES = Only Electrification Scenario.
Source: Authors.

2.4. Study Results (oil consumption, CO_2 emissions, and cost of implementation)

Final Energy Demand

The model results indicate that the increased deployment of CNG-fuelled vehicles across various vehicle categories and enhanced use of alternative fuels manifests itself by way of a marginal decline in the total final energy demand in the AFS to 122.1 million tons of oil equivalent (Mtoe) (0.41% reduction from BAU) by 2025 and to 154.4 Mtoe (0.64% reduction from BAU) by 2030. In the electrification centric scenarios of the MES, AES, HPS, and OES, a marginal increase of final energy demand is observed compared to the BAU scenario. The OES scenario has maximum increase to the extent of 0.57% by 2025 and 1.61% by 2030 when compared to their respective BAU levels.

Figure 2.2. Comparison of Total Final Energy Demand across the Scenarios

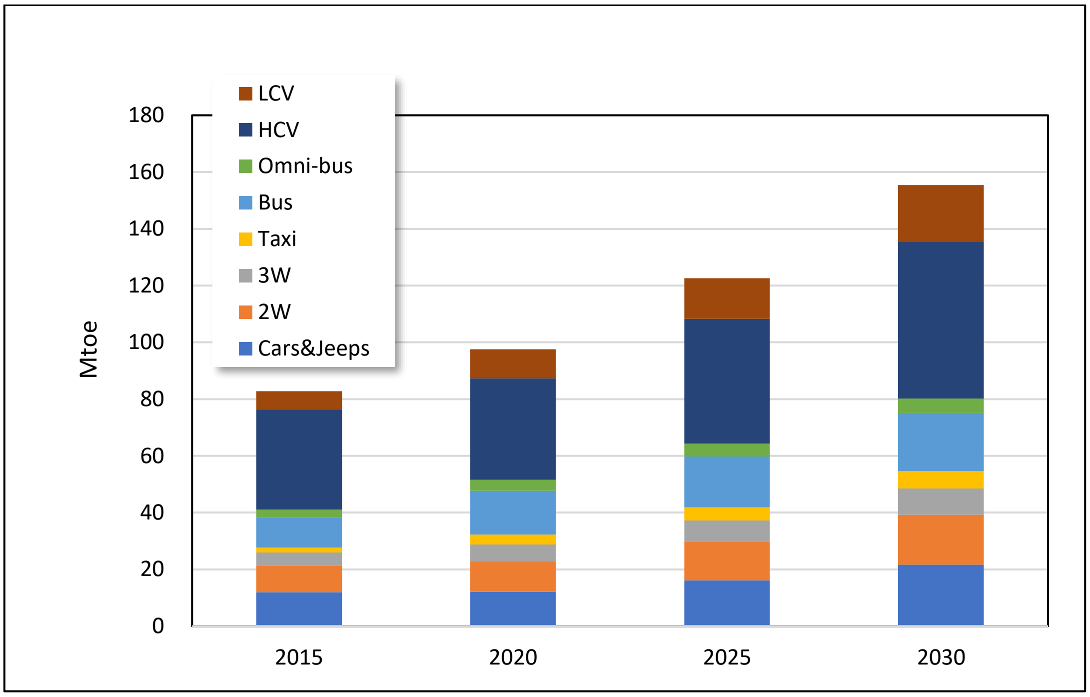


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, Mtoe = million tons of oil equivalent, OES = Only Electrification Scenario.
Source: Authors.

Energy Demand by Vehicle Type

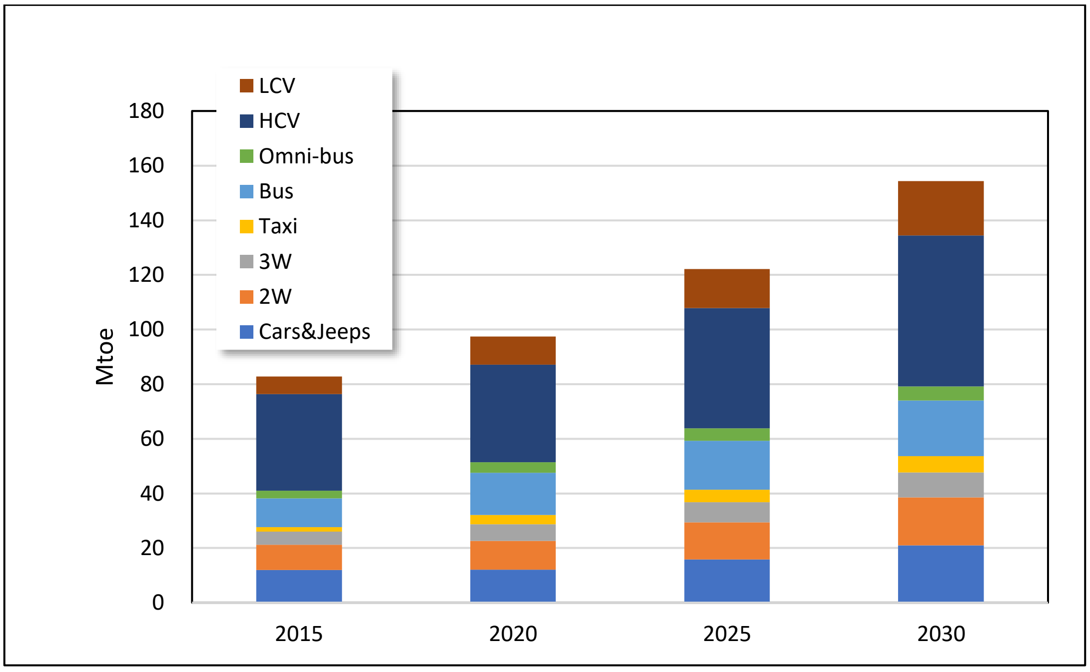
In the BAU scenario, the model results suggest that by 2030, HCVs will consume the highest amount of energy (55.3 Mtoe), thus contributing to around 36% of the final energy consumption by 2030. This is followed by cars and jeeps at 14% (21.7 Mtoe) accounting for 14%, and buses accounting for 13% (20.5 Mtoe). The other five scenarios of AFS, MES, AES, HPS, and OES reveal a similar pattern of energy consumption as the BAU scenario with HCVs consuming the maximum energy amongst all vehicle types.

Figure 2.3. Energy Demand by Vehicle Type in BAU Scenario



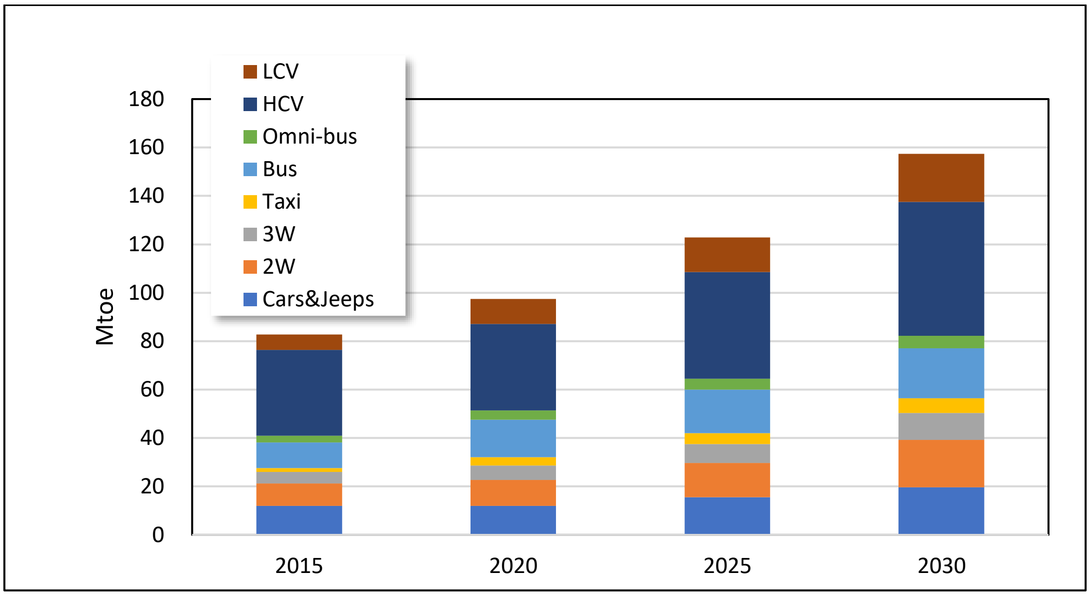
2W = two-wheeler, 3W = three-wheeler, BAU = business as usual, HCV = heavy commercial vehicle, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.4. Energy Demand by Vehicle Type in AFS



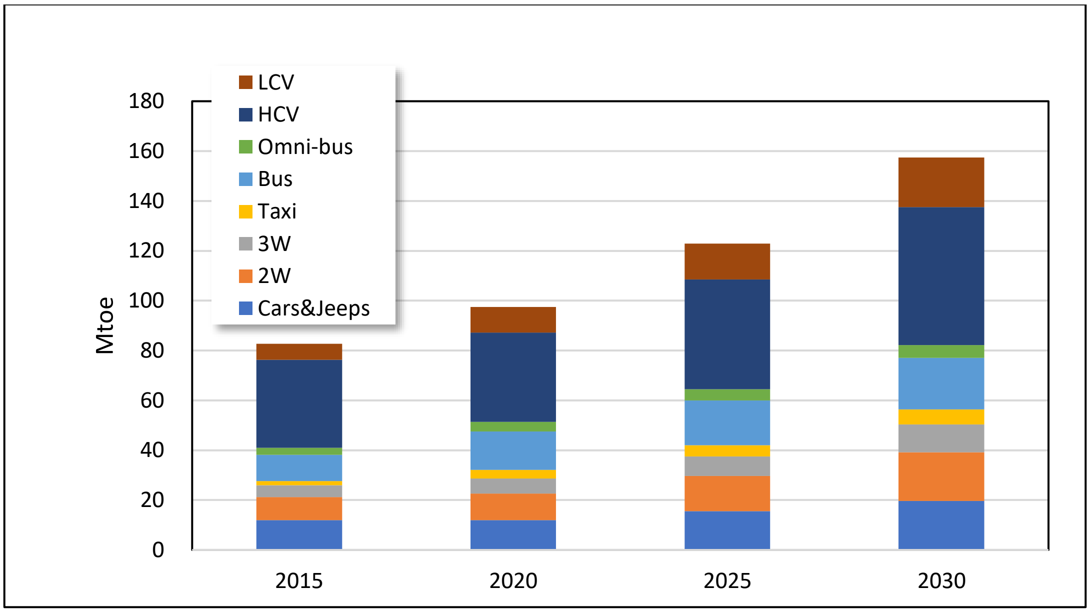
2W = two-wheeler, 3W = three-wheeler, AFS = Alternative Fuels Scenario, HCV = heavy commercial vehicle, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.5. Energy Demand by Vehicle Type in MES



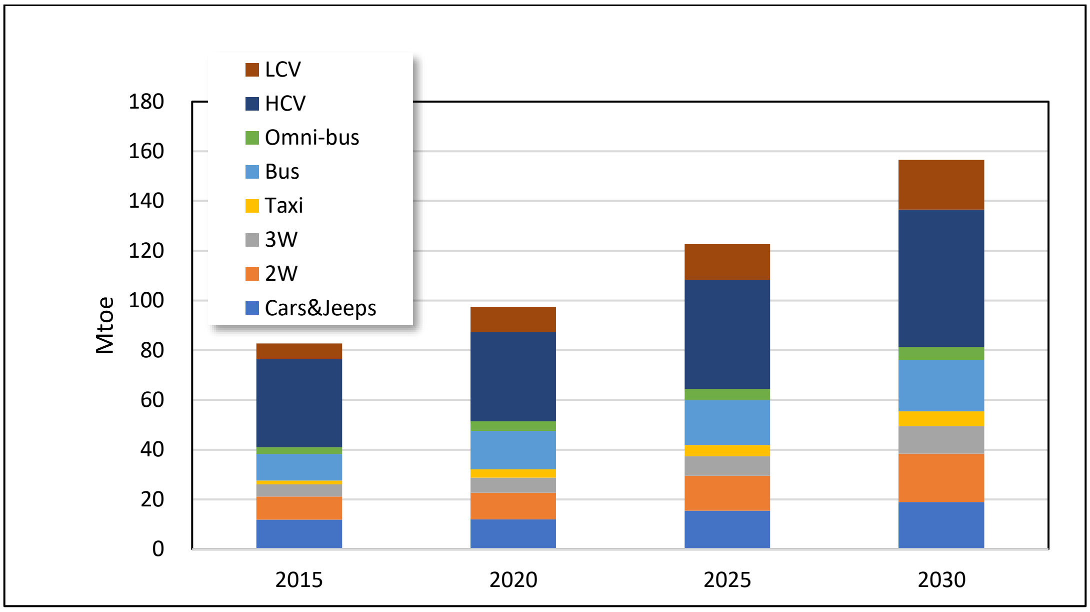
2W = two-wheeler, 3W = three-wheeler, HCV = heavy commercial vehicle, LCV = light commercial vehicle, MES = Moderate Electrification Scenario, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.6. Energy Demand by Vehicle Type in AES



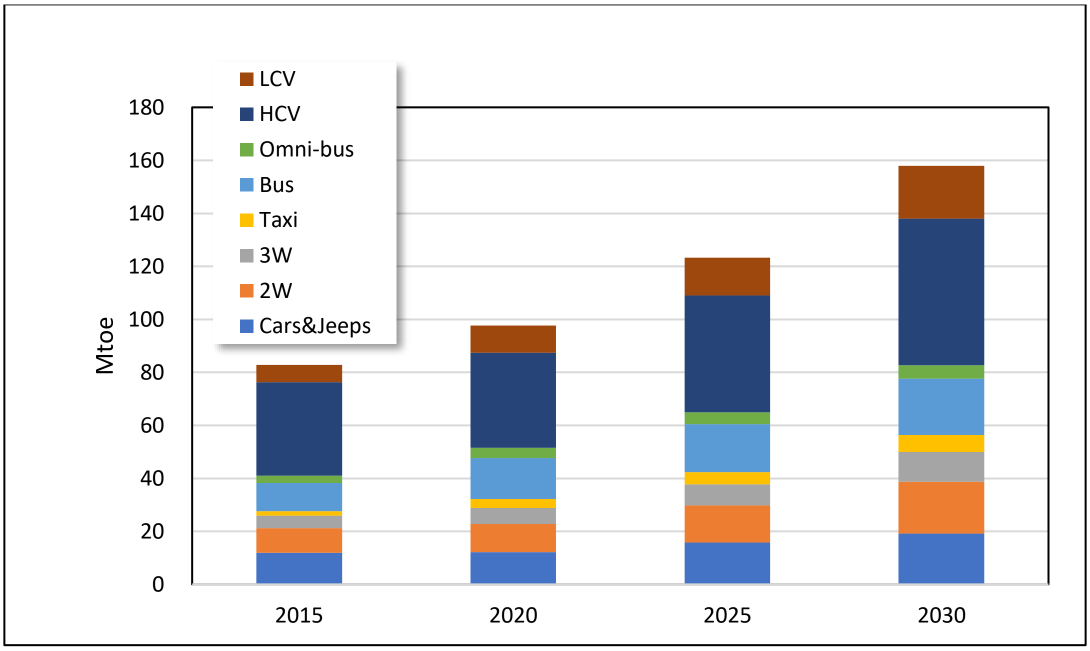
2W = two-wheeler, 3W = three-wheeler, AES = Aggressive Electrification Scenario, HCV = heavy commercial vehicle, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.7. Energy Demand by Vehicle Type in HPS



2W = two-wheeler, 3W = three-wheeler, HCV = heavy commercial vehicle, HPS = Moderate Electrification cum Hybrid Promotion Scenario, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.8. Energy Demand by Vehicle Type in OES



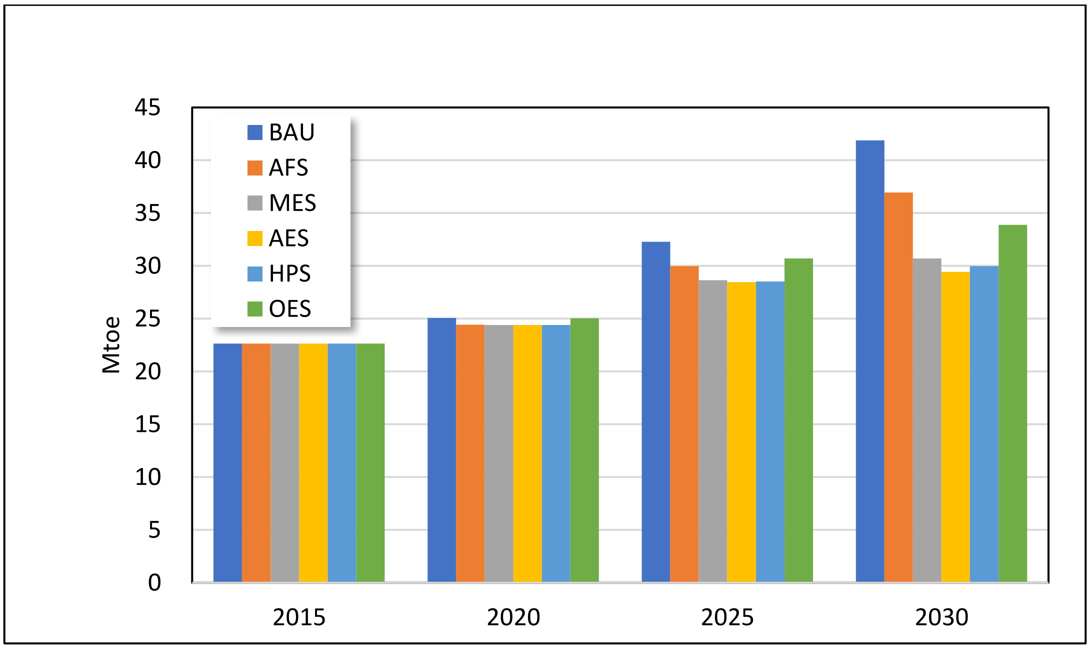
2W = two-wheeler, 3W = three-wheeler, HCV = heavy commercial vehicle, OES= Only Electrification Scenario, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

Energy Demand by Fuel Type

Gasoline

In the BAU scenario, gasoline consumption is observed to increase at a (compound annual growth rate (CAGR) of 4.2% from 22.6 Mtoe in 2015 to about 42 Mtoe in 2030, which is about 1.8 times the amount when compared to the base year. With increased ethanol blending with gasoline in the AFS, the growth in gasoline consumption is lower with a CAGR of 3.32% (37 Mtoe in 2030) when compared to the corresponding BAU levels. In the electrification scenarios of the MES, AES, HPS, and OES, owing to the rising pace of electrification, the growth in gasoline consumption slows with respective CAGRs of 2.06% (30.7 Mtoe), 1.77% (29.4 Mtoe), 1.91% (30 Mtoe), and 2.74% (34 Mtoe). In the AFS, for obvious reasons, although the growth in gasoline consumption is lower relative to the BAU levels, it is higher when compared to the MES, AES, HPS, and OES because of the increased share of HEVs in new sales of passenger cars and taxis. In BAU, gasoline is the 2nd largest consumed fuel, after diesel across all years from 2015 till 2030 accounting for 27% of total fuel consumption in 2030. It holds its position as the 2nd largest consumed fuel in all the years across all the other scenarios with percentage share reducing to 23%, 20%, 19%, 19%, and 21% respectively in the AFS, MES, AES, HPS, and OES in 2030 when compared to the corresponding BAU level.

Figure 2.9. Comparison of Gasoline Consumption across the Scenarios



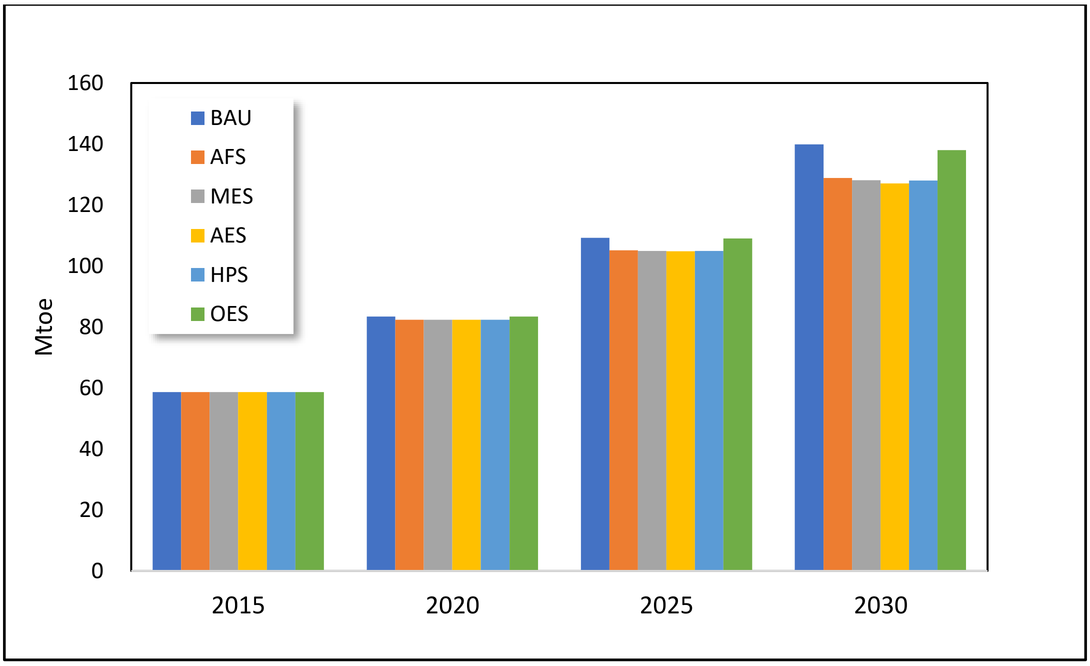
BAU = Business as Usual, AFS = Alternative Fuels Scenario, AES = Aggressive Electrification Scenario, MES = Moderate Electrification Scenario, HPS = Moderate Electrification cum Hybrid Promotion Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

Diesel fuel

In the BAU scenario, diesel consumption increases at a CAGR of 4.29% from 59 Mtoe in 2015 to about 110 Mtoe in 2030, which is about 1.8 times higher when compared to the base year. With a rising share of CNG vehicles in the overall vehicle fleet, particularly in public transport (buses, taxis, and three-wheelers) accompanied by a steady rise in biodiesel blending with diesel, in the AFS, the growth in diesel consumption is lower with a CAGR of 3.76% (102 Mtoe in 2030) when compared to the corresponding BAU levels. In the electrification scenarios of the MES, AES, HPS, and OES, owing to the rising pace of electrification, the growth in diesel consumption slows down with respective CAGRs of 3.72 % (101 Mtoe), 3.65% (100 Mtoe), 3.71% (101 Mtoe), and 4.18% (108.2 Mtoe).

In the OES, although the growth in diesel consumption is lower relative to the BAU levels, it is higher when compared to the MES, AES, and HPS because in the OES, the share of CNG-fuelled vehicles is assumed at the BAU levels. Thus, the extent of the decline in diesel consumption because of increased electrification levels in the OES is partially offset by the relatively slow increase in the share of CNG when compared to the MES, AES, and HPS where the share of CNG-fuelled vehicles is assumed at the AFS levels. In BAU, diesel is the largest consumed fuel across all years from 2015 till 2030 accounting for 71% of the total fuel consumption in 2030. Diesel remains the largest consumed fuel across all the years in all the other five scenarios with its percentage share reducing to 66%, 64%, 64%, 65%, and 69%, respectively in the AFS, MES, AES, HPS, and OES in 2030 when compared to the corresponding BAU level.

