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Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asia Summit Countries

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List of Abbreviations and Acronyms

AEDP	Alternative Energy Development Plan (Thailand)
AES	aggressive electrification condition scenario (India)
AFET	alternative fuels and energy technologies
AFS	alternative fuels scenario (India)
AFV	alternative fuel vehicle
BAU	Business as Usual
BEV	battery electric vehicle
BIS	Bureau of Indian Standards (India)
BOE	barrel of oil equivalent
BOI	Thailand Board of Investment
BPD	barrels of oil per day
CAFE	corporate average fuel efficiency
CAGR	compound annual growth rate
CGD	city gas distribution
CL	cropland
CNG	compressed natural gas
DEDE	Department of Alternative Energy Development and Efficiency (Thailand)
DEN	Dewan Energi Nasional (Indonesia)
DOE	Department of Energy (Philippines)
EAS	East Asia Summit
EEP	Energy Efficiency Plan (Thailand)
EGAT	Electricity Generating Authority of Thailand
ENCON Fund	Energy Conservation Fund (Thailand)
EPPO	Energy Policy and Planning Office (Thailand)
EV	electric vehicle
EVAT	Electric Vehicle Association of Thailand
FL	forest land
GBEP	Global Bioenergy Partnership

GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GL	grassland
HCV	heavy commercial vehicle
HDV	heavy duty vehicle
HEV	hybrid electric vehicle
HPS	moderate electrification cum hybrid promotion scenario (India)
ICE	internal combustion engine
IEA/SMP	International Energy Agency/Sustainable Mobility Project
KEN	Kebijakan Energi Nasional (National Energy Policy) (Indonesia)
LCA	life cycle assessment
LCV	light commercial vehicle
LUC	land use change
MEMR	Ministry of Energy and Mineral Resources (Indonesia)
MES	moderate electrification scenario [India]
METI	Ministry of Economy, Trade and Industry (Japan)
MMSCFD	millions standard cubic feet per day
MoF	Ministry of Finance
MOPNG	Ministry of Petroleum and Natural Gas (India)
MSW	Municipal Solid Waste
MTG	methanol to gasoline
MTOE	million tons of oil equivalent
NDC	Nationally Determined Contribution
NGA	national government agency (Philippines)
NRCT	National Research Council of Thailand
ODMT	oven-dry metric ton
OES	only electrification scenario (India)
OTP	Office of Transport and Traffic Policy and planning (Thailand)
Pertamina	Perusahaan Pertambangan Minyak dan Gas Bumi Negara (Indonesian State Oil and Gas Company)

PHEV	plug-in hybrid electric vehicle
PKS	palm kernel shell
PLN	Perusahaan Listrik Negara (State Owned Power Company)
TERI	The Energy and Resources Institute
TISI	Thailand Industrial Standards Institute
TtW	tank-to-wheel
UNFCCC	United Nation Framework Convention on Climate Change
UNECE	United Nations Economic Commission for Europe
VKT	vehicle kilometres travelled
WTE	waste-to-energy
WtT	well-to-tank
WtW	well-to-wheel
xEV	electrified vehicle

Executive Summary

1. Background and Objectives

The electrification of mobility is now in fashion and some countries are announcing bans on internal combustion engines. From the viewpoint of production to consumption of energy, electric cars are not always zero-emission vehicles, if the supplied electric power comes from fossil resources. In addition, the spread of electric supply stations is indispensable to the introduction of electric vehicles. However, the rapid expansion of supply stations is difficult.

On the other hand, vehicles with improved fuel efficiency like hybrid and plug-in hybrid electric cars have appeared and those cars are also effective for the reduction of greenhouse gas (GHG) emissions. Conventional infrastructure can be made available for these cars and the reduction of GHG emissions can be expected by the promotion of biofuels that are produced from domestic resources in East Asia Summit (EAS) countries. Further the improvement of emissions reduction can be expected by increasing the proportion of biofuels.