Figure 2.10. Comparison of Diesel Fuel Consumption across the Scenarios

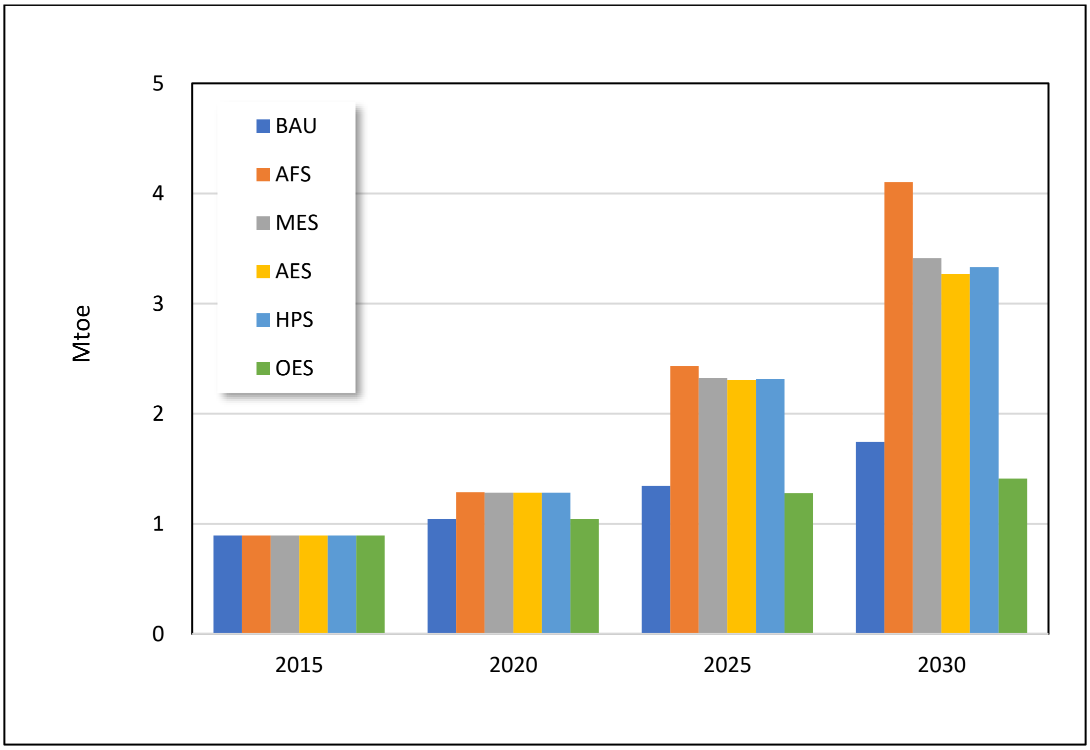


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

Ethanol

In BAU, ethanol consumption has almost tripled from 0.9 Mtoe in 2015 to 1.7 Mtoe in 2030 increasing at a CAGR of 4.33% from 2015 to 2030. Assuming that India will achieve the 10% mandated target of blending ethanol with gasoline by 2030 driven primarily by the increased domestic availability of fuel grade ethanol for blending with gasoline amongst other factors, in the AFS, MES, AES, and HPS, ethanol consumption in the Indian transport sector has exhibited a high double-digit growth with respective CAGRs of 10.64% (4.1 Mtoe in 2030), 9.27% (3.4 Mtoe in 2030), 9.05% (3.3 Mtoe in 2030), and 9.05% (3.3 Mtoe in 2030) respectively. In the OES, the magnitude and growth rate of ethanol consumption is lower than the BAU (17.6%) since the ethanol to gasoline blending ratio is assumed at the BAU levels. This contributes a relatively lower growth in ethanol at a CAGR of 3.04% during 2015–2030 when compared to the MES, AES, and HPS wherein the ethanol to gasoline blending ratio is assumed at the AFS levels.

Figure 2.11. Comparison of Ethanol Consumption across the Scenarios

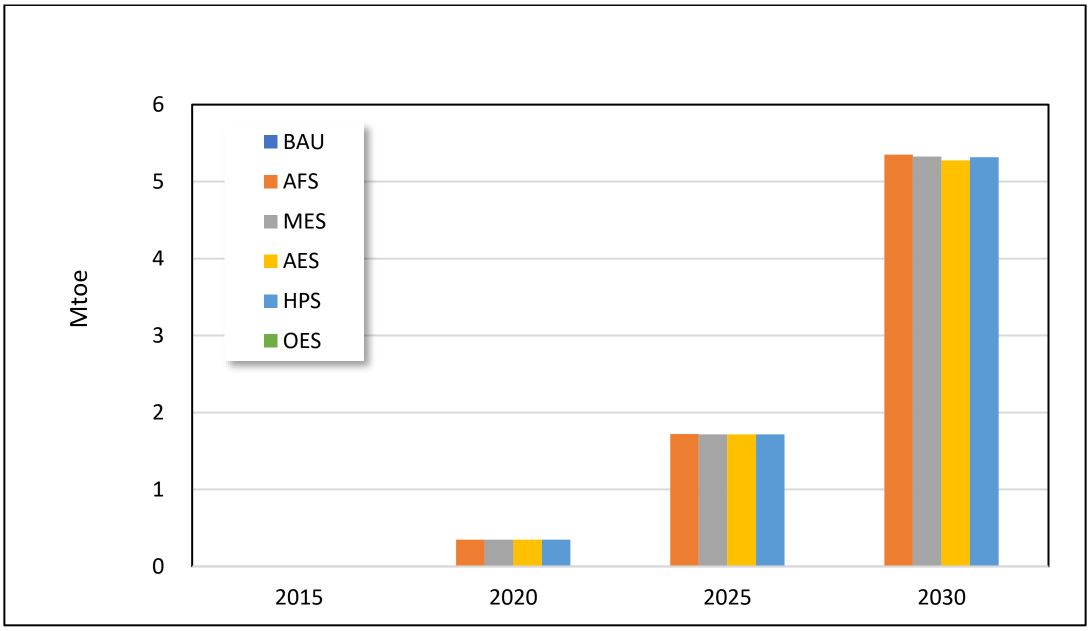


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

Biodiesel

The biodiesel blending with diesel for use as a fuel in India's transport sector has not taken off. In the BAU, throughout 2015–2030, biodiesel consumption in India's transport sector is absent owing mainly to the non-availability of biodiesel for blending with diesel. Assuming the country will achieve the 5% of blending biodiesel with diesel by 2030 driven primarily by the increased domestic availability of biodiesel for blending with diesel amongst other factors, the biodiesel consumption has increased from 0 in 2015 to 5.4, 5.3, 5.3 and 0.3 Mtoe in 2030 across all the four scenarios of the AFS, MES, AES, and HPS, respectively. In the OES, the magnitude and growth rate of biodiesel consumption is the same as the BAU since the biodiesel to diesel blending ratio is assumed at the BAU levels. In the BAU and OES, the percentage share of biodiesel in the overall fuel mix in 2030 is 0, however across all other four scenarios it increases to around 3.4% when compared to the corresponding BAU level.

Figure 2.12. Comparison of Biodiesel Consumption across the Scenarios



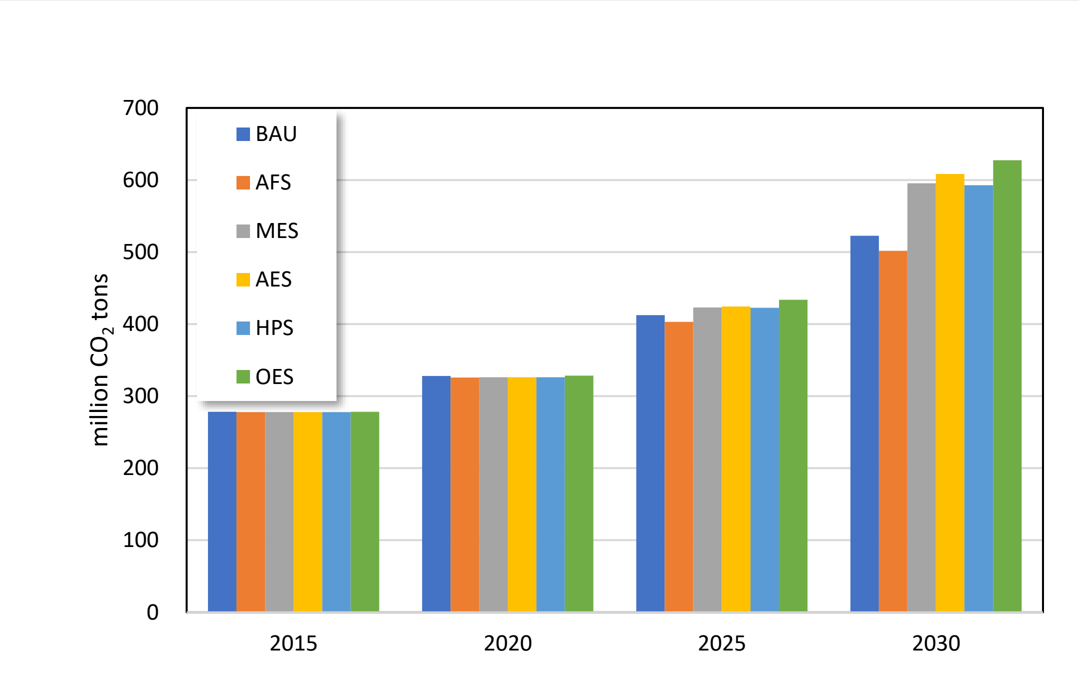
AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

CO_2 Emissions

Well-to-Wheel CO_2 Emissions

The total well-to-wheel (WtW) CO_2 emissions will more than double, increasing from 278 million tons of CO_2 ($MtCO_2$) in 2015 to 523 $MtCO_2$ by 2030 in the BAU scenario registering a CAGR of 4.3%. In the AFS, the increased share of CNG-fuelled vehicles in the road transport fleet and enhanced use of alternative fuels results in WtW CO_2 emissions reduction to 502 $MtCO_2$ by 2030 translating into about 4% reduction from the BAU levels in 2030. However, in electrification-related scenarios the WtW CO_2 emissions exhibit an increase of 14%, 16%, 13%, and 20% respectively, in the MES, AES, HPS, and OES relative to the BAU. The HPS scenario witnesses the least percentage increase in WtW CO_2 emissions relative to the BAU levels. This implies that the gains from reduction in aggressive electrification are more than offset by slow improvements in fuel efficiency and comparatively lower uptake of CNG-fuelled vehicles and alternative fuels. Also, it illustrates that road transport electrification as a policy lever for reducing CO_2 emissions is effective only with deep decarbonisation of the power sector. In terms of the energy carriers, in the BAU, diesel is seen to contribute about 70.5% of the CO_2 emissions by 2030 which can be attributed to the large percentage of diesel consumed by HCVs. This is followed by gasoline with 26.8% and around 0% contributions from LPG, biodiesel, and hydrogen.

Figure 2.13. Well-to-Wheel CO_2 Emissions from Road Transport Sector (2015–2030)

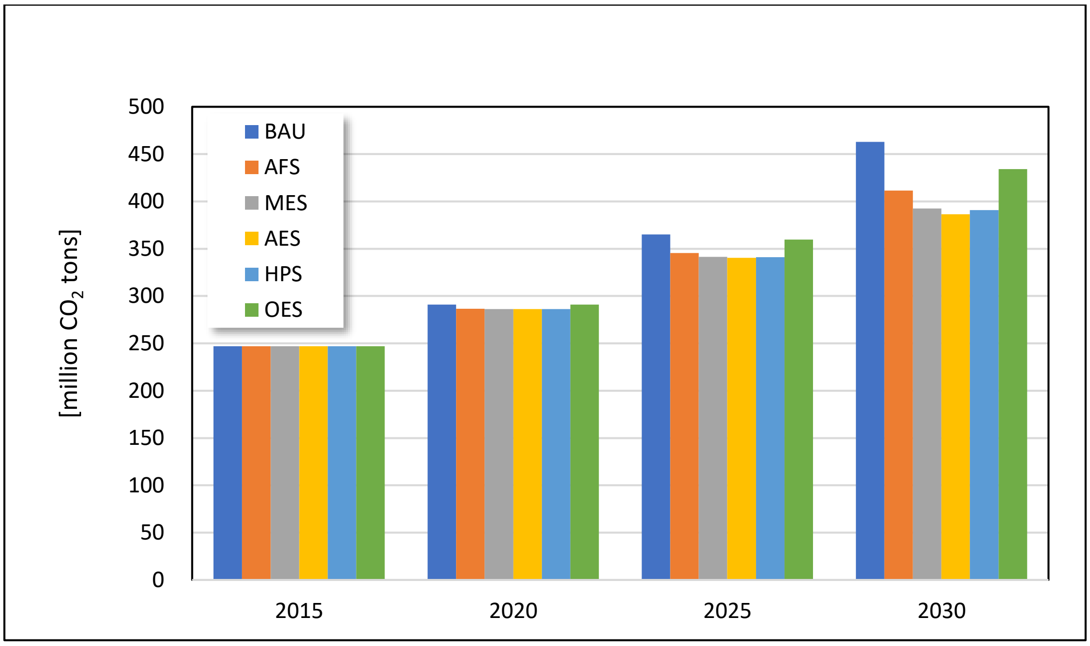


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

Tank-to-Wheel CO_2 Emissions

The total tank-to-wheel (TtW) CO_2 emissions will be more than double, increasing from 247 $MtCO_2$ in 2015 to 463 $MtCO_2$ by 2030 in the BAU scenario registering a CAGR of 4.27%. In the AFS, the increased share of CNG-fuelled vehicles in the road transport fleet and enhanced use of alternative fuels results in WtW CO_2 emissions reduction to 412 $MtCO_2$ by 2030 translating into 11.1% reduction from BAU levels in 2030. However, this is in sharp contrast to the results of WtW CO_2 emissions. In the electrification related scenarios, the TtW CO_2 emissions exhibit 15.2%, 16.5%, 15.5%, and 6.2% reduction, respectively, in MES, AES, HPS, and OES relative to the BAU scenario. The AES scenario witnesses the maximum reduction in TtW CO_2 emissions relative to the BAU levels followed very closely by HPS.

Figure 2.14. Tank-to-Wheel CO_2 Emissions from Road Transport Sector (2015–2030)



AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

Cost of xEVs Introduction

The overall cost of implementing xEVs depends on three main components – fuel cost, vehicle cost, and infrastructure cost. The model results show that the fuel cost is the highest amongst three components. The maintenance cost of the vehicles is not considered in the model. The electrification scenarios have a higher overall cost compared to the BAU conditions due to higher fuel and vehicle costs. The fuel cost is high as the cost of electricity is highest followed by cost of gasoline. The vehicle cost is high as the cost of HEV and BEV are considered 1.26 and 2 times higher than the conventional counter parts. For the year 2030, amongst all the electrification scenarios HPS scenario has the lowest cost of xEVs introduction at US$269 billion. For the years 2015 to 2030, the HPS scenario has the lowest cost of xEVs introduction.

Table 2.10. Overall Cost of xEVs Introduction for 2030 and Cumulative from 2015 to 2030 (in US$ billion)

Cost Component	2030						2015-2030					
	BAU	**AFS**	**AES**	**MES**	**HPS**	**OES**	**BAU**	**AFS**	**AES**	**MES**	**HPS**	**OES**
Fuel cost	156	152	163	162	161	167	1,798	1,775	1,813	1,811	1,807	1,836
Vehicle cost	93	95	127	116	103	124	1,060	1,084	1,201	1,169	1,145	1,188
Infrastructure cost of stations	-	-	9	4	4	9	1	1	38	19	20	38
Total	**249**	**248**	**299**	**283**	**269**	**300**	**2,858**	**2,859**	**3,052**	**3,000**	**2,971**	**3,062**

BAU = Business as Usual, AFS = Alternative Fuels Scenario, AES = Aggressive Electrification Scenario, MES = Moderate Electrification Scenario, HPS = Moderate Electrification cum Hybrid Promotion Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

2.5. Discussion

The six different scenarios illustrate how the implementation of xEVs affect CO_2 emissions. Even with aggressive EV adoption the well-to-wheel CO_2 emission levels are higher than the BAU scenario, implying that with the existing electricity generation mix, EVs alone cannot bring down the emission levels. Although the electrification scenarios show reduction in tank-to-wheel CO_2 emissions, indicating if additional electricity demand for EV is met through electricity generated from renewables, it would result in CO_2 emissions reduction. It is important to mention that in India, HCVs, LCVs, and buses, account for about 70% of energy consumption in the transport sector, however, in this study xEVs penetration is assumed mostly in the segment of two-wheelers, three-wheelers, cars, and taxis and a very limited level in buses. Therefore, scenarios assuming aggressive xEVs penetration do not reflect a major reduction in energy demand. However, this will have an impact on reducing the air pollution levels, especially in major cities. The electrification scenarios will have an influence on emissions levels when the power is generated from renewable sources.

It is worthwhile to note that the existing installed capacity in India's power sector is much higher than the peak demand. According to recent information furnished by the Central Electricity Authority (Ministry of Power, Government of India) in April 2019, India saw a maximum peak demand of 177 gigawatts (GW) on 29 April 2019, which was less than the installed capacity of around 356 GW. Further, the government is aggressively pursuing the renewable energy agenda by increasing the solar power generation capacity in the country. However, given this surplus power situation in India as a whole, there have been numerous instances in the recent past wherein the state electricity regulatory commissions are now issuing orders to the state distribution companies operating under the aegis of the state governments to stop procuring and/or bidding solar power due to regulatory, financial, and technical issues. Thus, for additional power generation from renewables to happen and for solar power plant generators to find off takers for the electricity generated by their plants, there is a need to increase the demand of electricity. Electric vehicles provide such an opportunity wherein the solar power will be used to power EVs.

2.6. Summary as Policy Recommendations

The study demonstrates that electrification scenarios alone do not have much effect in reducing the CO_2 emissions levels. The use of alternative fuels such as CNG and biofuels will play a crucial role as the CO_2 emissions levels are highest for HCV and buses. The electrification of HCV and buses will be a major challenge as they operate for longer distances. The battery size required for these vehicles is demanding and dedicated efforts are required to develop charging infrastructure along important routes and highways to quell the range anxiety. Their transition towards cleaner fuel along with improved fuel efficiency will strengthen the impact of xEVs introduction for emissions reduction. The policy strategy should consider both electrification as well as alternative fuels at the same platform to boost its impact. Thus, it is also pertinent that the government starts to implement the National Policy on Biofuels, which was approved in 2018. This action will go a long way to support the decarbonisation of India's transport sector.

The cost of implementing xEVs depends on the fuel cost, vehicle cost, and infrastructure cost. It is evident from the model results that the infrastructure cost when compared to the other two costs is quite low. However, the infrastructure development should account for the availability of parking space for charging stations within city limits as the majority of the metropolitan cities face parking space constraints. The charging time also makes a significant difference as even the fast charging stations require a minimum of 20 minutes to attain full charge, which is more than the time taken in traditional fuel stations. This in turn adds to the infrastructure cost in terms of land required. The vehicle and fuel costs determine the effectiveness of xEV introduction.

The present cost of xEVs are at the higher end, which makes it difficult for the end user to consider it as a viable option. The policy outline should consider both manufacturer and end user needs and bring about necessary incentives that are mutually beneficial. Among all the electrification scenarios it is seen that AES and HPS have the maximum impact in terms of CO_2 emissions reduction (tank-to-wheel) and low costs of implementation. A combination of these two scenarios would have bring about a sizeable impact of xEVs introduction. The major cost component in the electric vehicles is the cost of batteries. The policy strategy must include a more favourable outline towards the battery manufacturing companies. The policy approach must take an aggressive stance towards xEVs implementation along with alternative fuel promotion to see a significant reduction in CO_2 emissions levels.

The government has been undertaking various measures to boost electric car sales in the country. In 2019, the government approved a budget of 100 billion INR for the second phase of Faster Adoption and Manufacturing of Electric vehicles (FAME), which has been implemented in the country from 1 April 2019. The subsidy on xEVs is applicable to commercial vehicles, public transport vehicles, and two-wheelers. The FAME 2 scheme is applicable for a period of 3 years from 2019 to 2022. Around Rs1,000 crore has been earmarked for setting up charging stations for electric vehicles in India. The government will offer incentives for electric buses, three-wheelers, and four-wheelers to be used for commercial purposes. Plug-in electric hybrid vehicles and those with a sizeable lithiumion battery and electric motor will also be included in the scheme and fiscal support offered depending on the size of the battery. Accordingly, it is advised that the current FAME project is sustained and improved on to make xEVs affordable for the manufacturers and consumers for CO_2 emissions reduction.

In comparison to internal combustion engine vehicles, there is not a wide array of electric vehicles in India. The Indian electric vehicle sector is nascent, and there are few companies that manufacture xEVs locally. This also limits the ability of consumers to make choices from a variety of options. It is expected that as the xEV market grows in India, there will be more manufacturers, which also brings about competition and, in turn, reduces the price of xEVs. Therefore, it is important for the government to provide the enabling environment for the private sector to drive the local production of xEVs and to also attract foreign investors into India's vehicle market.

India's power generation sector is presently dominated by coal. Thus, the introduction of xEVs will be effective only when supported by alternative fuel implementation to replace gasoline and diesel. The use of CNG and biofuels will be an important factor in reducing the CO_2 emissions and can be practically implemented by focusing on availability and affordability of these fuels. The overall xEVs and alternative fuel policy is effective only with deep decarbonisation of the power sector. The electrification scenarios are effective only when the necessary incremental power is supplied from renewable sources. The use of clean energy source for electricity generation will bring about the required CO_2 emissions reduction. The effectiveness of xEVs introduction is also linked to the source of electricity generation thus tying it with the power sector. Therefore, the policy requires a comprehensive mixture of all key components that have an impact on the effectiveness of xEVs and alternative fuel introduction to reduce the CO_2 emissions levels.

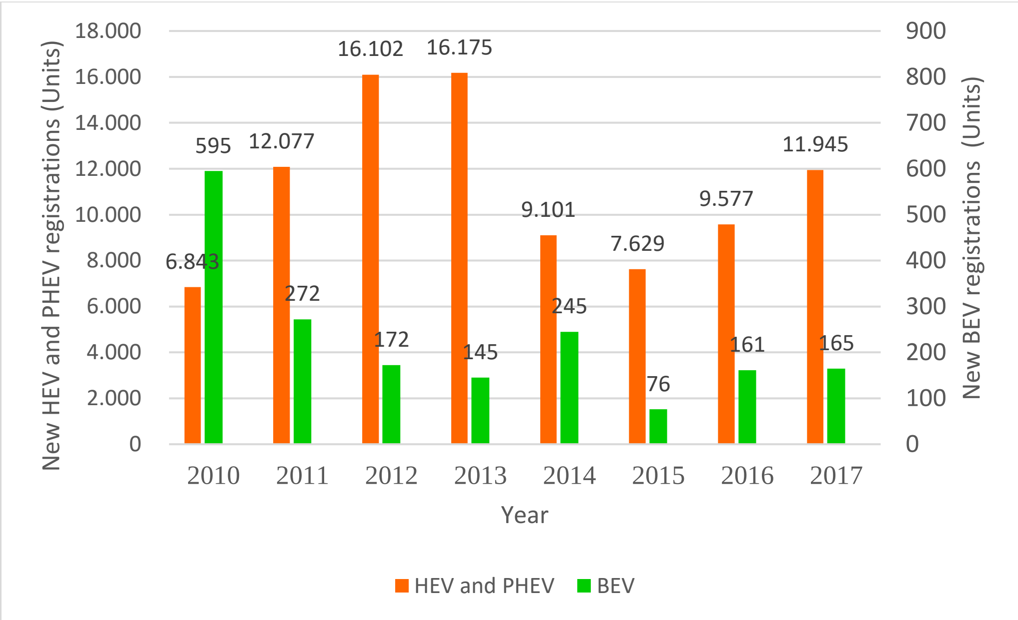
The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. Under the original plan, the government aimed to achieve a total installed solar capacity of 20 GW by 2022. This was proposed to be achieved in three phases. The first phase comprised the period from 2010 to 2013, the first year of the 12th five-year plan. The second phase extended up to 2017, whilst the third phase would have been the 13th five-year plan (2017–22). Targets were set as 1.4 GW in the first phase, 11–15 GW by the end of the second phase, and 22 GW by the end of the third phase in 2022. Consequently, sustained efforts are needed to achieve the National Solar Mission as this will go a long way to decarbonise India's power sector and thus, reduces the overall CO_2 footprint of xEVs introduction.

3. Electrified Vehicles (xEV) Mix Scenario Study for Thailand

3.1. Government Policies

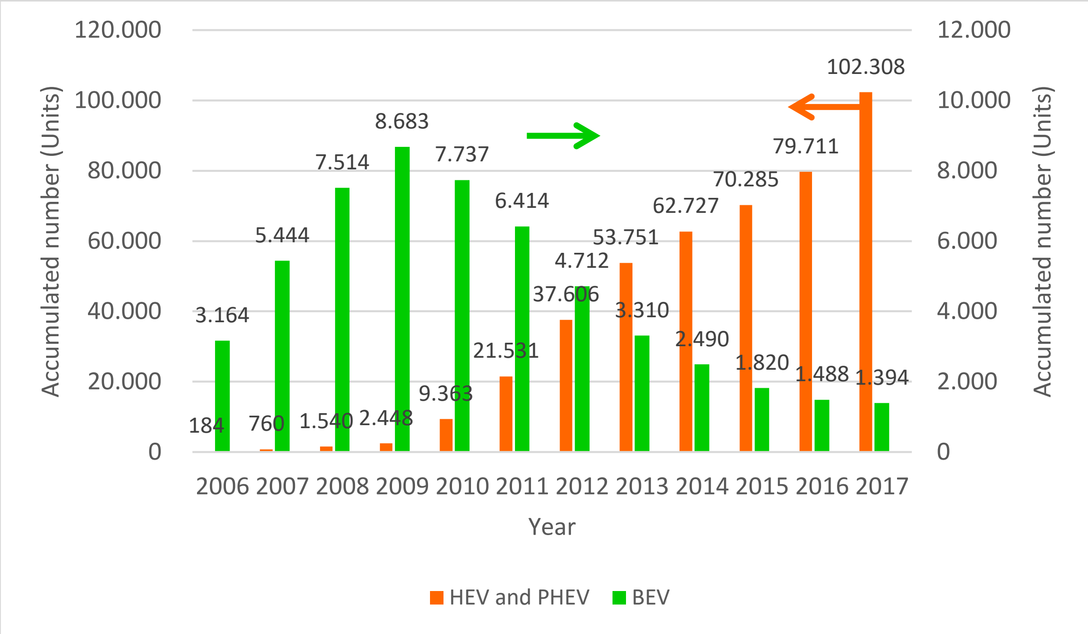
The introduction of electrified vehicles (xEVs) in Thailand has served to both improve vehicle fuel economy and air quality. However, the definite figure of xEVs is unclear because the official vehicle registration system from the Department of Land Transport does not distinguish between hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV) at present. For new vehicle registrations during 2010–2017, Figure 2.15 shows that new HEV and PHEV sales were in the order of 10,000 units (mostly HEV), whilst battery electric vehicles (BEV) were in the order of several hundreds. For accumulative vehicle registrations from 2006 to 2017, HEV and PHEV were around 100,000 units in 2017, whilst BEV were still about 1,400 units, as shown in Figure 2.16. When considering BEV, Figure 2.17 shows that the majority are electric motorcycles, which have dramatically decreased in terms of new BEV registrations, as shown in Figure 2.15. In other words, electric motorcycles appear to have lost attraction amongst Thai customers. This is partly because of the perceived inferior performance of electric motorcycles, such as maximum speed, driving distance per refuelling, and refuelling time, compared to gasoline motorcycles of similar price, the riding behaviour of Thai motorcyclists who claim to need the higher speeds provided by gasoline motorcycles, and the poor battery performance after 2 years of use (EGAT–NSTDA, 2016). As a result, the current Energy Efficiency Plan 2015–2036 (EPPO, 2015) excludes electric motorcycles, and has put emphasis on electric passenger cars instead.

Figure 2.15. Statistics of New xEV Registrations in Thailand



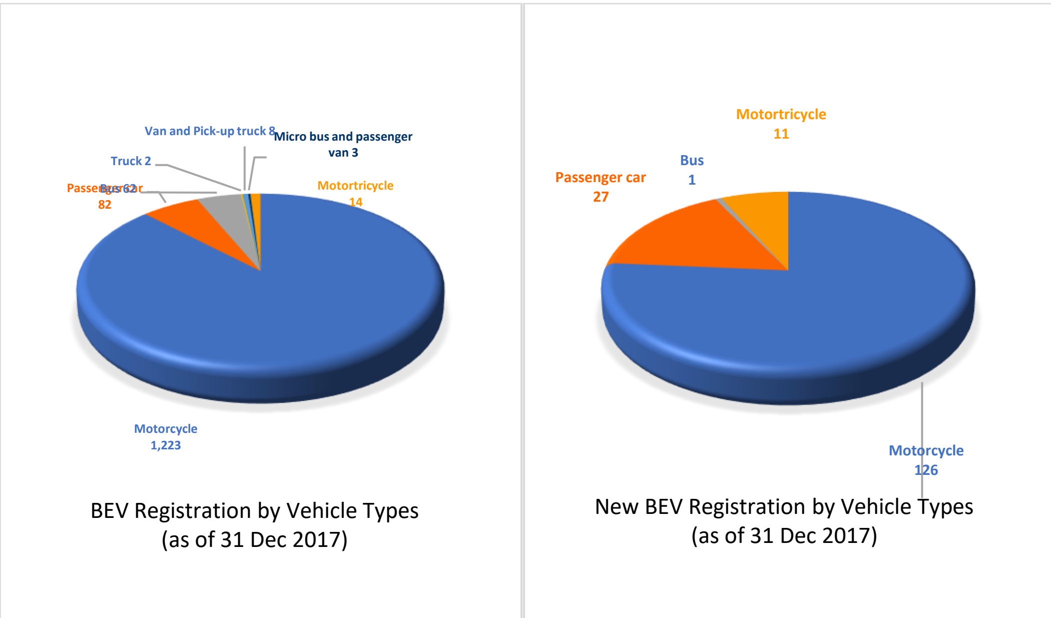
BEV = battery electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Collected by Electric Vehicle Association of Thailand from data of the Department of Land Transport. https://web.dlt.go.th/statistics/

Figure 2.16. Statistics of Accumulative xEV Registrations in Thailand



BEV = battery electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Collected by Electric Vehicle Association of Thailand from data of the Department of Land Transport. https://web.dlt.go.th/statistics/

Figure 2.17. Breakdown of New and Accumulative xEV Registrations by Vehicle Type in Thailand



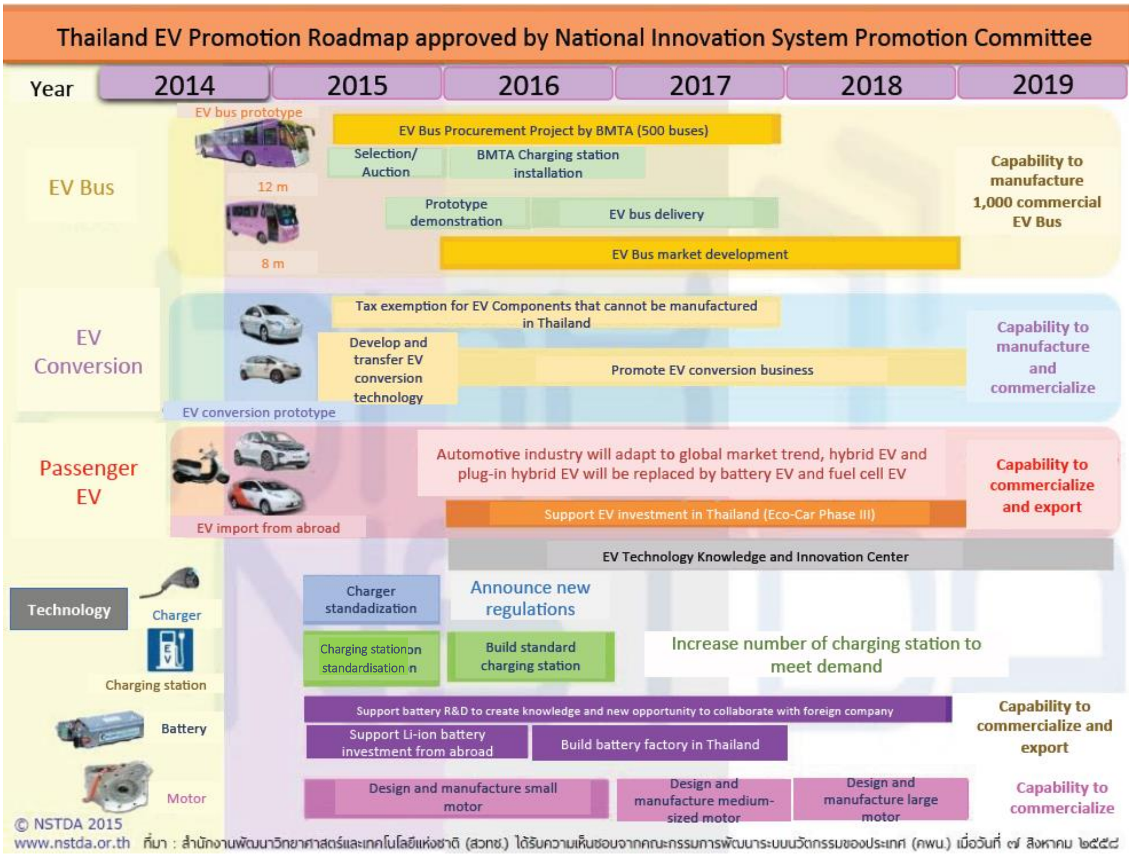
BEV = battery electric vehicle, xEV = electrified vehicle
Source: Collected by Electric Vehicle Association of Thailand from data of the Department of Land Transport. https://web.dlt.go.th/statistics/

Since 2015, Thailand has actively promoted the introduction and production of electric vehicles. First, the National Innovation System Promotion Committee, chaired by the Prime Minister, approved Thailand's EV Promotion Roadmap on 7 August 2015. This roadmap establishes subsidies for the production of three EV products: EV buses, retrofitted EVs, and passenger EVs, as well as EV components, such as EV chargers, batteries and motors, as shown in Figure 2.18. The roadmap further adopted the target of 1.2 million EVs on the road by 2036, in order to improve energy efficiency in the transport sector. In 2016, the National Science and Technology Development Agency under the Ministry of Science and Technology published a Research and Development (R&D) Action Plan to support the EV industry in Thailand, with a particular R&D focus on batteries and battery management systems, motors and drivetrains, as well as on lightweight structures and assembly, as shown in Figure 2.19. As a follow up to the Energy Efficiency Plan: 2015–2036 (EPPO, 2015), EPPO announced an EV Action Plan, as shown in Figure 2.20 to promote EVs in three phases of preparation.

- Phase 1 (2016–2017) aims to demonstrate existing EV technology from abroad and raise public awareness.
- Phase 2 (2018–2020) with intense R&D aims to initiate domestic research and development of EVs with supporting mechanisms for the private investor.
- Phase 3 (2021–2036) for expansion aims to scale up EV utilisation commercially).

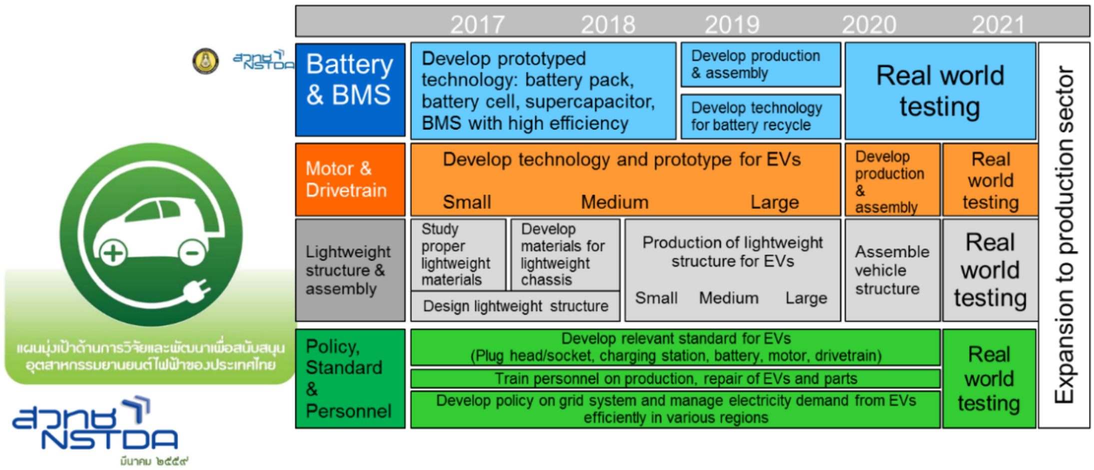
Recently, two funding agencies, the Energy Conservation Fund and the National Research Council of Thailand have dedicated a research budget for EVs and for energy storage for EVs.

Figure 2.18. Thailand's EV Promotion Roadmap



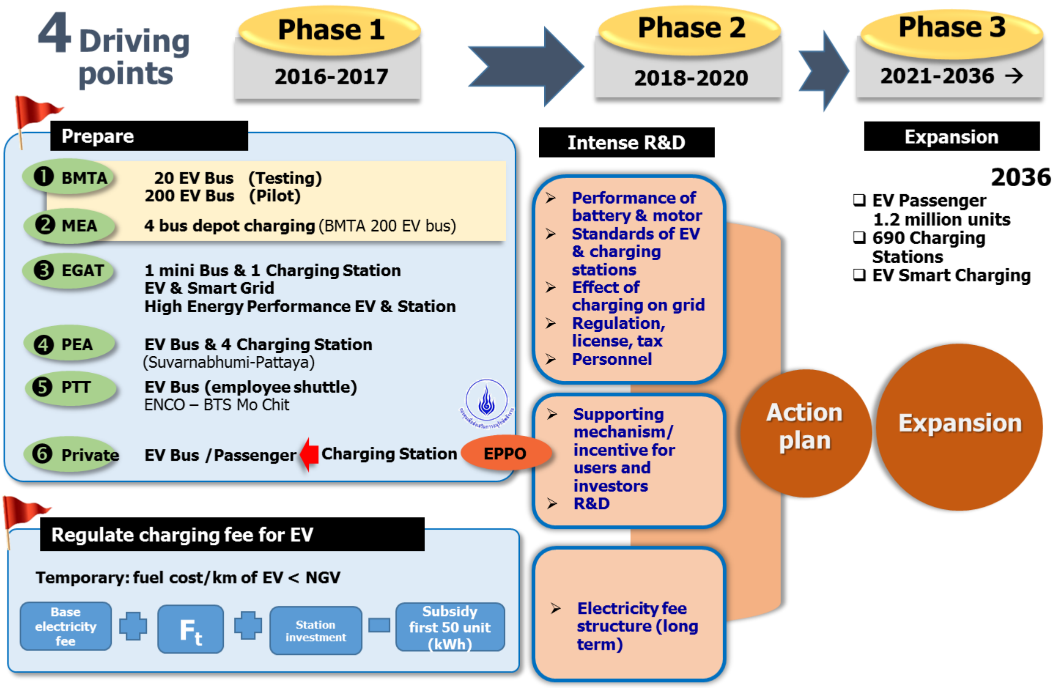
BMTA = Bangkok Mass Transit Authority, EV = electric vehicle.
Source: National Science and Technology Development Agency (2015). https://www.nstda.or.th/th/nstda-r-and-d/561-electronic-vehicle

Figure 2.19. R&D Action Plan to Support EV Industry in Thailand



BMS = battery management system, EV = electric vehicle, R&D = research and development.
Source: National Science and Technology Development Agency (2015). https://www.nstda.or.th/th/nstda-r-and-d/561-electronic-vehicle

Figure 2.20. Thailand's EV Action Plan

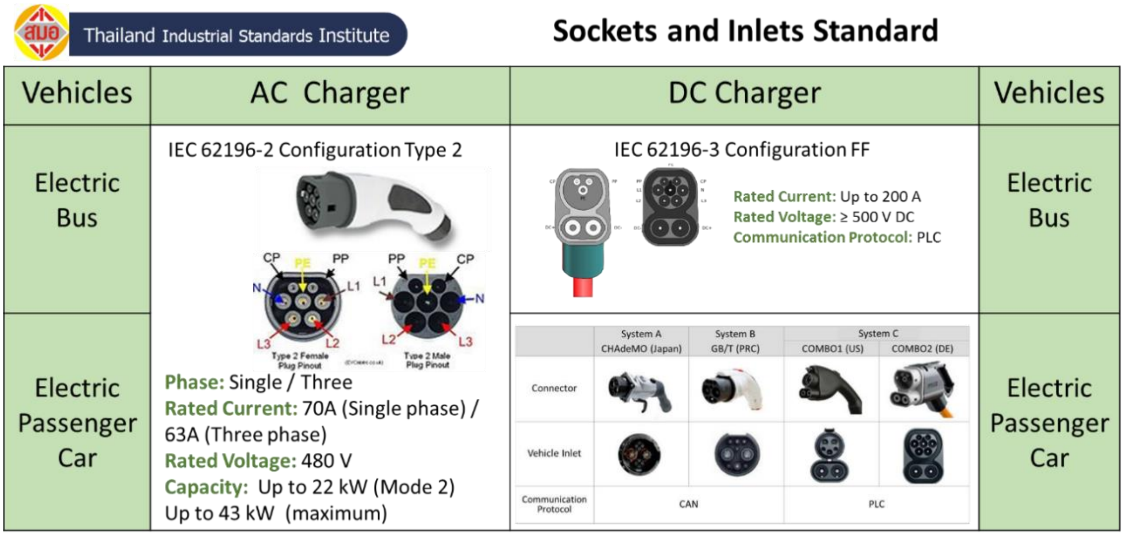


BMTA = Bangkok Mass Transit Authority EV = electric vehicle, NGV = natural gas vehicle
Source: National Science and Technology Development Agency (2015). https://www.nstda.or.th/th/nstda-r-and-d/561-electronic-vehicle

Together with actual EVs, the necessary infrastructure needs to be established to further support EV introduction to the market. Hence, the Thai Industrial Standards Institute has been preparing for related national standards, which may be adopted from other international standards such as the International Electro-technical Commission.

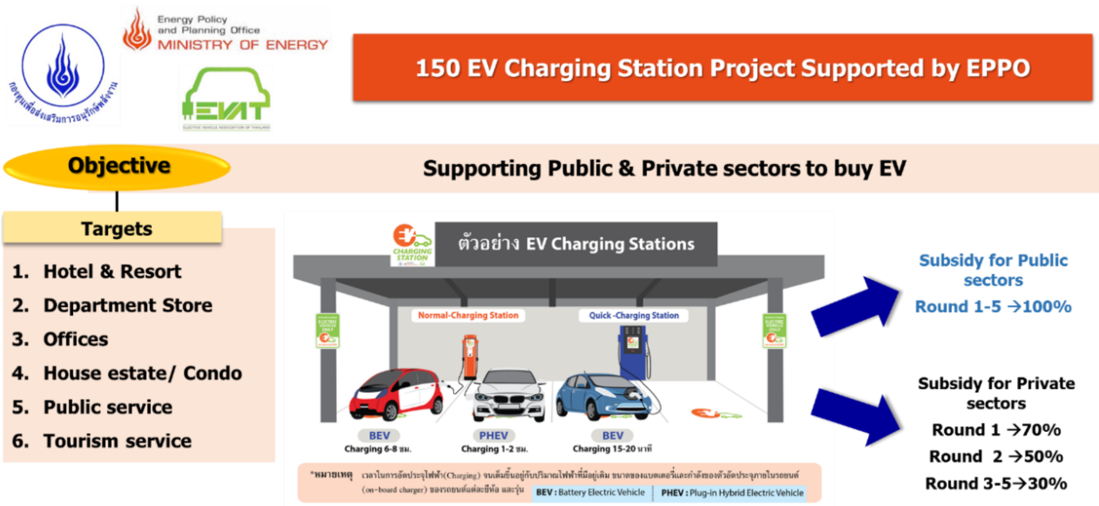
Figure 2.21 shows the Thai standard for EV charging protocol on both normal and quick charges for passenger car and bus. In addition, EPPO has contracted the Electric Vehicle Association of Thailand to conduct a charging station subsidy programme (EVAT, 2018). As shown in Figure 2.22 and Table 2.11, the objective is to subsidise the installation of 100 EV chargers, some to be installed by government organisations, and others by private sector partners with varying levels of support.

Figure 2.21. EV Charging Standard (socket and inlet) in Thailand



AC = alternating current, DC = direct current, EV = electric vehicle, kW = kilowatt, V = volt.
Source: Thailand Industrial Standards Institute.

Figure 2.22. EV Charging Station Subsidy Programme



EPP = Energy Policy and Planning Office, EV = electric vehicle.
Source: Ministry of Energy, Thailand.

Table 2.11. Number of EV Charging Stations in Thailand (as of 11 August 2020)

Service providers	No. of Locations	AC: Normal Chargers	DC: Fast Chargers	Total Chargers
Energy Mahanakorn Co., Ltd.	395	1,022	537*	1,559
EVAT (Electric Vehicle Association of Thailand)**	68	48	32	80
PTT	25	33	0	33
ChargeNow	16	38	1	39
MEA (Metropolitan Electricity Authority)	13	7	9	16
PEA (Provincial Electricity Authority)	11	13	13	26
EGAT (Electricity Generating Authority of Thailand)	10	11	12	33
Chosen Energy Co., Ltd	7	12	0	12
EVolt Technology Co., Ltd.	6	18	0	18
PumpCharge	6	10	2	12
Total	557	1,212	606	1,818

* Chargers have been installed and will be opened soon.
** EVAT has been implementing a subsidy scheme under the Ministry of Energy.
EV = electric vehicle, AC = alternating current, DC = direct current.
Source: Adapted from EVAT (2020), http://www.evat.or.th/attachments/view/?attach_id=242667

Recently, EV is further promoted by recourse to the 2017 revision of the CO_2-based excise tax originally enforced in 2016, as shown in Table 2.12, to lower the excise tax rate for a range of xEVs including hybrid pickups. Thailand's Board of Investment (BOI) rolled out a stimulus package to promote investment in EVs, as shown in Figure 2.23, with fiscal incentives given to various kinds of electric vehicles, as well as EV-associated products such as charging stations (BOI, 2018).