Against this background, this report investigates the following two subjects: (1) evaluation of CO_2 emissions reduction by mobility electrification, and (2) supply potential of next generation biofuels from non-conventional resources during fiscal years 2018–2019. In the first subject, the best way of effective GHG emissions reduction is clarified based on scenarios assuming various electrified vehicles ([xEV]: hybrid electric vehicles [HEV)] plug-in hybrid electric vehicles [PHEV], and battery electric vehicles [BEV]) and the introduction of biofuels. The second subject discusses the high concentration of biofuels in perspective, the supply potential of unconventional biomass resources, biofuel production from unconventional biomass, and life cycle assessment (LCA) for biofuel production.

Based on these results, we propose the possibilities on the reduction of energy consumption in the transport sector and the introduction of next generation biofuels in the EAS countries. The outcome will contribute to the EAS energy research roadmap (Pillar 3: Climate Change Mitigation and Environmental Protection Corresponding to ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025, 3.5 Programme Area No.5: Renewable Energy, and 3.6 Programme Area No.6: Regional Energy Policy and Planning).

2. Methodology

The working group consisted of invited energy experts, including policymakers and engineering scientists from each country. This study covers the following topics.

2.1. Evaluation of CO_2 emissions reduction by mobility electrification

Energy and electric vehicle-related policies and basic information were investigated in three countries (India, Indonesia, and Thailand). The governments' xEV introduction targets (how many, by when) were identified to settle the conditions for a scenario simulation based on the information collected. Some scenarios for the xEV mix simulation were proposed by considering all the types of xEVs to find out a reasonable and most effective xEV mix. The effectiveness of xEV mix scenarios in terms of the reduction of oil consumption and CO_2 emissions whilst using biofuels and natural gas was evaluated. The total cost of the introduction of xEVs, including infrastructure cost, was also compared to judge and propose the most appropriate solution as a policy recommendation.

We also surveyed governments' efforts for introducing motorised vehicles in the Philippines.

2.2. Supply potential of next generation biofuels from non-conventional resources

In Indonesia, the amount and production area of forest resources, agricultural waste, municipal solid waste (MSW), and algae available for power generation and biofuel production were investigated. In addition, we surveyed the development status of next-generation biofuel production technology.

Promising non-conventional raw materials for producing bioethanol were clarified based on their composition. Factors that are effective for reducing potential energy consumption and GHG emissions in the bioethanol manufacturing process from non-conventional raw materials were also examined. The environmental impact assessment of biofuel production was investigated by LCA.

3. Results and Discussion

3.1. Evaluation of CO_2 emissions reduction by mobility electrification

We analysed current and future energy issues of the introduction of electric vehicles of each country based on the supplied data from three countries (India, Indonesia, and Thailand) and discussed possible measures. The simulation was carried out by setting the scenario for each country according to the actual situation of each country. Summaries are shown below.

India

Electrified vehicle and alternative fuel introduction scenarios:

- Business as Usual (BAU) Scenario (Base)
  In this scenario, the status quo is maintained and is characterised by the continuation of the existing trends.
- Alternative Fuels Scenario (AFS)
  This scenario is characterised by policy impetus for increasing the share of compressed natural gas (CNG)-fuelled vehicles coupled with the attainment of increased targets for ethanol blending with petrol and biodiesel blending with diesel.
- Moderate Electrification Scenario (MES)
  In the medium electrification scenario, the electrification target is reasonably high compared to the BAU scenario. This scenario covers the increasing adoption of

battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs). Electrification takes place across all categories of road vehicles including taxis, passenger cars, tricycles, and buses.

- Aggressive Electrification Scenario (AES)
  In this scenario, the electrification target is much higher than the BAU scenario and includes the active adoption of battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs) for passenger mobility. Electrification levels will be higher across all categories of road vehicles including taxis, passenger cars, tricycles, and buses.

- Moderate Electrification cum Hybrid Promotion Scenario (HPS)
  In the HPS, the share of new sales of hybrid electric vehicles is higher than that of MES.

- Aggressive Electrification condition and Only Electrification Scenario (OES)
  This scenario is a hybrid of the BAU scenario and the aggressive electrification scenario described above.

Results based on simulation:

- The electrification scenarios alone do not have much effect in reducing CO_2 emission levels.

- The alternative fuels scenario (AFS) and moderate electrification cum hybrid promotion scenario (HPS) have the maximum impact in terms of CO_2 emissions.