Table 2.12. Revised Excise Tax Rate Table for Automobiles to Promote EV Investment

Current excise tax with BOI

Passenger car – Internal combustion engine (ICE)

Vehicle type	Engine size (cm^3)	Powertrain	Fuel used	Clean – Eco [CO_2 emission, g/km]	Safety certificated: R13H w/ABS&ESC	Safety certificated: R94	Safety certificated: R95	Excise tax rate (%)
Passenger car	≤ 3,000	Gasoline/ Diesel/NGV	E10/E20/Diesel	≤ 150	✓			25
			E85/NGV					20
			E10/E20/Diesel	151-200				30
			E85/NGV					25
			E10/E20/Diesel	> 200				35
			E85/NGV					30
	> 3,000	Gasoline/ Diesel/NGV						40
ECO Car 1	≤ 1,300	Gasoline	E10/E20/E85	≤ 120		✓	✓	14
	≤ 1,400	Diesel	B5/B10					14
ECO Car 2	≤ 1,300	Gasoline	E10/E20	≤ 100	✓	✓	✓	12
			E85					10
	≤ 1,500	Diesel	B5					12
			B10					10
PPV – Pickup based Passenger Vehicle	≤ 3,250	Gasoline/Diesel		≤ 200	✓			20
				> 200				25
	> 3,250	Gasoline/Diesel						40

CAR

Pickup truck – Internal combustion engine (ICE)

Vehicle type	Engine size (cm^3)	Powertrain	Fuel used	Clean – Eco [CO_2 emission, g/km]	Safety certificated: R13H w/ABS&ESC	Safety certificated: R94	Safety certificated: R95	Excise tax rate (%)
No Cab	≤ 3,250	Gasoline/Diesel		≤ 200				2.5
				> 201				4
Space Cab	≤ 3,250	Gasoline/Diesel		≤ 200				4
				> 200				6
Double Cab	≤ 3,250	Gasoline/Diesel		≤ 200				10
				> 200				13
	> 3,250	Gasoline/Diesel						40

Pickup truck

Electric motor driven vehicles (Electrified vehicle, xEV)

BOI

Vehicle type	Engine size (cm^3)	Powertrain	Investment supported measure (BOI)	Clean – Eco [CO_2 emission, g/km]	Safety certificated: R13H w/ABS&ESC	Safety certificated: R94	Safety certificated: R95	Excise tax rate (%)
Passenger car	≤ 3,000	HEV		≤ 100	✓			8
			BOI					4 (until 2025)
				101-150				16
			BOI					8 (until 2025)
				151-200				21
			BOI					10.5 (until 2025)
				> 200				26
			BOI					13 (until 2025)
	> 3,000	HEV						40
Double cab	≤ 3,250	HEV		≤ 175	✓			8
PPV (Pickup passenger vehicle)	≤ 3,250	HEV		≤ 175	✓			18
Passenger car BEV								8
			BOI					2 (until 2025)
Passenger car Fuel Cell EV (FcEV)								8
Pickup BEV								10

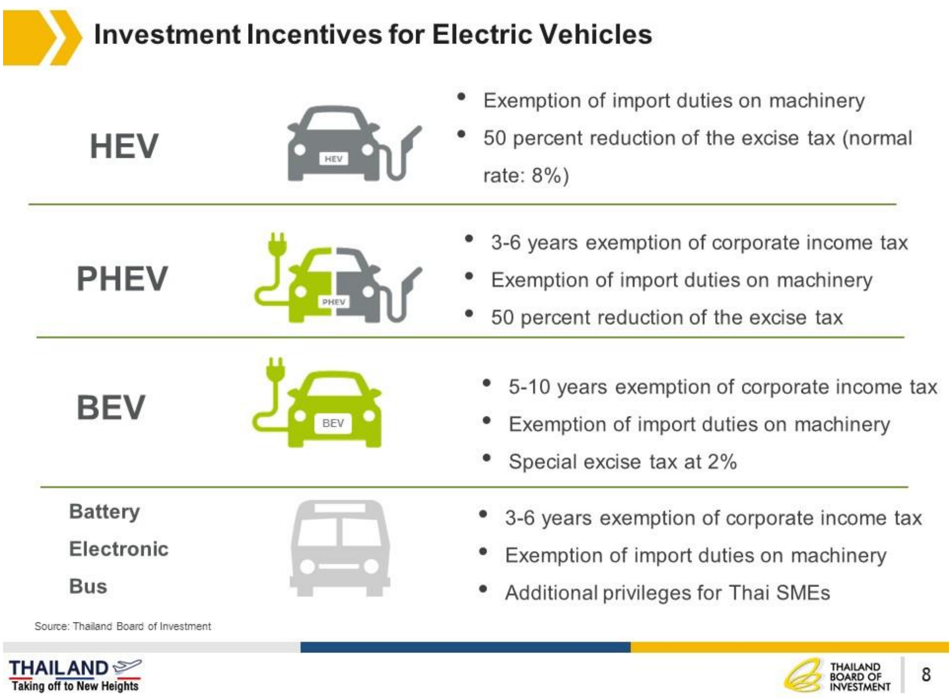
CAR - xEVs

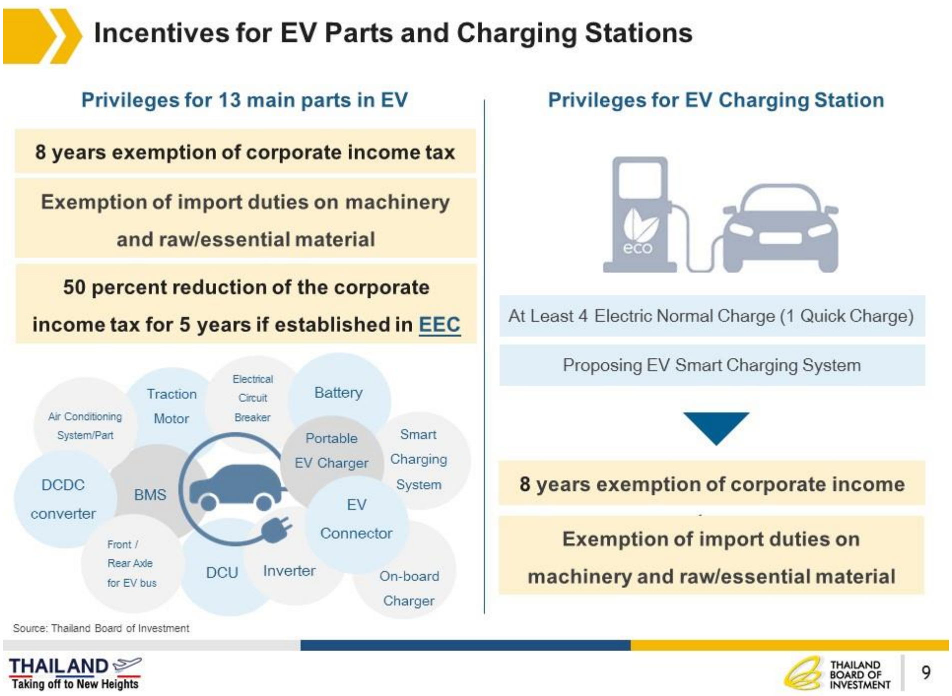
Implementation on 16 September 2017, http://car.go.th/new/Excisecar#collapse-Two

BOI = Board of Investment.

Source: Thailand Automotive Institute. http://www.thaiauto.or.th/2012/news/news-detail.asp?news_id=3198

Figure 2.23. Fiscal Incentives for Investment in xEVs in Thailand





BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, SMEs = small and medium-sized enterprises, xEV = electrified vehicle.
Source: Thailand Board of Investment.

3.2. Parameters and Figures used for Scenario Simulation

Prior to running simulation based on different scenario, various parameters need to be defined as follows:

Vehicle Cost

Vehicle statistics, including new sales volume and average price, were classified into different categories, as shown in Table 2.13, in order to estimate the true vehicle price without taxation (GIZ, 2018). Since the CO_2-based excise tax scheme was enforced in 2016, the weighted-average price of a normal internal combustion engine (ICE) passenger vehicle was estimated to be THB0.669 million. Hence, the relative prices for HEVs, PHEVs, and BEVs can be estimated. Furthermore, opportunity cost to the government from giving lower excise tax rates can be estimated in Table 2.14.

Table 2.13. Vehicle Statistics in Thailand (a) with xEV Price Assumption (b)

(a) Vehicle types	Sale volume (unit)				Average price (฿ million)				Tax	Average ex-factory price (฿ million)
	2014	2015	2016	2017	2014	2015	2016	2017	[%]	2016–2017
1.Eco car	118,519	106,836	114,095	156,234	0.53	0.57	0.58	0.59	14.0	0.513
2.City car, subcompact	167,522	98,457	76,447	86,200	0.52	0.47	0.71	0.71	20.0	0.590
3.Compact car C-segment	67,623	41,205	47,820	53,797	0.79	0.80	1.04	1.04	20.0	0.867
4.D-segment: Full-size sedan	19,343	16,407	12,312	9,118	1.49	1.54	1.52	1.53	25.0	1.219
5.Mini-MPV and B-SUV	34,926	43,899	39,417	40,293	0.77	0.97	0.93	0.92	25.0	0.740
6.SUV and MPV	19,101	22,149	13,790	22,974	1.45	1.31	1.37	1.46	25.0	1.141
										0.669

(b) Price for simulation	(%)	฿
ICE	100	668,853
HEV	126	842,755
PHEV	156	1,043,411
BEV	200	1,337,706

BEV = battery electric vehicle, HEV= hybrid electric vehicle, ICE = internal combustion engine, MPV = multi-purpose vehicle, PHEV = plug-in hybrid electric vehicle, SUV = sport utility vehicle, xEV = electrified vehicle.
Source: Authors.

Table 2.14. Opportunity Cost to the Government from Lower Excise Tax for xEV

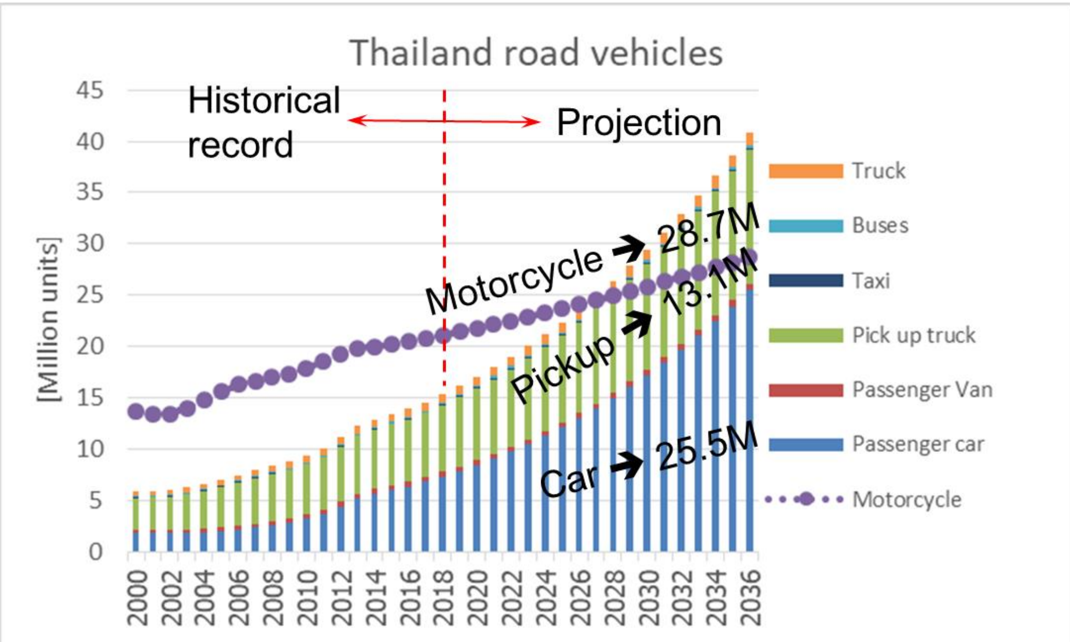
(c) Vehicle type	%	Ex-factory	Tax %	Tax (฿)	Owner price (฿)	ΔTax (฿)
ICE	100	668,853	-	130,847	799,701	0
HEV	126	842,755	4	33,710	876,465	-97,137
PHEV	156	1,043,411	4	41,736	1,085,148	-89,111
BEV	200	1,337,706	2	26,754	1,364,461	-104,093

BEV = battery electric vehicle, HEV= hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

Vehicle Stock Number Projection

By recourse to the vehicle ownership model based on logistics function (with saturation level), logarithmic function of level of economic activity and logarithmic function with time, the calculated vehicle numbers are well-fitted with historical records back to 1999 (Saisirirat and Chollacoop, 2017). Hence, vehicle stock numbers are forecast in Figure 2.24.

Figure 2.24. Vehicle Stock Numbers Projection



M = million.
Source: Authors.

Vehicle Kilometres Travelled

Another important parameter is vehicle kilometres travelled (VKT), which will reference the most recent study, as shown in Table 2.15 (OTP, 2017).

Table 2.15. Vehicle Kilometres Travelled Used in the Model

VKT (kilometre)	
Car	20,230.0
Van	24,742.0
Pickup two doors	24,270.0
Motorcycle	17,820.0
Three-wheeler (Tuk Tuk)	34,604.9
Taxi	72,154.0
Fixed route bus	36,819.4
Non-fixed route bus	41,296.9
Truck	33,047.1

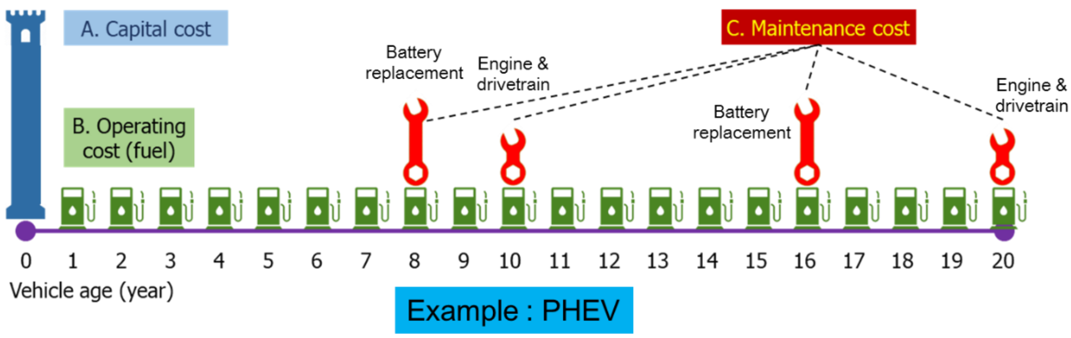
VKT = vehicle kilometres travelled.
Source: Authors.

Total Cost of Ownership Calculation

The total cost of ownership for various vehicles will be estimated based on the following assumptions:

- Vehicle lifetime is 20 years, as shown in Figure 2.25.
- Real discount rate is 5.21%, which is estimated from modified internal rate of return and inflation rate
- Vehicle cost follows Table 2.14, as shown in Table 2.16
- Operating cost from fuel consumption and VKT, as shown in Table 2.17
- Cost of various fuel/energy options, as shown in Table 2.18
- Cost of battery, as shown in Table 2.19
- Cost of EV fast charger is US$58,500 per 10 BEVs

Figure 2.25. Overall Scheme for Estimating Total Cost of Ownership



PHEV = plug-in hybrid electric vehicle.
Source: Authors.

Table 2.16. Total Cost of Ownership, Details in Capital Cost

GIZ study for Sedan	[%]	Ex-factory	Tax [%]	Tax [THB]	Owner price [THB]	ΔTax [THB]
ICE	100	668,853	-	130,847	799,701	0
HEV	126	842,755	4	33,710	876,465	-97,137
PHEV	156	1,043,411	4	41,736	1,085,148	-89,111
BEV	200	1,337,706	2	26,754	1,364,461	-104,093

GIZ Study Pickup truck	Sale volume [unit] 2016	Sale volume [unit] 2017	Average price [THB]
7.PPV	60,683	59,576	1,510,279
8.Single cab (1.0 Cab)	48,127	44,485	561,941
9.Extra cab (1.5 Cab)	176,758	186,727	725,710
10.4 doors pickup (2.0 Cab)	108,602	157,299	910,179
Average			877,961

BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, PPV = Pickup based passenger vehicles.
Source: Authors.

Table 2.17. Total Cost of Ownership, Details in Operation Cost

Properties for sedan			Properties for pickup based vehicles		
VKT (km)		20,000	VKT (km)		24,000
FE (L/100km)	ICE SI	6.75	FE (L/100km)	ICE Diesel	7.08
	Gasohol E20*	6.98		Biodiesel B7^	7.13
	Gasohol E85*	8.97		B10^	7.15
	HEV	4.74		B20^	7.22
	PHEV	3.22	^Biodiesel has lower fuel economy and power		
	[ULG:Elec.]	[68%:32%]	(10% lower for B100 and 2% for B20)		
	BEV	1.92			
*Equivalent energy consumption					

BEV = battery electric vehicle, PHEV = plug-in hybrid electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, FE = fuel economy, VKT = vehicle kilometres travelled.
Source: Authors.

Table 2.18. Total Cost of Ownership, Details in Fuel/Energy Cost

Fuel price (THB/liter)

UNIT:BAHT/LITRE 24-Apr-19	EX-REFIN. (AVG)	WHOLESALE PRICE(WS)	VAT	WS&VAT	MARKETING MARGIN	VAT	RETAIL	
GASOHOL95 E10	17.8472	26.5022	1.8552	28.3573	1.6754	0.1173	30.15	Baseline gasoline price
GASOHOL91	17.4408	26.0958	1.8267	27.9225	1.8295	0.1281	29.88	
GASOHOL95 E20	18.2991	23.3391	1.6337	24.9725	2.0254	0.1418	27.14	E20
GASOHOL95 E85	20.8301	15.6226	1.0936	16.7162	4.3213	0.3025	21.34	E85
H-DIESEL	17.5907	24.4687	1.7128	26.1815	1.8771	0.1314	28.19	

http://www.eppo.go.th

[BAHT/LITRE]	EX-REFINE						RETAIL	
Diesel	17.41							
B7	17.59	24.4687	1.7128	26.1815	1.8771	0.1314	28.19	Baseline diesel price
B10	17.67	estimated in this work					28.27	
B20	17.92						28.52	
Biodiesel (B100)	19.93							

Time of use tariff (TOU) Cost for charging xEV (THB)	Energy charge (THB/kWh) On peak	Energy charge (THB/kWh) Off peak	Service charge (THB/month)
1.3.1: 12 – 24 kV	5.1135	2.6037	312.24
1.3.2: Below 24 kV	5.7982	2.6369	38.22

kWh = kilowatt hour, xEV= electrified vehicle.
Source: Authors.

Table 2.19. Total Cost of Ownership, Details in Battery Cost Assumption

Sedan		Conventional car	E85 car	HEV car	PHEV car	EV car	Note
10 years maintenance (Engine & Gearbox)		50,000	50,000	50,000	50,000	-	
8 years maintenance* **(Major maintenance cost of EV is battery replacement)**				For 1.625 kWh	For 13.4 kWh	For 40 kWh	
Cost of battery change							[THB/kWh]
Nissan LEAF	**@2017**			13,996	115,413	344,516	209.00
Toyota Axio HV	**@2020**			11,890	98,050	292,686	168.13
	@2025			8,381	69.112	206,304	100.00
	@2030			8,381	69,112	206,304	100.00
	@2035	Note: Constant after 2025		8,381	69,112	206,304	100.00

EV = electric vehicle, HEV = hybrid electric vehicle, kWh = kilowatt hour, PHEV = plug-in hybrid electric vehicle.
Source: Authors.

3.3. Scenarios

The following five scenarios were subjected to simulation with the BAU scenario (baseline) as a reference.

BAU Scenario (baseline)

Refer to the current trend of the road transport system plus the success of Thailand's biofuel policy including:

- Gasohol E20 and biodiesel B10 can successfully announced, namely ethanol share shift to gasohol E15 and biodiesel B7.6 for commercial grade diesel
- 1,800 hybrid buses will be purchased (BMTA, 2018)

Alternative Energy (AE) Scenario

- Gasohol E20 will succeed in the market. Ethanol demand will achieve 7.5 million L/d in 2037
- Biodiesel B10 will succeed in the market. Biodiesel demand will achieve 8 million L/day in 2037

Plug-in xEVs Expansion (1.2 million xEVs) Scenario

- On-road plug-in xEVs (PHEV:BEV = 50:50) achieve 1.2 million units by 2036

Hybrid Expansion Scenario

- **HEV BOI Promotion**: total HEVs sale achieve 320,000 units by 2023, 5 years after the investment plan commitment to BOI in 2018 (Prachachart, 2018), and 4.7 million units in 2036
- **HEV Extreme**: HEVs dominate 50% sale of passenger cars (gasoline originated) by 2036, noted 7.1 million on-road HEVs in 2036

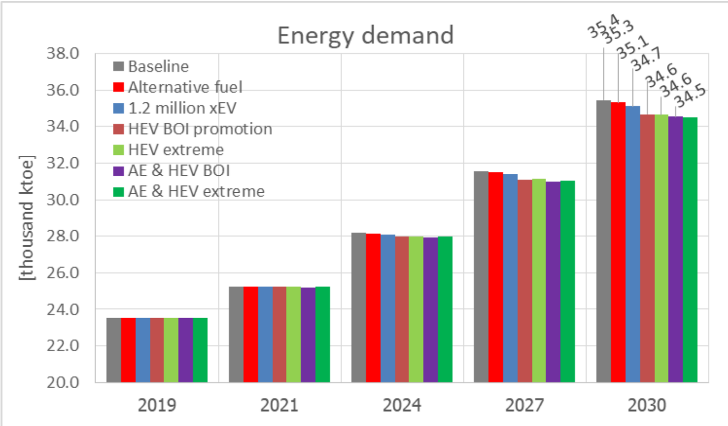
Combination Scenarios

- Consider combination of Alternative Fuels and HEV BOI promotion (noted AE & HEV BOI)
- Consider combination of Alternative Fuels and extreme HEV expansion (noted AE & HEV Extreme)

3.4. Study Results (Oil consumption, CO_2 emissions, and cost of implementation)

The simulation results from six scenarios: the alternative energy scenario, 1.2 million xEVs scenario, HEV BOI scenario, HEV Extreme scenario, combination AE & HEV BOI scenario and combination AE & HEV Extreme scenario together with BAU scenario (Baseline) as a reference, are shown in Figure 2.26, Figure 2.27, Figure 2.28, Figure 2.29, and Figure 2.30 for non-economic parameters, and Figure 2.31, Figure 2.32, Figure 2.33, Figure 2.34, Figure 2.35, Figure 2.38, and Figure 2.39 for economic parameters, respectively.

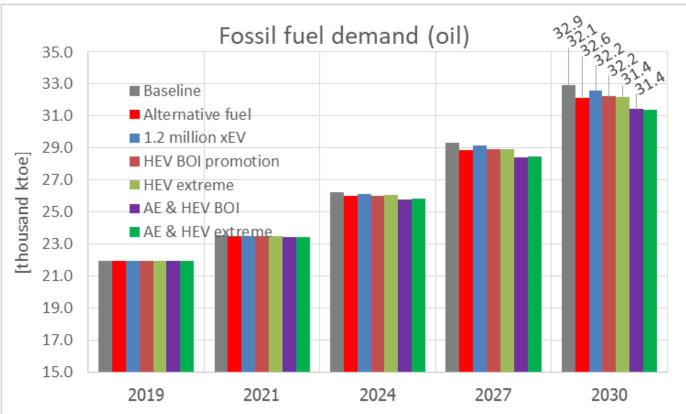
Figure 2.26. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Energy Demand Reduction



Energy demand reduction @2030 [x10³ ktoe]			
A	Alternative Energy (AE)	0.13	0.36%
B	1.2M xEVs	0.31	0.88%
C1	HEV BOI	0.77	2.16%
C2	HEV extreme	0.80	2.26%
D1	AE & HEV BOI	0.89	2.52%
D2	AE & HEV extr	**0.93**	2.63%

AE = alternative fuels, BAU = business as usual, BOI = Board of Investment, HEV = hybrid electric vehicle.
Source: Authors.

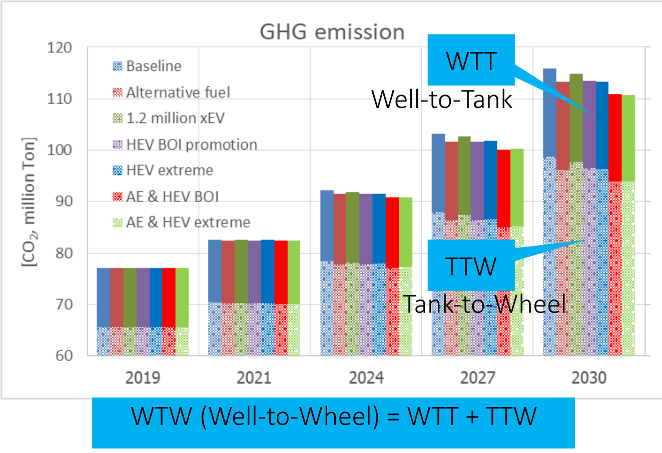
Figure 2.27. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Fossil Fuel Reduction



Fossil fuel (oil) reduction @2030 [x10³ ktoe]			
A	Alternative Energy (AE)	0.82	2.49%
B	1.2M xEVs	0.33	0.99%
C1	HEV BOI	0.70	2.13%
C2	HEV extreme	0.74	2.25%
D1	AE & HEV BOI	1.50	4.56%
D2	AE & HEV extr	**1.55**	4.69%

AE = alternative fuels, BAU = business as usual, BOI = Board of Investment, HEV = hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

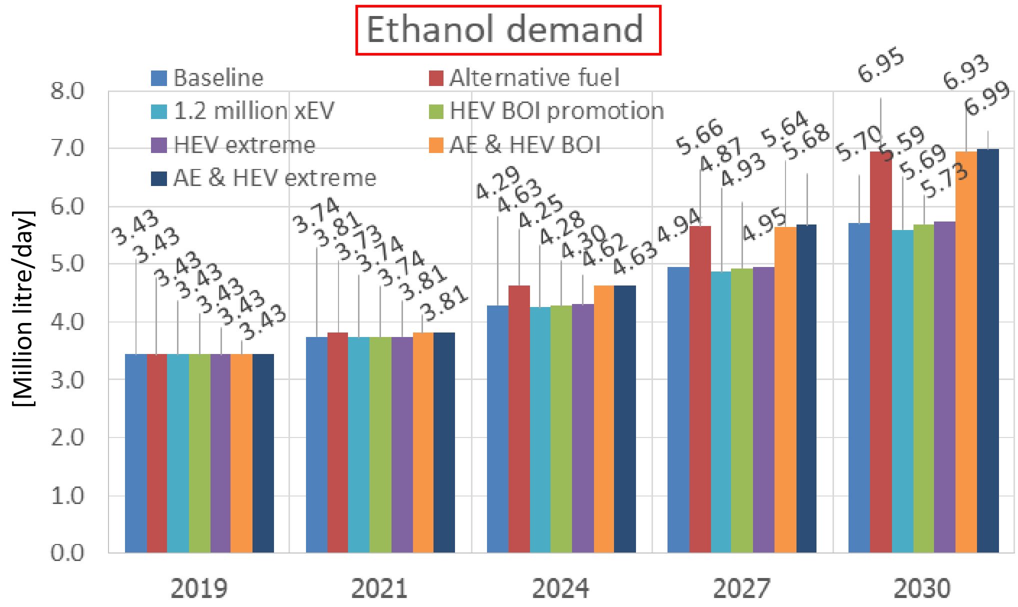
Figure 2.28. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Greenhouse Gas Emissions Reduction



	CO_2 reduction	[million Ton] @2030			%WTW reduction
		WTT	TTW	WTW	
A	AE	-0.01	2.50	2.49	2.15%
B	1.2M xEVs	0.02	0.97	0.99	0.85%
C1	HEV BOI	0.19	2.24	2.43	2.10%
C2	HEV extreme	0.26	2.33	2.59	2.24%
D1	AE & HEV BOI	0.18	4.68	4.85	4.19%
D2	AE & HEV extr	0.25	4.78	5.02	4.34%

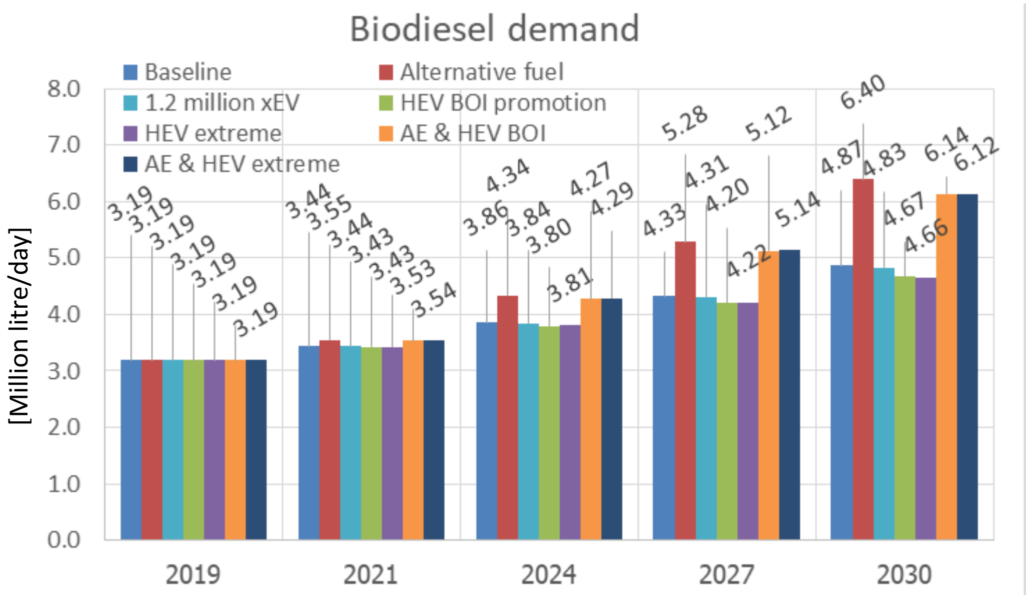
AE = alternative fuels, BAU = business as usual, BOI = Board of Investment, HEV = hybrid electric vehicle.
Source: Authors.

Figure 2.29. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Increased Bioethanol Demand



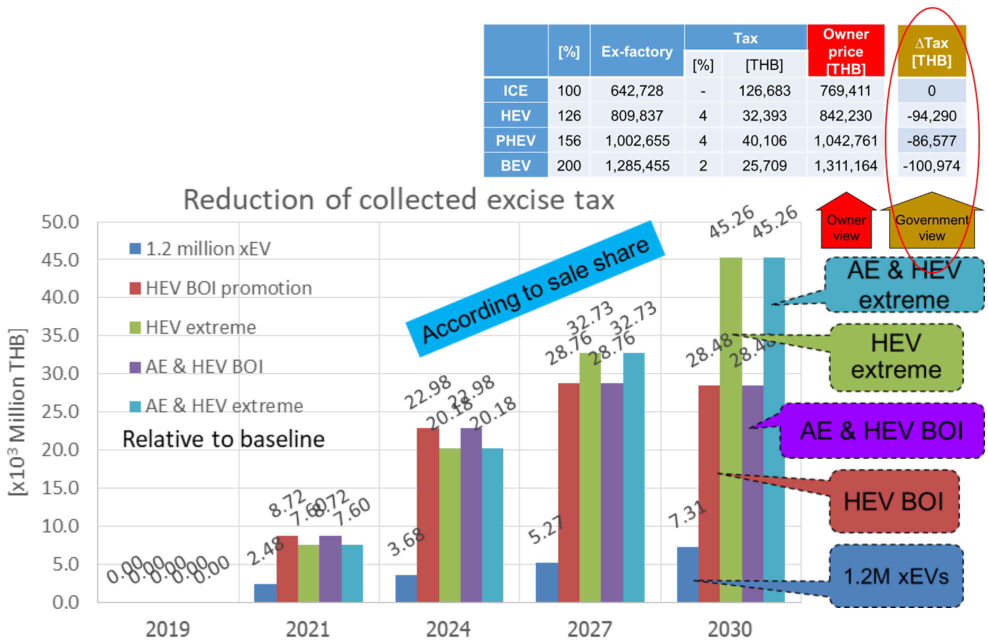
AE = alternative fuels, BAU = business as usual, BOI = Board of Investment, HEV = hybrid vehicle.
Source: Authors.

Figure 2.30. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Increased Biodiesel Demand



AE = alternative fuels, BAU = business as usual, BOI = Board of Investment, HEV = hybrid vehicle.
Source: Authors.

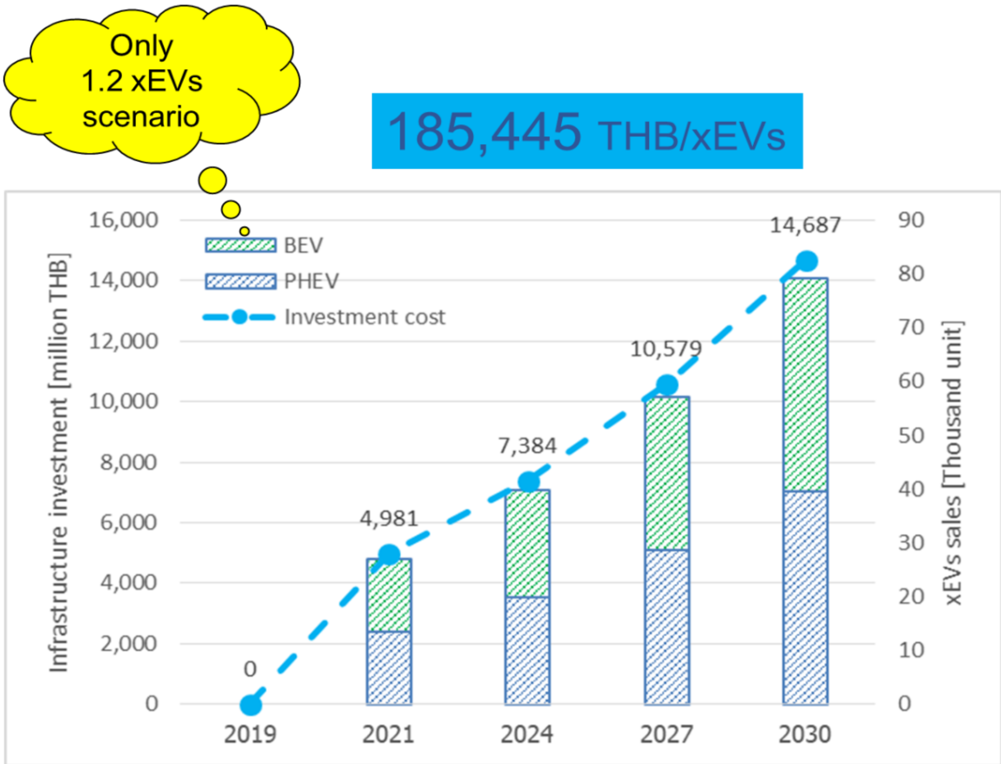
Figure 2.31. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Excise Tax Reduction



	[%]	Ex-factory	Tax [%]	Tax [THB]	Owner price [THB]	ΔTax [THB]
ICE	100	642,728	-	126,683	769,411	0
HEV	126	809,837	4	32,393	842,230	-94,290
PHEV	156	1,002,655	4	40,106	1,042,761	-86,577
BEV	200	1,285,455	2	25,709	1,311,164	-100,974

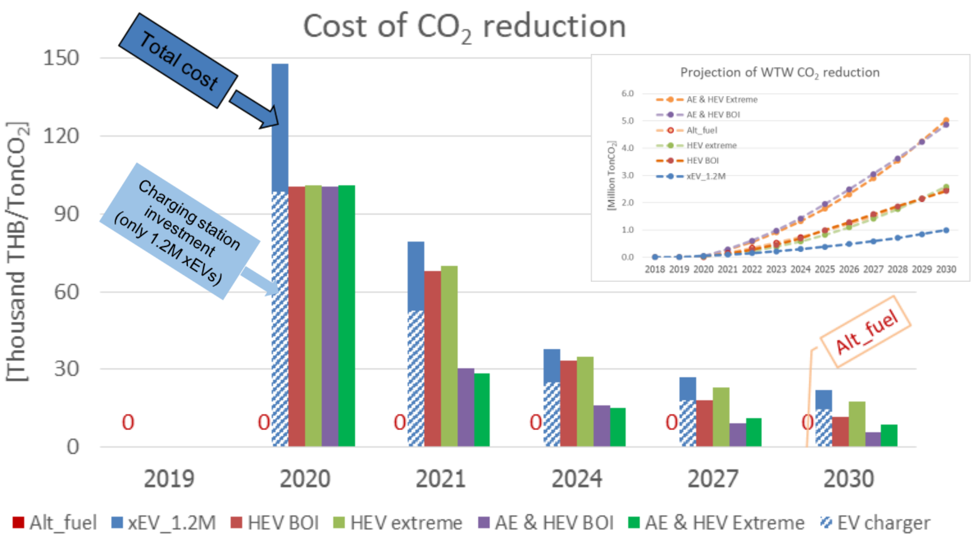
AE = alternative fuels, BAU = business as usual, BEV = battery electric vehicle, BOI = Board of Investment, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Authors.

Figure 2.32. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Additional Investment for xEVs



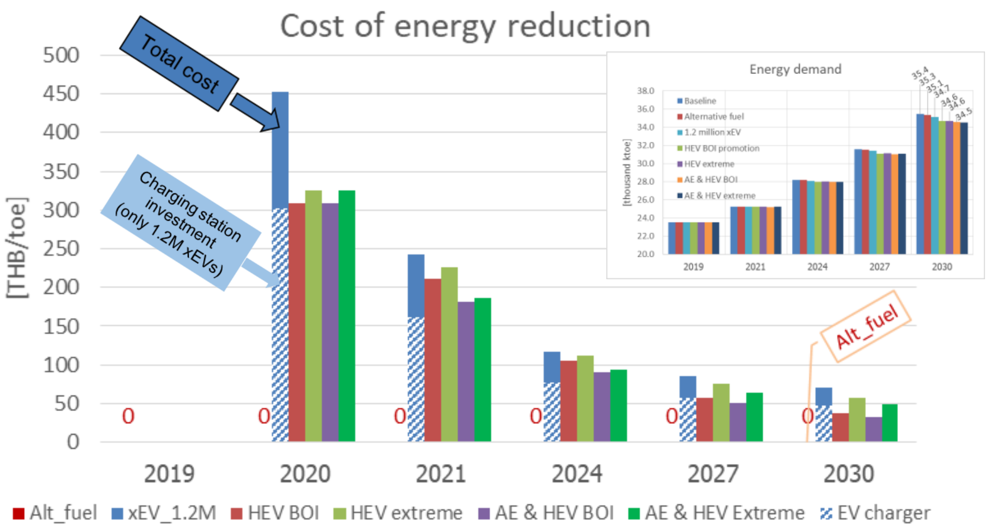
BEV = battery electric vehicle, BOI = PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

Figure 2.33. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Cost of CO_2 Reduction



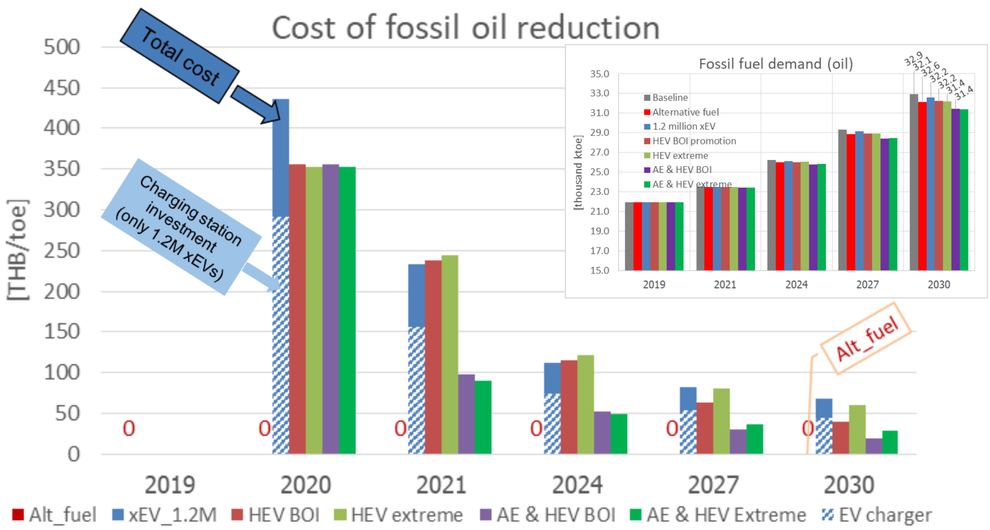
AE = alternative fuels, BOI = Board of Investment, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

Figure 2.34. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Cost of Energy Reduction



BEV = battery electric vehicle, BOI = PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

Figure 2.35. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Cost of Fossil Oil Reduction

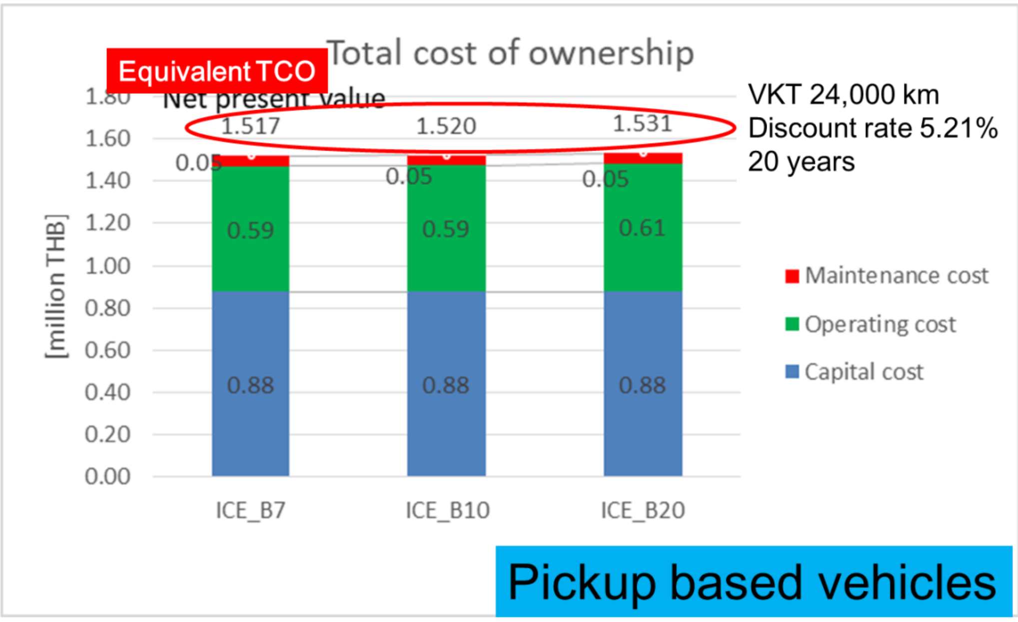


BEV = battery electric vehicle, BOI = PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

Figure 2.36. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Total Cost of Ownership: Sedan Case

TCO = total cost of ownership, VKT = vehicle kilometres travelled.
Source: Authors.

Figure 2.37. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Total Cost of Ownership: Pickup Case



TCO = total cost of ownership, VKT = vehicle kilometres travelled.
Source: Authors.

3.5. Discussion

From energy aspects shown in Figure 2.26 and Figure 2.27, EV technology (plug-in xEVs or hybrid expansion scenarios) can help reduce total energy demand but the alternative fuels scenario is better for reducing fossil fuel consumption from imports. Combination scenarios (in the order of AE & HEV BOI and AE & HEV extreme) can help reduce 1.50 and 1.55 thousand ktoe (1 Mtoe equal to thousand ktoe) of imported fossil fuel in 2030 (about 4.6–4.7% of projected fossil fuel consumption). In addition, both minimum (HEV BOI) and maximum (extreme) HEV scenarios are better than the 1.2 million xEVs scenario because of larger stock of HEVs than xEVs (4.7 and 7.1 million HEVs for minimum HEV and maximum HEV scenarios).

From an environmental aspect, for both well-to-tank (WtT) and tank-to-wheel (TtW) greenhouse gas emissions, as shown in Figure 2.28, by using biofuels as carbon-neutral fuel (considered as zero TtW CO_2 emissions), the alternative fuels scenario shows lower TtW emissions than the 1.2 million xEVs scenarios. For WtT emissions, which rely on net energy consumption and WtT CO_2 emissions factor, WtT emissions of the hybrid expansion scenarios are better than the alternative fuels scenario, which implies that the impacts of energy efficiency of HEV is higher than the difference in WtT emissions between fossil fuel and biofuels. Combination scenarios (AE and HEV BOI, AE and HEV extreme) can help reduce 4.85 and 5.02 million tons of WtW CO_2 emissions (4.68 and 4.78 million tons from TtW), and this amount is equivalent to about 4.2%–4.3% of baseline WtW CO_2 emissions.

From the biofuels demand aspects shown in Figure 2.29 and Figure 2.30, the alternative fuels scenario can help increase 1.25 million L/day of ethanol and 1.53 million L/day of biodiesel in 2030. According to the scenario definition, the share of diesel cars will be reduced with increasing EV share. Therefore, biodiesel demand will be reduced in the 1.2 million xEVs and both the HEV BOI scenario and HEV extreme scenario. On the other hand, ethanol demand will be increased slightly in the extreme HEV scenarios, but reduced in the HEV BOI and 1.2 million xEVs scenarios. In summary, combination scenarios (in the order of AE and HEV BOI, AE and HEV extreme) can help increase ethanol demand by 1.23 and 1.29 million L/day (21.52%–21.58% of baseline) and biodiesel by 1.27 and 1.26 million L/day (26.06% and 25.83% of baseline).

From an economic analysis, Figure 2.31 shows the government collected vehicle excise tax, which depends on both the tax incentive (per vehicle) and sale share (number of sale) in the automotive market. The effect of HEV for both HEV scenarios (HEV BOI and HEV extreme) will be higher than that of the 1.2 million xEVs scenario according to the market share shown in Table 2.20. Therefore, the government collected excise tax will be reduced by B7.31 billion, B28.48 billion and B45.26 billion in the 1.2 million xEVs, HEV BOI and HEV extreme scenarios by 2030 compared to the BAU scenario.

Table 2.20. xEVs Share in Various Scenarios

2030 sale share (%)	HEV	PHEV	BEV	Total
Baseline	1.57%	0.00%	0.00%	1.57%
1.2M xEVs	1.46%	3.47%	3.47%	8.40%
Min HEV	28.02%	0.00%	0.00%	28.02%
Max HEV	43.60%	0.00%	0.00%	43.60%

BEV = battery electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

On the other hand, the 1.2 million xEVs scenario requires investment cost for charging station installation, as shown in Figure 2.32, under the assumption of THB ~185,445 per xEVs. Therefore, the total government cost of 1.2 million xEVs scenario is the highest when comparing the others. In addition, Figure 2.33 shows the impacts of alternative fuels vehicles on CO_2 emissions reduction with cost per unit of CO_2 emissions reduction (THB per ton-CO_2) being lower with larger stock numbers of alternative fuels vehicle. Likewise, the cost per unit of energy and fossil-oil reduction is lowest for the alternative fuels scenario as shown in Figure 2.34 and Figure 2.35.

From the total cost of ownership (TCO) aspect, Figure 2.36 shows that the TCO of sedan xEVs (HEV, PHEV, and BEV) introduction are still higher than conventional ICE sedans due to higher vehicle purchase cost and battery replacement cost despite the fact that operating cost is much lower. With biofuels consideration, the TCO of conventional ICE sedans using biofuels (gasohol E20 and E85) is lower than running with fossil fuel due to the current incentives on biofuels price. However, the TCO of pickup-based vehicles, as shown in Figure 2.37 are similar for all three kinds of biodiesel blends due to the assumption of the fuel price structure in this study.

3.6. Summary as Policy Recommendation

From the overall analysis of biofuels and xEV integration into the transport sector, combination scenario (alternative fuels + minimum HEV) with the following assumption:

- Gasohol E20 will succeed (90%) with some E85 share (10%) in the automotive market (assuming ethanol share in gasohol demand as E26.5) in 2036
- Biodiesel demand for transport sector will achieve half of AEDP target or 7 million L/day in 2036 (assuming that biodiesel blending ratio of commercial grade diesel fuel achieves B12)
- Minimum HEV: total HEV sales achieve 320,000 units by 2023, 5 years after investment plan commitment to BOI in 2018 (Prachachart, 2018), and 4.7 million units in 2036 seems to yield the suitable impact as shown in Table 2.21.

Table 2.21. Impact of Combination Scenario (alternative fuel + minimum HEV)

Parameters of interest	Calculated potentials	Percentage (compared to baseline)
Total energy (ktoe)	1.06×10^3	3.00%
Fossil fuel (ktoe)	1.89×10^3	6.97%
Ethanol (million litre/day)	2.90	46.70%
Biodiesel (million litre/day)	1.04	23.30%
GHG (WtT/WtW, tonCO_2,eq)	5.79 & 6.12×10^6	5.29%

GHG = greenhouse gas, HEV = hybrid electric vehicle, ktoe = kiloton of oil equivalent, WtT = well to tank, WtW = wheel to tank.
Source: Authors.