- The electrification scenario shows a reduction in CO_2 emissions from tank-to0wheel, but it leads to a reduction in CO_2 emissions when the EV's additional electricity demand is met by electricity generated from renewable energy.

- In this study, the penetration of xEV is assumed mainly in the two-wheeled, three-wheeled vehicles, and automotive segments. Heavy commercial vehicles, light commercial vehicles, and buses account for about 70% of the transport sector’s energy consumption in India. The reduction of energy consumption in this category is an important issue for the future.

- The existing installed capacity of the Indian power sector is in excess of demand. In order to realise power supply with renewable energy in this situation, the increase in power demand due to the introduction of electrified vehicles can be the driving force.

Thailand

Electrified vehicle and alternative fuel introduction scenarios:

- Business as Usual (BAU) Scenario (Base)
  Refer to the current trend of the road transport system plus the success of Thailand's biofuel policy including ethanol share shift to gasohol E15 and biodiesel B7.6 for commercial grade diesel, and the introduction of 1,800 hybrid buses.

- Alternative Fuels Scenario
  Gasohol E20 and Biodiesel B10 will succeed in the market 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 Thailand Board of Investment Plan)
  Total HEV sales achieve 320,000 units by 2023, and 4.7 million units by 2036.

- Hybrid Expansion Scenario (HEV Extreme)
  HEVs dominate 50% sales of passenger cars (gasoline originated) by 2036, noted 7.1 million on-road HEVs by 2036.

- Combination Scenario
  The following two cases were simulated:
  (1) Combination of Alternative Fuels and HEV BOI promotion
  (2) Combination of Alternative Fuels and extreme HEV expansion

Results based on simulation:

- The impacts of energy efficiency of HEV is higher than the difference in well to tank emissions between fossil fuel and biofuels.

- The share of diesel cars will be reduced with increasing EVs share (biodiesel reduced; ethanol increased).

Indonesia

Electrified vehicle and alternative fuel introduction scenarios:

- Business as Usual (BAU) Scenario (Base)
  This scenario assumes that biofuel use will be maintained at 2018 conditions. The simulation conditions are 0.5% per year fuel economy improvement, no CNG vehicle introduction and 2015 biodiesel directive up to B20, but no ethanol use for all new vehicles of a certain manufacturing year.

- Biofuel Scenario
  The mandatory biodiesel content of diesel blends was set to 30% by 2020 and bioethanol content in gasoline measures was set to 10% by 2020 and 20% by 2025. The conditions of the simulation are 0.5% per year fuel economy improvement of all vehicles, no introduction of CNG vehicles, implementation of biodiesel directive up to B30 and bioethanol directive up to E20, motorcycles are compatible with ethanol.

Furthermore, simulations were performed under the conditions of B30 introduction and no bioethanol introduction and B20 and E20 introduction.

- CNG Implementation Scenario
  The scenario included using CNG for heavy vehicles and taxis. CNG heavy vehicles in the five major cities accounted for 48% of the new heavy vehicles and all taxi sales were assumed to be CNG-based. In this scenario, the introduction of CNG heavy-duty vehicles and taxis were combined with the implementation of the Biofuels Directive and the government's EV plan. The parameters of this scenario are fuel economy improvement of 0.5% per year for all vehicles, 48% of all new taxis, buses, and trucks in the cities of Palembang, Bandung, Medan, Jakarta, and Surabaya being CNG capable the introduction of B30 and E20, and government EV plans.

- Vehicle Electrification (xEV) Scenario
  It investigates a government plan to introduce an electric-based vehicle (xEV) consisting of a battery electric vehicle (BEV), a hybrid electric vehicle (HEV), and a plug-in hybrid electric vehicle (PHEV). As an individual xEV change scenario, we simulated a modified EV plan assuming that the xEVs of all private cars are HEVs, PHEVs, and BEVs, respectively.

Results based on the simulation:

- In comparison by transportation fuel type, CO_2 emissions from electricity is significantly higher.
- PHEV and BEV acceleration scenarios have only slightly higher CO_2 emissions than HEV acceleration scenarios.
- The effect of reducing oil consumption is in the order of bioethanol introduction >> CNG > xEV ~ biodiesel.