The overall conclusions are:

- From economic aspects, EV technology has opportunity cost to the government (from lower excise tax rates) of B7.31 billion, B28.48 billion, and B45.26 billion for 1.2 million xEVs, minimum HEV, and maximum HEV scenarios, respectively. Also 1.2 million xEVs requires government infrastructure investment for public EV charging stations.
- In addition, the cost of CO_2 emissions reduction (B per ton-CO_2) will be as high as B160,000 per ton-CO_2 in 2020 for the 1.2 million xEVs scenario (in the early period of EVs entering the market). Then declining with increasing CO_2 emissions reduction potentials, cost of CO_2 emissions reduction for the 1.2 million xEVs scenario could be further reduced to B26,500 ton-CO_2 in 2030
- TCO shows that ICE vehicles are still the most cost effective as from an ownership viewpoint (economic aspect) for both sedans and small pickup trucks.

4. xEV Mix Scenario Study for Indonesia

4.1. Government Policies

The national energy mix of primary energy consumption is defined by the National Energy Policy (abbreviated as KEN in the Indonesian language). According to KEN, the oil consumption in the primary energy mix is to be reduced to 30% by 2025 and 25% by 2050. Meanwhile the portion of renewables is targeted to be increased to 23% by 2025 and 31% by 2050. Based on the Handbook of Energy and Economic Statistics of Indonesia by the Ministry of Energy and Mineral Resources, 68% of total oil consumption is estimated to be consumed by road transportation, thus government policies that reduce oil consumption and promote renewable energy use in the transport sector will be significant in achieving the KEN target.

An existing biofuel mandate has been in place since 2008 by the Ministry of Energy and Mineral Resources. However, due to limited stocks, the production of gasoline–ethanol blend was eventually suspended in 2009. However, biodiesel production met a good degree of success and in 2012, biodiesel content was ahead of schedule and able to reach 5% with an increase to 7.5% beginning 2013. By 2018, the national oil company, Pertamina stated that 90% of the biodiesel supply for 20% biodiesel mixed petroleum diesel (B20) has been achieved. In 2014, the ministry revised the mandatory biofuel content to more aggressive measures. Mandatory biodiesel content in diesel fuel mixtures were set at 30% by the year 2020 and bioethanol content in gasoline measures were set at 10% by 2020 and 20% by 2025. This fuel requirement has been reiterated in the Ministry of Energy and Mineral Resources Regulation No.12 Year 2015 (Table 2.22).

Table 2.22. Mandatory Biofuel Content based on Regulation No.12 Year 2015

Fuel	2014	2015	2016	2020	2025
Gasoline mixture bioethanol content	1%	2%	5%	10%	20%
Diesel fuel mixture biodiesel content	10%	10%	20%	30%	30%

Source: Authors.

With proven natural gas reserves of 3 trillion cubic metres, Indonesia has the 13th largest proven reserves in the world and the 2nd largest in the Asia Pacific. In 2012, Indonesia produced 73 billion cubic metres of natural gas making it the 11th largest natural gas producer worldwide. As such, natural gas is viewed as a promising alternative fuel to gasoline and diesel fuels. In 2010, the Indonesian Ministry of Energy and Mineral Resources issued Regulation No.19 Year 2010 concerning the Utilization of Natural Gas for Transportation Fuel which mandated the increase of natural gas resource allocation for the transport sector from 10% to 25% by 2026.

In regards to low emission vehicles, the Ministry of Industry issued Regulation No.33 of Year 2013 on the Development of Affordable and Energy Efficient Four-Wheel Vehicles. However, this regulation does not address xEVs. The new regulations and roadmap for electric vehicles is currently undergoing finalisation. The current schedule for electric vehicle production is shown in Table 2.23 and Table 2.24.

Table 2.23. Government EV Plan and Vehicle Sales Forecast for Cars, Trucks, and Buses

	2020	2025	2030	2035
Auto Total Production	1,500,000	2,000,000	3,000,000	4,000,000
Auto total Export	250,000	310,000	900,000	1,500,000
Auto total Sales	1,250,000	1,690,000	2,100,000	2,500,000
Sales PV (PV Market* 60%)	750,000	1,014,000	1,260,000	1,500,000
Sales CV (CV Maret* 40%)	500,000	676,000	840,000	1,000,000
Bus Total Sales	5,000	6,760	8,400	10,000
Truck Total Sales (PU)	150,000	202,800	252,000	300,000
Truck Total Sales (Truck)	103,750	140,270	174,300	207,500

EV = electric vehicle, PV = personnel vehicle, CV =commercial vehicle, PU = passenger use.
Source: Ministry of Industry.

Table 2.24. Government EV Plan and Vehicle Sales Forecast for Motorcycles

	2020	2025	2030	2035
Production	8,000,000	10,000,000	12.500.000	15,000,000
Export	500,000	1,000,000	1,500,000	2,000,000
Domestic Sales	7,500,000	9,000,000	11,000,000	13,000,000
% Electric Motorcycles	10%	20%	25%	30%
Electric motorcycles sales	750,000	1,800,000	2,750,000	3,900,000

EV = electric vehicle.
Source: Ministry of Industry.

4.2. Parameters and Figures used for Scenario Simulation

Vehicle Population

As the model will examine the current government policies including the xEV roadmap, vehicle production used will be forecast by the Ministry of Industry (Tables 2.23 and 2.24).

Travel Distance

Theoretically, vehicle emissions are positively correlated to fuel consumption, and fuel consumption will depend on distance travelled. In other words, the longer the travel distance, the more fuel consumed. Total consumption will be determined based on the fuel economy and the distance travelled.

The annual travel distance was obtained from a study conducted by the Gadjah Mada University Centre for Transportation and Logistics Studies. Table 2.25 lists the travel distances for four vehicle types in the present study. The average annual travel distance was calculated by estimating the number of active days within 1 year. For instance, for passenger cars, the average annual travel is 18,480 kilometres (km), which was obtained by assuming 28 operational days per month with a daily travel distance of 55 km, thus a monthly calculated travel of 1,540 km.

Table 2.25. Average Annual Mileage (km travelled) by Type of Vehicle

Type of Vehicle	Number of Days per Month (day)	Average Travel per Day (km)	Average Travel Annually (km)
Passenger car	28	55	18,480
Bus	15	200	36,000
Truck	20	150	36,000
Motorcycle	28	30	10,080

km = kilometre.
Source: Authors.

Fuel Economy

The majority of fuel economy data was adopted from empirical research that investigated the fuel consumption of motorcycles, passenger cars (gasoline and diesel), buses, and trucks in Indonesia, specifically in the cities of Yogyakarta, Semarang, and Surakarta. The data were collected through a field study which were then cross-validated with data from the government institutions.

It was found that for an engine capacity of 1.5 litres (L), the average fuel economy for various brands of passenger cars was 10 km/L. The average fuel economy for an engine capacity of 1.8 L was 9.75 km/L, whereas that for an engine capacity of 2 L is 7 km/L, which was the least. It implies that the higher engine capacity, the lower the fuel economy. Selected fuel economy of 9.1 km/L, which is based on the actual fuel economy was found to be reasonable. Table 2.26 shows the base fuel economy for various vehicle and fuel types modelled. The fuel economy for compressed natural gas (CNG) vehicles is not yet available in Indonesia, so it is assumed.

Table 2.26. Fuel Economy based on Vehicle and Fuel Type

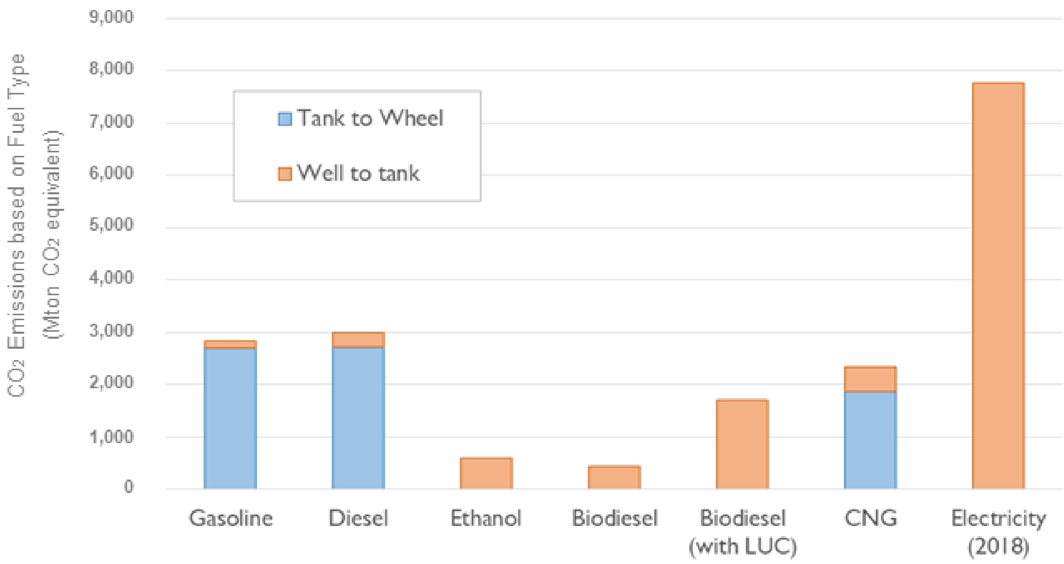
Vehicle type – Fuel type	Fuel Economy (km/L)	Remarks
Passenger car – gasoline	9.1	
Passenger car – diesel	10.3	
Bus – diesel	5.9	
Truck – diesel	5.9	
Motorcycle – gasoline	26.8	
Passenger car – CNG	9.8	Based on ratio of FE, 2015 Civic CNG and gasoline
Bus – CNG	5.9	Assumed to be similar to bus – diesel fuel
Truck – CNG	5.9	Assumed to be similar to truck – diesel fuel

CNG = compressed natural gas, FE = fuel economy.
Source: Authors.

Specific Carbon Emissions

Data of CO_2 emissions were collected through a literature survey of life cycle assessment studies. Indonesian data were utilised when available (Restianti and Gheewala, 2012a, 2012b; Wirawan 2009; Nazir and Setyaningsih, 2010). For cases where Indonesian data were not available, best estimates using other data were used (Sevenster and Croeze, 2006). Collected CO_2 emissions data were arranged in a database, which was divided into two parts: well-to-tank CO_2 emissions and tank-to-wheel CO_2 emissions. Well-to-tank emissions are the calculated emissions related to the production and distribution process of a given fuel, whilst tank -to-wheel emissions relate to the operation of the vehicle fuelled.

Figure 2.38. Specific CO_2 Emissions based on Fuel Type



CNG = compressed natural gas, LUC = land use change.
Source: Authors.

A comparison of CO_2 emissions for gasoline, diesel, CNG, electricity, and variety of biofuel blends are shown in Figure 2.38. Biodiesel and ethanol are assigned to have tank-to-wheel emissions value of zero assuming a carbon reducing nature of the crops used as the source of the biofuel. Indonesia's electric power generation is estimated to have very large well-to-tank emissions due to the dominance of coal-fired power plants in Indonesia.[3]

4.3. Scenarios

Business as Usual (BAU) Scenario (reference)

The end of 2014 witnessed a significant drop in the price of oil from monthly highs exceeding US$110 per barrel to levels below US$60 per barrel, which continued into early 2015. In 2019, the oil prices consistently hovered around US$60 per barrel. This reduction in oil prices resulted in less appeal for alternative fuels (i.e. biofuels), which in turn resulted in losses for biofuel producers, including Indonesian biofuel producers. As this may cause difficulties in procuring the future supply of biofuels for the Indonesian fuel blend, this scenario will estimate the effects of reduced biofuel use based on 2015 regulations but maintaining the condition at 2018 where B20 supply was achievable nationwide.

[3] PT PLN (2018), 'Rencana Usaha Penyediaan Tenaga Listrik 2018–2027', Jakarta: PT PLN.

The parameters for Scenario 1 assume that biofuel use is maintained at 2018 conditions:

- 0.5%/year of fuel economy improvement for all new vehicles for a given production year
- No introduction of CNG vehicles
- Follow 2015 biodiesel mandate up to B20, but no utilisation of ethanol

Biofuel Scenarios

As per the 2015 regulations of mandatory biofuel content, mandatory biodiesel content in diesel mixtures were set at 30% by the year 2020 and bioethanol content in gasoline measures were set at 10% by 2020 and 20% by 2025. The effect of increased biofuel use is thus explored in this scenario. There are no current regulations regarding ethanol compatibility requirement for motorcycles, and therefore the compatibility is still undetermined. In this study it is assumed that motorcycles are bioethanol compatible.

Case simulates full implementation of the biodiesel mandate to B30 and E20:

- 0.5%/year of FE improvement for all vehicles
- No introduction of CNG vehicles
- Implementation of 2015 biodiesel mandate up to B30
- Implementation of 2015 bioethanol mandate up to E20
- Motorcycles are compatible with ethanol

In addition, separate scenarios were included to evaluate the isolated implementation of B30 and E20:

- B30 is a modified biofuel plan with implementation of 2015 biodiesel mandate up to B30, but no bioethanol
- E20 is a modified biofuel plan with implementation of 2015 bioethanol mandate up to E20, but only biodiesel up to B20

Vehicle Electrification (xEV) Scenarios

This investigates the government's plan to introduce electricity-based vehicles (xEVs) which consist of battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs). This case assumes the conditions of the BAU scenario but with the added condition of the introduction of xEVs according to the government schedule. The government schedule includes the implementation of BEVs for trucks, buses, and motorcycles, which will require additional charging stations.

In addition, separate xEV variation scenarios will be tested:

- HEV scenario is a modified EV plan, which assumes all private car xEVs are HEVs
- PHEV scenario is a modified EV plan, which assumes all private car xEVs are PHEVs
- BEV scenario is a modified EV plan, which assumes all private car xEVs are BEVs

CNG Implementation Scenario

As mentioned before, Indonesia has large proven reserves of natural gas, and the Ministry of Energy and Mineral Resources has mandated that the allocation of natural gas resources to the transportation sector be increased from 10% to 25%. Therefore, in this research, we set up a CNG scenario and included a scenario in which CNG is adopted for large vehicles and taxis.

We have included a scenario employing CNG for heavy duty vehicles and taxis. As it is unlikely that CNG implementation will involve construction of CNG infrastructure covering most of Indonesia before 2035, we have only included the cities of Palembang, Bandung, Medan, Jakarta, and Surabaya. These CNG heavy duty vehicles and taxis in these cities will be simulated as 48% of new heavy-duty vehicles and all taxi sales to be CNG based. Based on 2013 taxi sales, this means 1.5% of passenger car sales are attributed to CNG taxis. Regarding CNG buses, it is assumed that 40% of truck chassis sold are converted into buses based on the Central Bureau of Statistics vehicle population increase ratios between buses and trucks. The ratio of public transport vehicle sales to total vehicle sales is assumed to be constant. It will be assumed that new CNG heavy duty vehicles and taxis will be introduced in 2020. We combined this CNG heavy duty vehicles and taxis with biofuel mandate implementation and the government EV plan. Thus, the parameters for this scenario are:

- 0.5%/year of FE improvement for all vehicles
- Introduction of CNG for public transport (taxi/bus) and trucks in Palembang, Bandung, Medan, Jakarta, and Surabaya (five cities) resulting in 48% of all new taxis, buses, and trucks being CNG capable
- Follow 2015 biofuel mandate up to B30 and E20
- Follow government EV plan

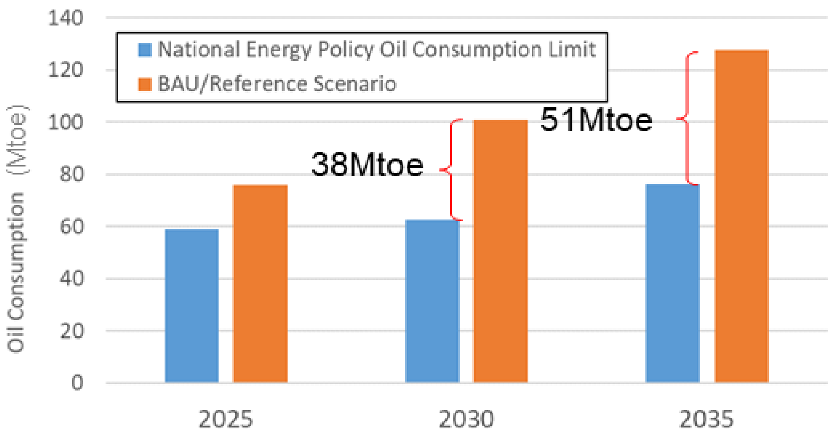
4.4. Study Results (oil consumption, CO_2 emissions, and cost of implementation)

Reference / BAU Scenario

The BAU scenario is used as a base reference and assumes that biodiesel use will be in accordance with 2015 mandatory biofuel regulations but is to be capped at B20 and bioethanol is assumed not to be implemented due to supply issues. The introduction of new fuel types and technologies are also assumed to be non-existent. Also assumed is a gradual technological development resulting in slow fuel economy improvement of 0.5%/year.

Figure 2.39. Oil Consumption in BAU Scenario

(NEP oil limit for road transportation is assumed to be 59% of total oil limit)

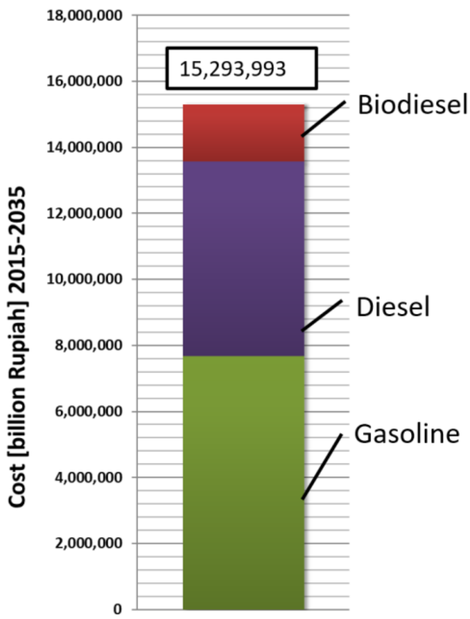


BAU = business as usual, Mtoe = million tons of oil equivalent, NEP = National Energy Policy.
Source: Authors.

Comparing the BAU scenario to the road transport target, it can be seen that the BAU scenario cannot meet the maximum oil consumption for road transportation. In 2025, the scenario exceeds the oil target by 38 Mtoe and by 51 Mtoe in 2030.

Figure 2.40 shows the total cost of the BAU scenario. As there has been no additional implementation of alternative fuels, the only cost is the cost of fuels. For the BAU scenario, the total cost is Rp15,294 trillion. This will be used as a reference cost when comparing the cost change due to implementation of each scenario.

Figure 2.40. Total Cost (cost of fuel, infrastructure, etc.) from 2015 to 2035 for BAU Scenario

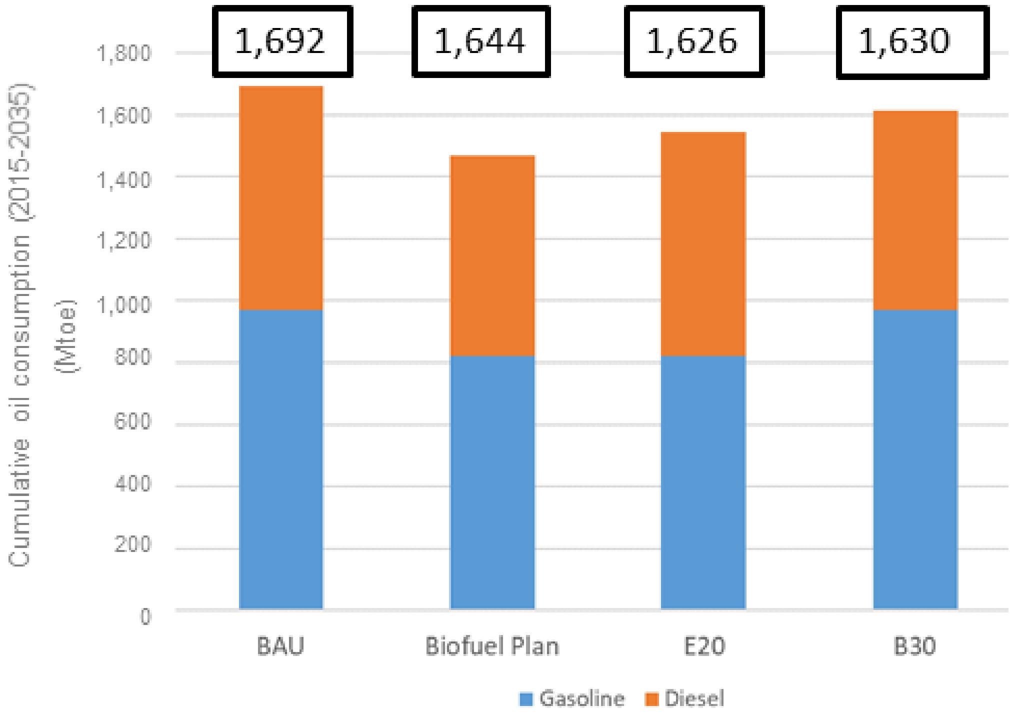


Source: Authors.

Biofuel Scenarios

The introduction of a more aggressive use of biofuels as according to the 2015 mandatory biofuel content regulations will reduce oil use. Figure 2.41 shows the results of oil consumption for the biofuel scenarios. As can be seen, increase of implementation from B20 to B30 results in a reduction of 4.6% compared to BAU. Meanwhile the adoption of E20 resulted in a reduction of 8.7%, a larger effect. The combination of these two into the government biofuel plan results in a cumulative reduction of 13.2%.

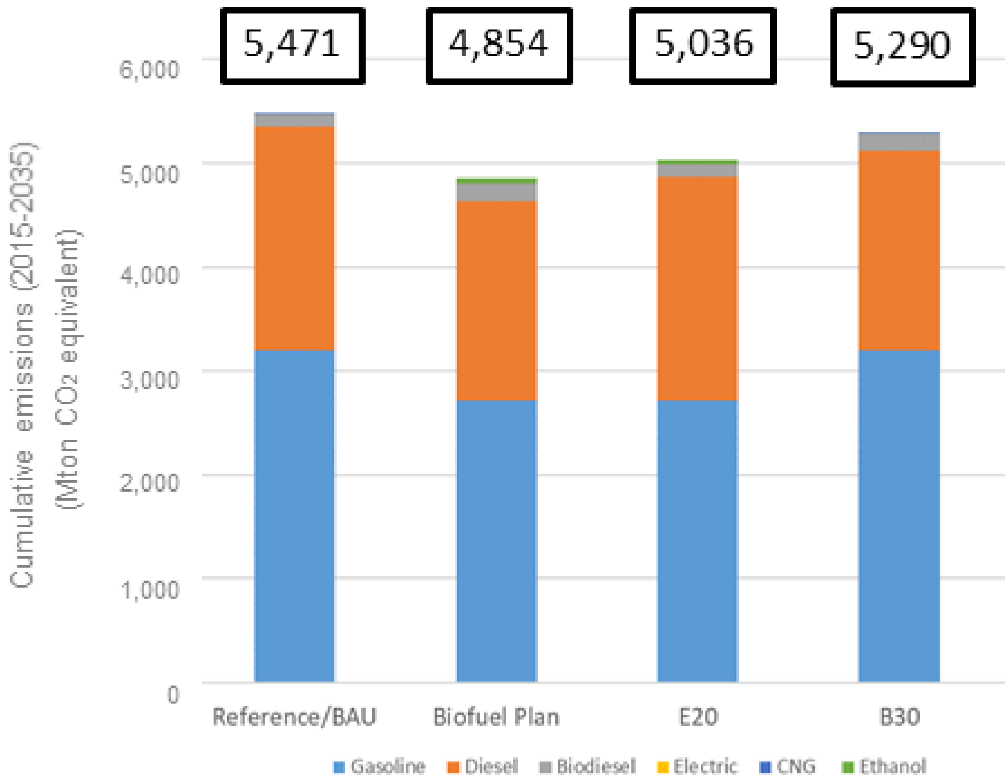
Figure 2.41. Comparison of Oil Consumption from 2015 to 2035 of Biofuel Scenarios and BAU



BAU = business as usual, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.42 shows the cumulative emissions reduction for the biofuel scenarios compared to BAU. As with oil consumption, again the E20 has a larger reduction of carbon emissions (8.0%) compared to the B30 scenario (3.3%).

Figure 2.42. Comparison of Carbon Emissions from 2015 to 2035 of Biofuel Scenarios and BAU

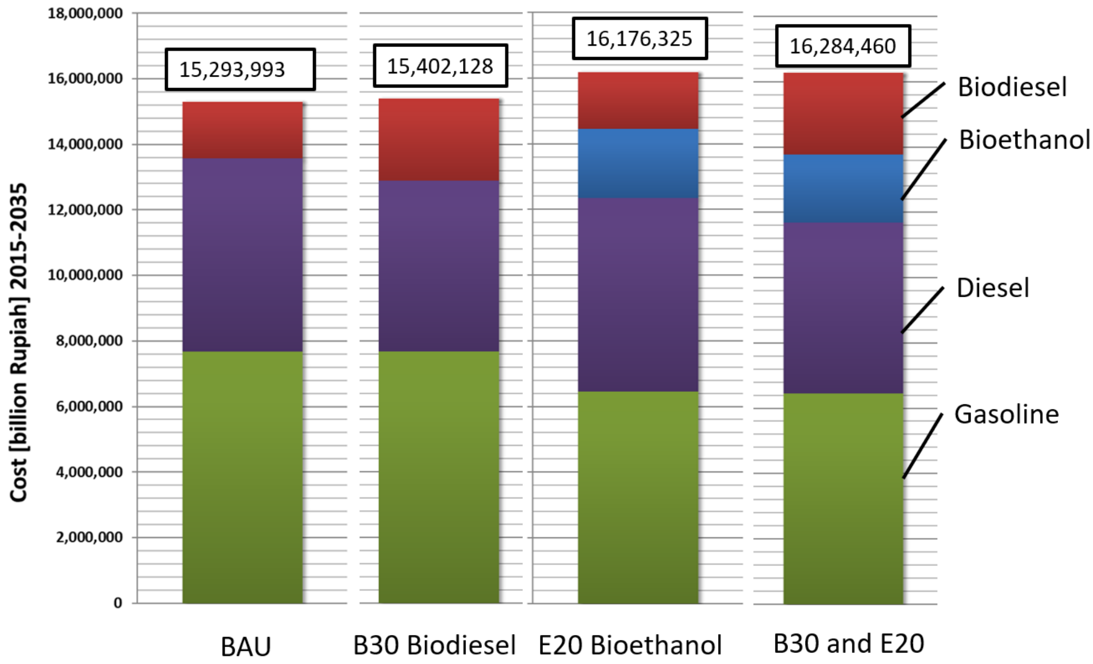


BAU = business as usual, CNG = compressed natural gas.
Source: Authors.

Costs involved in the implementation of the biofuel scenarios are shown in Figure 2.43. The increase of cost to additional biodiesel implementation is less than 1% compared to the BAU scenario. However, increasing the bioethanol content to E20 will require a 5.9% increase of cost.

Most of the cost for all scenarios are due to the fuel cost of gasoline. This is due to most vehicles in Indonesia, including motorcycles, being gasoline based. Therefore, the substitution of gasoline fuels with bioethanol would affect the oil consumption of the majority of the vehicle population in Indonesia. This is an important reason why E20 resulted in a large reduction of oil consumption.

Figure 2.43. Comparison of Total Cost (cost of fuel, infrastructure, etc) from 2015 to 2035 for Biofuel Scenarios and BAU



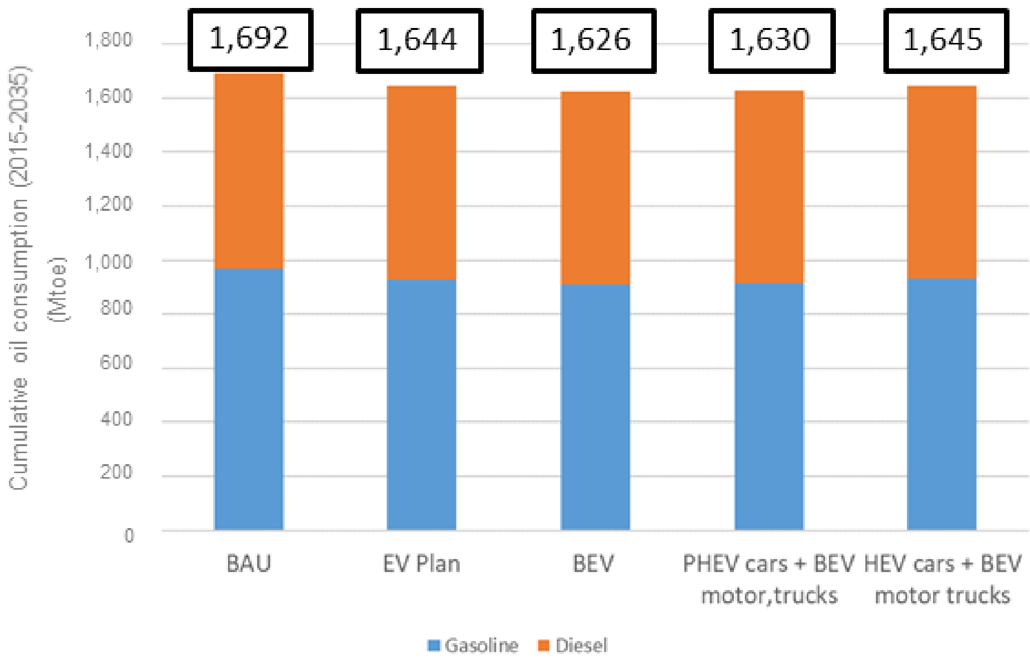
BAU = business as usual.
Source: Authors.

Vehicle Electrification (xEV) Scenarios

The introduction of electric vehicles is hoped to reduce both oil consumption and carbon emissions. However, the large specific emissions factor of electricity causes doubts as to whether or not xEVs will reduce emissions despite their higher efficiency.

Figure 2.44 shows the total oil consumption of the xEV scenarios compared to the BAU scenario. The largest oil reduction was achieved by the BEV scenario which reduced the consumption by 48 MTOE or 3.9% followed by PHEVs at 3.7%. The HEV scenario reduced consumption by 2.8% only slightly lower than the government EV plan since the plan comprises most HEV sales, while PHEV and BEV sales are a much smaller number, especially during the earlier years.

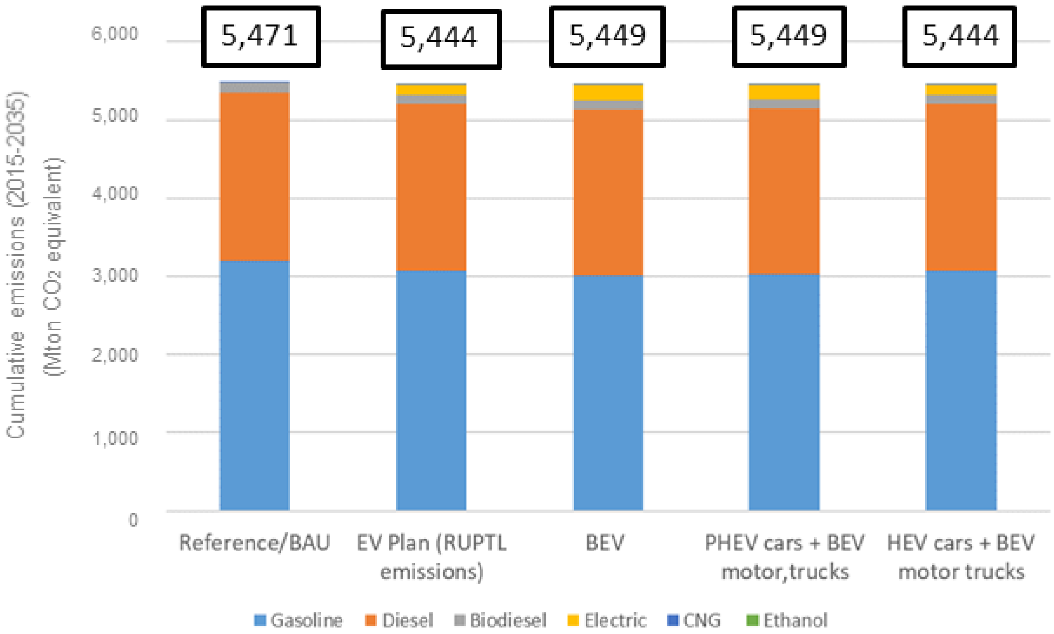
Figure 2.44. Comparison of Oil Consumption from 2015 to 2035 of xEV Scenarios and BAU



BAU = business as usual, BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, Mtoe = million tons of oil equivalent, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

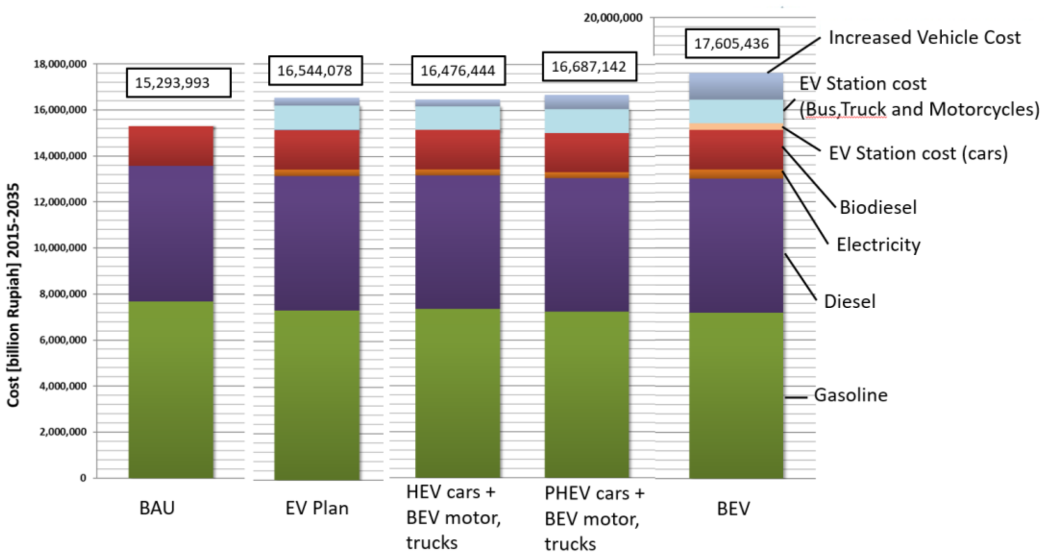
The emissions comparison of the xEV scenarios compared to the BAU scenario are shown in Figure 2.45. The emissions reduction due to the government EV plan and the HEV scenario were similar at 27 million tons-CO_2 or 0.5%. Meanwhile, the BEV and PHEV scenarios reduced emissions by 22 million tons-CO_2 or 0.4%. Even though all scenarios could reduce emissions compared to the BAU scenario, the reduction was very small. This is likely due to only a small number of xEV vehicles being present in the population, compared to the large existing vehicle population.

Figure 2.45. Comparison of Carbon Emissions from 2015 to 2035 of xEV Scenarios and BAU



BAU = business as usual, BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, Mton = million ton, = million tons of oil equivalent, PHEV = plug-in hybrid electric vehicle, RUPTL = Rencana Umum Penyediaan Tenaga Listrik, xEV = electrified vehicle.
Source: Authors.

Figure 2.46. Comparison of Total Cost (cost of fuel, infrastructure, etc) from 2015 to 2035 for xEV Scenarios and BAU



BAU = business as usual, BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, Mton = million ton, = million tons of oil equivalent, PHEV = plug-in hybrid electric vehicle.
Source: Authors.

Figure 2.46 shows a comparison of the total cost for the xEV scenarios and the Reference/BAU case. It can be seen that a large portion of costs are due to the construction of EV stations for buses, trucks, and especially for motorcycles. Each charging point was assumed to cost US$48,500 and that charging points would facilitate 10 passenger cars. As buses and trucks will travel longer distances, it is estimated that one charging point can accommodate 2.5 buses and/or trucks. For motorcycles, a charging point is assumed to be able to accommodate 25 motorcycles. As such, the total cost to accommodate BEV trucks, buses, and motorcycles amounts to around Rp1 quintillion, mostly for EV motorcycles.

Increased vehicle costs were considered as xEVs are more expensive. BEVs were assumed to cost 200% the cost of equivalent internal combustion engines (ICE) (which were assumed at US$20,000), while HEVs and PHEVs were assumed to cost 126% and 156%, respectively. While there are increased passenger vehicle costs due to xEVs being more expensive, the effect is still limited as most passenger xEVs were HEVs. The increased cost of vehicles in the BEV scenario is most significant reaching as high as the cost of the charging station construction and thus this scenario is the most expensive, an increase of 15% compared to the BAU scenario due to the expensive costs of BEVs. Meanwhile, the government EV plan is milder at a 6.4% increase.

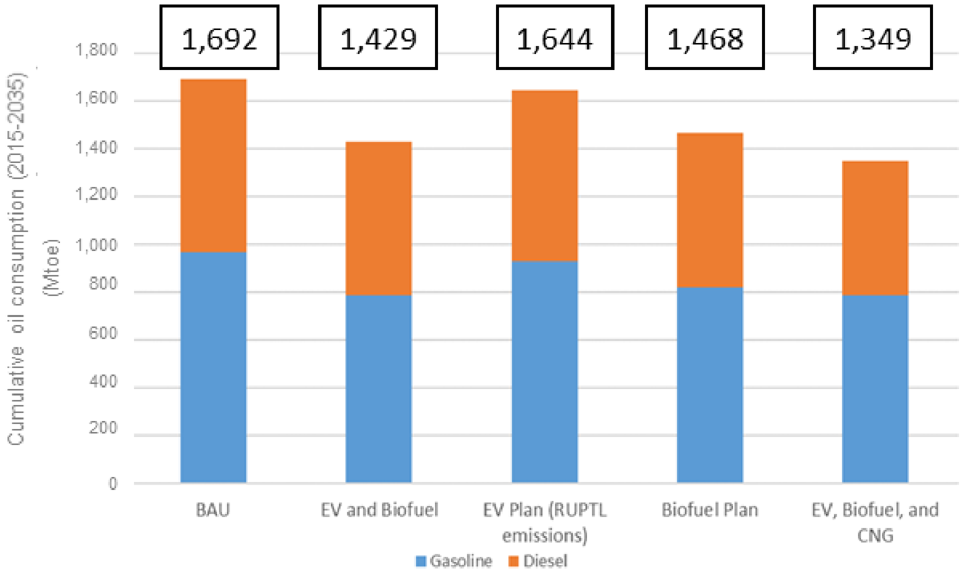
A large portion of the cost is to accommodate charging stations for electric buses, trucks, and motorcycles, which will grow significantly according to the production numbers specified by the EV plan. By 2035 there will be more than 35 million electric motorcycles, while electric buses and trucks will number 42,000 and 112,000 respectively.

CNG Implementation Scenario

A perceived lack of safety of CNG vehicles has many Indonesians reluctant to switch from gasoline or diesel fuels to CNG. Therefore, the most likely candidate for CNG use are public vehicles, which may be policy driven to adopt CNG fuels. In addition, also added to CNG capable vehicles are trucks, which as they fulfil a commercial and/or industrial function, are also easier to be subject to regulations.

The CNG case assumes the availability of CNG infrastructure for five cities: Jakarta, Bandung, Medan, Palembang, and Surabaya. As the vehicle population in these cities is estimated to comprise 48% of the national vehicle population, it is simulated that beginning in 2020, 48% of all taxi, bus, and truck sales will be CNG capable vehicles.

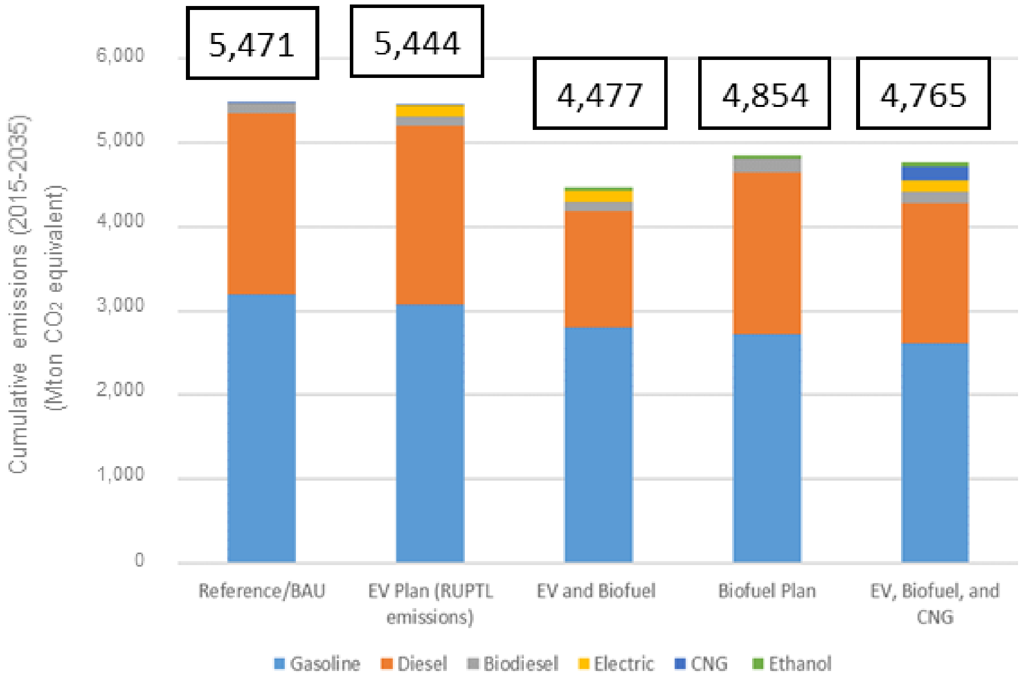
Figure 2.47. Comparison of Oil Consumption from 2015 to 2035 of CNG Implementation Scenario Combined with Other Scenarios and BAU



BAU = business as usual, CNG = compressed natural gas, EV = electric vehicle, MTOE = million tons of oil equivalent, RUPTL = Rencana Umum Penyediaan Tenaga Listrik.
Source: Authors.

Figure 2.47 shows the oil consumption for CNG with the biofuel plan and EV plan comparison to BAU and isolated EV and biofuel plans along with a mix. As can be seen, the largest reduction of oil consumption was achieved by CNG for heavy duty vehicles (HDVs) and taxis combined with the EV plan and biofuel plan. This reduced oil consumption by 20.2% or 343 Mtoe. Meanwhile, the combined EV and biofuel plan could reduce the oil consumption by 15.5% or 263 Mtoe, not so much larger than the isolated biofuel plan, which reduced oil consumption by 13.2% or 224 Mtoe.

Figure 2.48. Comparison of Carbon Emissions from 2015 to 2035 of CNG Implementation Scenario Combined with Other Scenarios and BAU

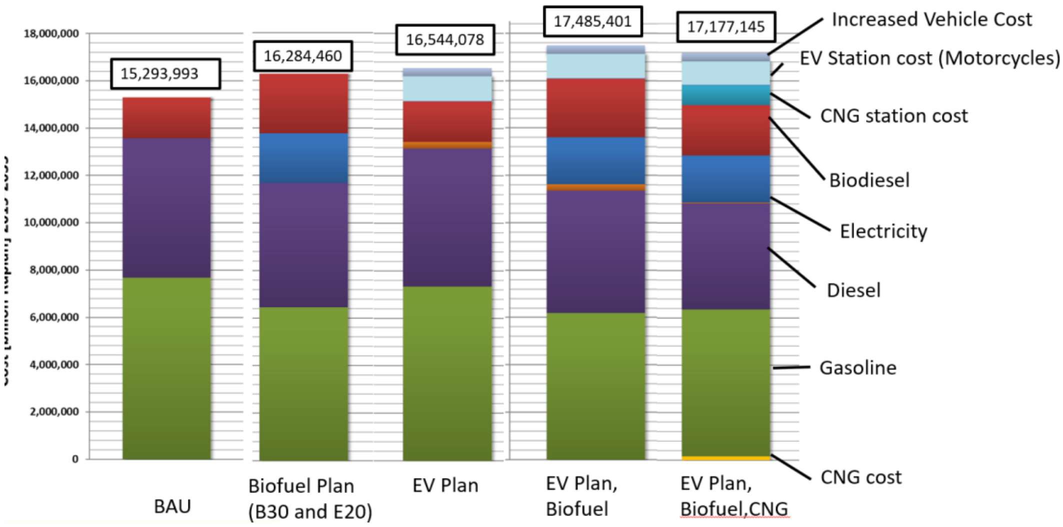


BAU = business as usual, CNG = compressed natural gas, EV = electric vehicle, Mton = million ton, RUPTL = Rencana Umum Penyediaan Tenaga Listrik.
Source: Authors.

Figure 2.48 displays the cumulative carbon emissions. It is shown that the largest emissions reduction is due to the combined EV and biofuel plan, which achieved a reduction of 994 million ton-CO_2 or 18.1%. This is because of the carbon neutrality of the biofuels resulting in a low total well to wheel specific emissions of biodiesel and bioethanol. If CNG for HDVs is introduced, the emissions are higher, a lesser reduction of 706 million ton-CO_2 or 12.9% is achieved. This is because by introducing CNG for HDVs, the use of biodiesel is reduced. Meanwhile biodiesel has lesser specific emissions compared to CNG.

The increase in cost for natural gas implementation involves the construction of infrastructure. It is assumed that pipeline construction is already included in the national development scheme as it not only caters for transport but also for industry, power plants, and residential gas and therefore is not added to the cost. Thus, the cost increase for infrastructure involves only the construction of natural gas stations for road transport fuelling. It is assumed that each natural gas station costs US$3 million and can serve 300 vehicles.

Figure 2.49. Comparison of Total Cost (cost of fuel, infrastructure, etc) from 2015 to 2035 of CNG Implementation Scenario Combined with Other Scenarios and BAU



BAU = business as usual, CNG = compressed natural gas, EV = electric vehicle.
Source: Authors.

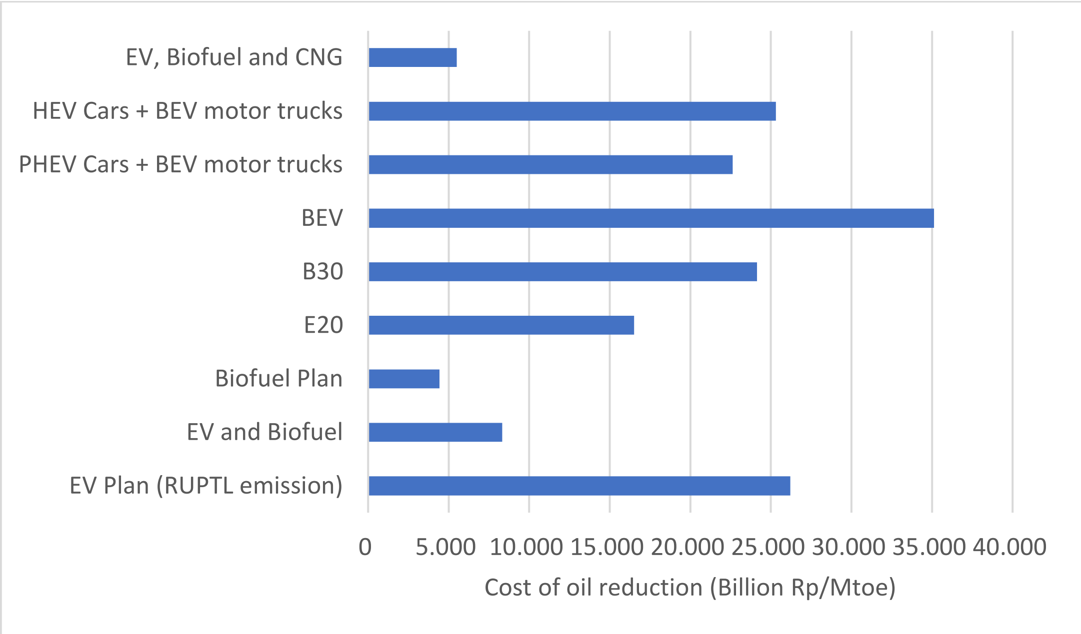
Figure 2.49 displays the cumulative costs for the combined scenarios in comparison to BAU and the isolated EV plan and biofuel plan. All plans have an increased cost compared to the BAU scenario: biofuels will cost more than fossil fuels, the EV plan will have an increased vehicle cost, and both the EV plan and CNG will require additional infrastructure. The highest cost is shown by the combined EV and biofuel plan, which experiences a 14.3% increase in cost compared to BAU. Interestingly, the added implementation of CNG to the combined EV and biofuel plan results in a lower cost compared to the initial EV and biofuel plan combination despite still requiring a substantial cost to construct CNG station infrastructure. This is due to the much lower cost of CNG compared to gasoline, diesel, and biofuels.

4.5. Cost Effectiveness of Oil and Carbon Reduction Measures

As measures taken to reduce oil consumption and carbon emissions will impact the total cost, two parameters have been introduced to describe the increase of cost required to reduce consumption by 1 MTOE of oil and cost required to reduce emissions by 1 million ton-CO2.

Figure 2.50 shows the total cost for oil consumption reduction for each measure. The implementation of the government EV plan alone for the purpose of reducing oil consumption incurs very high cost. This high cost is due to the cost of charging stations, especially for BEV motorcycles, which will grow to a large population according to the government EV plan. The government EV plan resulted in a cost of Rp26 billion per MTOE, while the largest cost was for an isolated BEV scenario resulting in Rp35 billion per MTOE.

Figure 2.50. Cost per Mtoe Oil Consumption Reduction for Each Measure

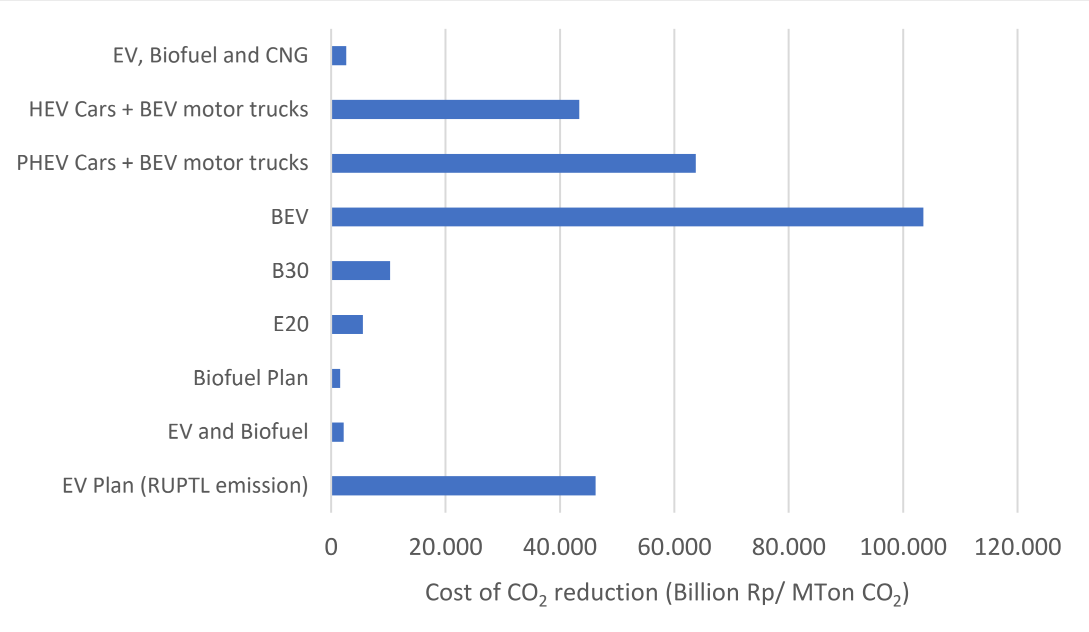


BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, Mtoe = million tons of oil equivalent, Mton = million ton, = million tons of oil equivalent, PHEV = plug-in hybrid electric vehicle, RUPTL = Rencana Umum Penyediaan Tenaga Listrik.
Source: Authors.

The implementation of biofuels is much more cost effective as no additional infrastructure is required and the biofuel directly substitutes oil-based fuels. Biofuels will also involve the existing vehicle population, as a large portion of these vehicles will be using these biofuels. As a result of this, a mixed biofuel and EV scenario can reduce the cost per Mtoe significantly from Rp26 billion per MTOE to Rp8.3 billion per Mtoe. Including CNG for HDVs into the mix reduces it further to Rp5.5 billion per Mtoe, only 25% more higher than the isolated biofuel scenario (Rp4.4 billion per Mtoe).

A similar condition is obtained regarding the cost for the reduction of carbon emissions (Figure 2.51). It can be seen that the modified EV plan with BEVs has the highest cost per million ton-CO2 reduction while the biofuel plan has the lowest. Implementing an EV plan with a biofuel plan somewhat alleviates the high specific cost. In general, xEV scenarios are the most expensive, both in regards to CO_2 reduction and oil reduction per rupiah. The implementation of PHEVs costs the lowest per ton CO_2 as it is assumed that PHEVs will be charged at home and thus do not require public charging stations. Thus, the PHEV scenario obtains a partial CO_2 reduction as if it operates partially as a BEV, but without additional infrastructure. Nevertheless, as all xEV scenarios incorporate BEV trucks, buses, and motorcycles and thus require charging stations, the cost per MTOE oil consumption reduction and cost per million ton-CO_2 emissions reduction remains high.

Figure 2.51. Cost per Million Ton-CO_2 Emissions Reduction for Each Measure



BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, Mton = million ton, = million tons of oil equivalent, PHEV = plug-in hybrid electric vehicle, RUPTL = Rencana Umum Penyediaan Tenaga Listrik.

Source: Authors.

The BEV scenario was also the most expensive at Rp103 billion per million ton-CO_2, whilst the government EV plan cost Rp46 billion per million ton-CO_2. Again, the high cost of all xEV scenarios was due to BEV trucks, buses, and motorcycles and thus require charging stations. It was seen also in regards to emissions that introducing biofuels in combination with the EV plan resulted in a very significant reduction of cost. The cost was reduced from Rp46 billion per million ton-CO_2 to Rp2.2 billion per million ton-CO_2 compared to the isolated EV plan. However, adding in CNG for HDVs and taxis resulted in a slight increase of cost to Rp2.7 billion per million ton-CO_2.

4.6. Summary as Policy Recommendation

A model has been developed to calculate the fuel consumption, energy use, carbon emissions, and cost of the implementation of different policies in the road sector. Scenarios representing BAU, effects of xEV adoption, and alternative fuels were set up and simulated. The reference/base scenario assumes a reduced and/or limited implementation of the mandatory biofuel schedule as set by the Ministry of Energy and Mineral Resources according to Ministerial Regulation No 25/2013 on the Revision of Regulation No. 32 Year 2008 concerning The Provision, Utilization and Commerce of Biofuels as Alternative Fuels. xEV scenarios simulated the government EV plan and with variations to the composition of HEV, PHEV and BEV.

Based on the simulation results, below are the following conclusions:

- Full biofuel plan implementation achieves the highest reduction as E20 affects gasoline consumption by the large motorcycle population.
- The biofuel plan as according to the 2015 mandate is shown to be drastically more cost effective than the EV plan in regards to both the reduction of CO_2 emissions and the reduction of oil consumption.
- This is due to the effect of xEVs in reducing oil consumption and CO_2 emissions is limited as the contribution is only from the new vehicle population EV plan impacting new vehicles, whilst the biofuel plan affects the fuel consumption of the entire vehicle population, both old and new.
- The implementation of BEV cars is expensive, largely due to the high cost compared to ICE cars and the high cost of constructing large numbers of charging points, and second, cost inflation is due to increased vehicle prices compared to ICE vehicles.
- It has been shown that BEV motorcycles (one station can serve 25 motorcycles) will require a large number of charging stations, thus increasing the cost of infrastructure increased significantly.
- The implementation of BEV cars can also be costly if it requires the construction of a large number of charging stations.
- Amongst the EV scenarios, implementation of HEVs has been shown to be the most cost effective to reduce oil consumption and carbon emissions as HEVs do not require additional infrastructure.
- The alternative EV plan with biofuel and CNG for HDV vehicles costs results in a reduced cost compared to the EV plan in regards to both oil reduction and carbon reduction. It is shown to be more cost effective than all other scenarios except the biofuel plan in isolation. In addition, it can be a viable option as BEV HDVs could be difficult to implement due to travel distance and charging requirements.

The recommendations are as follows:

- As biofuel implementation results in the largest reduction in oil consumption and carbon reduction as a single measure, biofuels should still be promoted, especially bioethanol implementation.
- With the current planned adoption rate, as xEVs result in a similar total carbon reduction and oil consumption reduction, all types can be promoted.
- However, as it is likely HEVs will be preferred due to the lower cost and not requiring new infrastructure, the adoption HEVs initially can familiarise society with xEVs, give time to prepare infrastructure and maintenance knowledge.
- If BEVs are to be adopted, measures should be implemented so that more vehicles can be served per charging station. People are encouraged to charge vehicles at home or charging times can be reduced drastically (e.g. battery swapping).
- The implementation of CNG (e.g. for heavy duty vehicles) can be used to offset the costs of BEV infrastructure and biofuel costs. Thus, a combination of xEVs with biofuel and CNG as alternative fuels should be promoted.

5. Future Plan for xEV Introduction in the Philippines (reference information)

The Government of the Philippines is continuously implementing programmes that promote the utilisation of alternative fuels and energy technologies (AFET) to effectively diversify and manage the country's utilisation of energy resources, thus improving the country's energy security as well as contributing to mitigating the adverse environmental effect of energy utilisation. AFET development leads to greater energy supply diversity and energy sustainability, and also contributes to the reduction of CO_2 emissions.

Major initiatives under these programmes include conducting nationwide information and awareness campaigns on AFET, the formulation of related policies, the promotion of indigenous and emerging energy technologies and innovations, and the implementation of the locally funded 'Alternative Fuels for Transportation and Other Purposes' project. These initiatives intend to reduce the country's dependence on imported oil by providing energy consumers with alternative fuels and energy technologies and more environmentally-friendly options aside from conventional fuels such as gasoline and diesel. The transport sector accounts for about 90% of imported oil utilisation.

The programme also calls for the promotion and mainstreaming of alternative fuels and advance transportation technologies, such as liquefied petroleum gas (auto-LPG), compressed natural gas (CNG), hybrid vehicles, plug-in hybrid electric vehicles (PHEV), and electric vehicles (EV).

Electric and Hybrid Electric Vehicles

The Department of Energy (DOE) has endeavoured to replace national government service vehicles with hybrid vehicles to promote energy efficiency and clean air across the country.

In 2013, the Government of Japan coordinated with the Department of Foreign Affairs and the DOE for the Japan Non-Project Grant Aid for the introduction of Japanese Advanced Products and its System (Next Generation Vehicle Package) for the Philippines. The aim of grant-aid for the country is to support and complement the government's rehabilitation and reconstruction efforts in areas affected by Typhoon Yolanda. It will also provide support to Japanese manufacturers through the introduction of their advanced technology vehicles while contributing to the government's efforts of promoting efficient and environmentally friendly alternative fuel vehicles (AFV).

Under the terms of the grant-aid, next generation vehicles such as hybrid vehicles, plug-in hybrid electric vehicles, and EVs, including charging stations will be procured by the Government of Japan and delivered to the Philippines through the DOE for deployment to identified beneficiaries. Target beneficiaries of the grant-aid include the Philippine national police stations in the provinces of Leyte and Samar which were devastated by Typhoon Yolanda, and national government agencies (NGA) regional offices in Region VIII that are instrumental to emergency response operations and rehabilitation. NGAs that can assist in conducting research, performance testing, and the promotion of AFVs were also allotted with vehicles for promotional purposes.

The Philippines acquired 24 units of the 2017 Toyota Prius through Japan's Non-Project Grant Aid. The 2017 Toyota Prius features an optimised fuel engine and electric motor to attain the highest level of energy efficiency. Eight hybrid cars will also be given to government offices in Region VIII to support the economic and social recovery of communities devastated by Typhoon Yolanda.

Figure 2.52. The 2017 Toyota Prius, Test Drive by Energy Secretary

Philippine Energy Secretary Alfonso Cusi with Japanese Ambassador to the Philippines Kazuhide Ishikawa as his passenger, had a test drive of one of the 24 units of the donated Toyota Prius (2017 model).

Source: Department of Energy of the Republic of Philippines (https://www.doe.gov.ph/press-releases/photo-release-hybrid-car-test-drive).

Deliveries commenced in the 1st quarter of 2017 and were completed by the 2nd quarter of 2017. After successful deployment, the DOE will start to conduct performance testing of said vehicles to develop energy performance criteria for EVs and electric charging stations.

To promote mainstreaming of alternative fuels, the DOE has drafted various issuances to pave the way for the procurement and institutionalised patronage of AFVs amongst government agencies and government-managed institutions and corporations. These draft issuances set guidelines in the acquisition of AFVs.

In support of electric vehicle technologies, the DOE also drafted an issuance that provides the framework for electric charging stations.

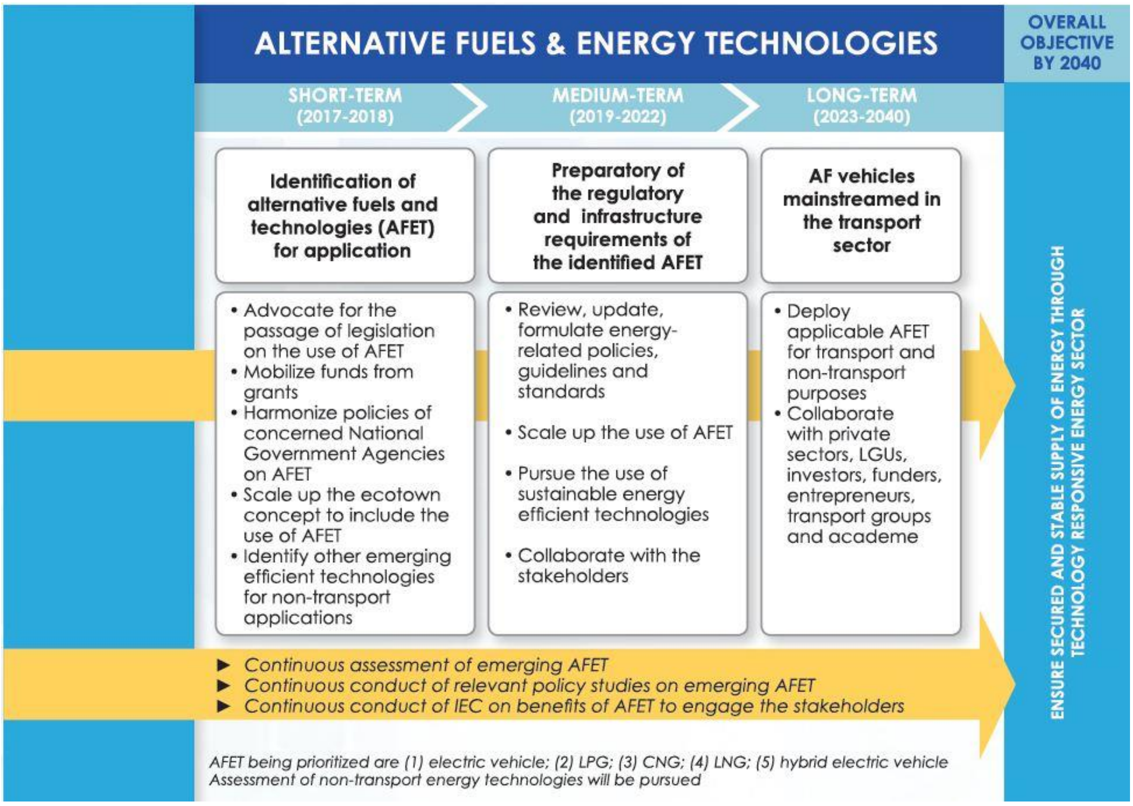
To ensure the proper use of the vehicles donated by the Government of Japan that were distributed to various NGAs, the DOE has issued Guidelines on the Use of Next Generation Vehicles. These guidelines cover the proper monitoring of performance data, which shall be used in validating energy efficiency to further promote next generation vehicles. It also provides the guidelines for the use and maintenance of the vehicles in order to prolong their economic life and maximise their promotional value.

Alternative Fuels and Energy Technologies Roadmap

The AFET Roadmap indicates the department's over-all long-term plans and strategies to attain the efficient management of energy resources through fuel diversification and adoption of new and advanced energy technologies.

To attain the overall goal of 'Ensuring Secure and Stable Supply of Energy through Technology Diversification', the DOE shall embark on activities in line with the identified strategies throughout the planning period. Activities for the short and medium-term period (from 2017 up to 2022) include identification of AFETs for the application and preparation of the regulatory and infrastructure requirements of identified AFETs, respectively. By 2023–2040, alternative fuels vehicles should have been mainstreamed in the country's transport sector.

Figure 2.53. Alternative Fuels and Energy Technologies Roadmap 2017–2040



CNG = compressed natural gas, IEC = Information, Education and Communication Campaign, LGU = local government unit, LNG = liquefied natural gas, LPG = liquefied petroleum gas.
Source: Philippine Energy Plan 2017–2040, Department of Energy.

The AFET Roadmap envisions the successful adoption and commercialisation of alternative fuels and energy technologies through strong and collaborative partnership with the private sector and full government support in providing enabling mechanisms and building-up local capacity for research and development of emerging energy technologies.

Promotion of Electric Vehicles

The country's electric vehicle industry hopes to achieve a nation where the use of electric vehicles is highly promoted, encouraged, and supported by government and society in order to develop an environmentally, ecologically, and economically sustainable transport landscape.

The industry is represented by the Electric Vehicle Association of the Philippines, which aims to establish a national development programme for electric vehicles that is anchored on the existing Motor Vehicle Development Program for the automotive industry. The programme shall be implemented in four phases in 10-year period. The first phase was the launching of the programme in 2013 that also included technology upgrading needed by the industry. The second phase involved build-up of the local market and production capacity enhancement in 2014–15, whilst the third phase was devoted for local and export market expansion, along with horizontal and vertical integration with the local automotive industry in 2016–18. The final phase covering 2019–23, will be the full integration, regional and global developmental evolution in technological advancement, and market size up.

The promotion of electric vehicles is a collaborative effort amongst the DOE, concerned government agencies, local government units, academies, car manufacturers, and the industry.

Various Initiatives from Academies, Local Government Units, and Car Manufacturers

Ateneo de Manila University's electric jeepney (e-jeep) is a typical part of daily life inside the university. It is not just for the students – it is also helpful for those who have difficulty in walking long distances on campus, such as elderly or disabled staff and visitors. As the university president Father Jett Villarin said 'Any institution, such as a campus, has a footprint. Our goal is to assess that footprint and to actually reduce it. We just need to reconfigure the way we produce energy, the way we move people, goods and services'. The e-jeeps are operated and maintained entirely by Meralco subsidiary 'eSakay' – drivers, six vehicles running around the campus, and four-bay charging stations.

Figure 2.54. Ateneo De Manila University's Electric Jeepneys

Source: Rappler (2019b).

Muntinlupa City, which is fast shaping up as the greenest city in the country, has deployed e-jeeps in various sites in the city. It has the greatest number of e-jeeps running in one city due to the efforts of the local government unit and the private sector. The President of the Electric Vehicle Association of the Philippines, Rommel Juan observes that Muntinlupa City gives free rides to its residents, one way of introducing green transport to more commuters and gaining acceptance as well.

Figure 2.55. Electric Jeepneys Ride for Free in Muntinlupa City

Source: Manila Bulletin (2016).

Meanwhile, 20 units of e-jeeps are fielded to provide transport service to workers, office staff, shoppers, visitors, and residents inside the Filinvest City Alabang, a huge mixed-use real estate development in Muntinlupa City.

Figure 2.56. Electric Jeepneys inside Muntinlupa City's Filinvest City Alabang

Source: Manila Bulletin (2016).

On 18 January 2019, the Land Transportation Franchising and Regulatory Board launched a new e-jeep route from Makati City to Mandaluyong City. Fifteen e-jeeps are now plying new route from 5 am to 12 midnight. The new e-jeeps, dubbed as eSakay, were done in partnership with Meralco (a major electricity distribution utility) and the city governments of Makati and Mandaluyong under the public utility vehicle modernisation programme. The e-jeeps are 100% electric and feature an automated fare collection system through Beep, a GPS tracking system, CCTV cameras, free WiFi on-board, and USB ports.

Figure 2.57. Electric Jeepneys Plying New Route from Makati City to Mandaluyong City

Source: Rappler (2019a).

The car manufacturers have also started their respective initiatives to mainstream electric vehicles in the country's vehicle population. Nissan Philippines Inc. shall start selling EVs by 2020 as it plans to promote electrification in Southeast Asia. Nissan Philippines, in a statement, said the Nissan Leaf would be available in the country by 2020 as part of the automotive brand's commitment to push for higher EV sales. The company wants EVs to account for 25% of its sales volume under the Nissan's Move to 2022 plan. The plan also includes the assembly and localisation of electrification components in the Southeast Asian region, in addition to selling EVs.

Figure 2.58. Nissan Electric Vehicle, 'Leaf' Model

Source: Philippine Star (2019).

Meanwhile, Toyota Motor Philippines jumpstarted its hybrid electric vehicle (HEV) campus tour series by forging a partnership with MAPUA University's Mechanical and Manufacturing Engineering Department. The first leg of the educational caravan, held at the MAPUA school grounds in Intramuros, Manila, offered both students and faculty a first-hand look at the benefits of HEV technology through symposiums and all-day test drive activities. MAPUA University is currently the first Toyota partner in its series of HEV campus tours, with the University of Santo Tomas and De La Salle University to follow in the coming months. This Toyota Motor Philippines effort is aligned with the Toyota Environmental Challenge 2050, posed by Toyota Motor Corporation President, Akio Toyoda to promote a sustainable approach to the future of mobility.

Mitsubishi Motors Corporation has turned over various units of e-vehicles such as the Outlander(PHEV and i-MiEV electric vehicles and charging stations to different government agencies, the DOE, the Department of Environment and Natural Resources, the Department of Trade and Industry, the Department of Science and Technology, and the Office of the President. The initiative aims to promote the use of hybrid EVs and create greater public awareness of EVs as well as helping the country to sustain a clean and healthy environment.

Figure 2.59. Toyota HEV 'Prius' Campus Tour at Mapua University

Source: Carmudi (2019).

Figure 2.60. Mitsubishi Motors Corporation's Handover of PHEVs and i-MIEVs

PHEV = plug-in hybrid electric vehicle.
Source: Autodeal (2018).

Pending Bills (under the 17th Congress)

There are various legislative bills pending under the 17th Congress which will provide incentives and promote mainstream use, manufacture, assembly, and conversion of electric, hybrid, and other alternative fuel vehicles in the country.

- Senate Bill No. 678 'An Act Providing Incentives for the Mainstream Use, Manufacture, Assembly and Conversion of Electric, Hybrid and Other Alternative Fuel Vehicles and for Other Purposes'
- Senate Bill No. 460 'An Act Providing Incentives for the Manufacture, Assembly Conversion and Importation of Electric, Hybrid and Other Alternative Fuel Vehicles and for Other Purposes'
- Senate Bill No. 709 'An Act Promoting the Mainstream Use of Electric, Hybrid and Other Alternative Fuel Vehicles and for Other Purposes'

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