Recommendations

Based on the results of the simulation, the working group made the following recommendations regarding the effective introduction of electrified vehicles common to all countries.

(1) The combination of vehicle electrification (xEV mix basis) and alternative fuels utilisation, such as biofuels, should be promoted as it is the most effective in reducing oil consumption and/or CO_2 emissions.

(2) xEV mix (including HEV) consideration for vehicle electrification has a positive effect on promoting the use of biofuels.

(3) The 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/CO_2 emissions by replacing diesel fuel mainly.

(4) The known effect of BEV introduction on oil consumption and/or CO_2 emissions reduction is limited as BEVs are type of new vehicle population.

(5) Well-to-wheel basis CO_2 emissions of BEV are not always lower than HEV (or even compared to internal combustion engine vehicles) depending on the CO_2 emissions of power generation and reducing CO_2 emissions of power generation is an issue.

(6) The cost of implementation is lower with a combination of xEV mix and alternative fuels utilisation due to the higher costs of the introduction of BEVs with charging infrastructure construction, cost effectiveness of oil consumption and/or CO_2 emissions reduction as well.

In addition, it is presumed that the demand for each type of biofuel will change in the future with the introduction of electrified vehicles. The policy of electrified vehicle introduction should be discussed together with the power generation plan and biofuel introduction policy.

3.2. Supply potential of next generation biofuels from non-conventional resources

In this topic, members focused on two subjects: (1) the promising resources for producing next generation biofuel, and (2) the optimum process selection for producing bioethanol. The conclusions are shown as follows:

The promising resources for producing next generation biofuel

- Non-conventional resources for biofuel production in Indonesia were investigated.
- Supply potential is limited to several areas. The Riau province of central Sumatra has the greatest potential.
- Non-conventional resources for biofuel production include forest residues, wood processing waste, and agricultural waste.
- The availability of wood processing waste depends on its type and the area where it is discharged.
- As agricultural waste, rice straw, rice husk, empty fruit bunch, and palm frond are expected to be supplied in a considerable amount.
- To produce gasoline and diesel fuel, co-processing of palm oil and palm-derived bio crude oil with petroleum fractions have been developed at petroleum refineries.
- Ethanol production from lignocellulose is currently only working on small-scale test plants.
- Municipal solid waste (MSW) is mainly disposed of in landfill sites, causing environmental problems. MSW may be used as an energy resource for power generation. Therefore, the utilisation of MSW can contribute to global warming gas emissions control at power generation by the control of coal use.
- Indonesia has a long coastline, so it is suitable for algae cultivation and fuel production from algae. However, fuel production from algae is only at the research stage.

The optimum process selection for producing bioethanol

- There are many non-conventional biomass types that can be expected to yield ethanol comparable to starch crops.
- Productivity of lignocellulosic ethanol is difficult to estimate accurately because

there are many development factors in the whole process.

- Many elemental technologies are currently under development.
- Estimated ethanol yield is 30%–40% of lignocellulosic biomass (dry base). By the utilisation of pentose (C5 sugar), the ethanol yield can be improved (1.4 times as compared with the case of using only hexose).
- By utilising lignin, the environmental impact can be reduced, and economics can be improved.
- When lignocellulose ethanol is used at high concentrations, the effect of GHG emissions on ethanol production becomes larger. For ethanol production, it is more important to select raw materials and optimisation of processes with less environmental impact.

3.3. Recommendations

- The supply potential of non-conventional biomass resources depends on the region. Therefore, the location of the fuel production facility should be considered in consideration of the biomass production area.
- Most production technology of next generation biofuel from non-conventional resources is still at the research and development stage. Therefore, research and development should be continued to provide data that can accurately estimate production efficiency, environmental compatibility, and economy.
- In the short term, reducing the ratio of fossil fuels in stages is effective for alleviating the environmental impact. Energy production by sharing non-conventional biomass and fossil resources is a practical method as it does not require high-hurdle technology. Specifically, liquid fuel production by co-processing palm oil or bio crude oil derived from palm oil and petroleum, co-gasification or co-firing power generation of biomass and coal may be mentioned.

4. Conclusion as Policy Recommendations

Passenger cars are the mainstream of the current introduction of electrified vehicles. In order to reduce energy consumption and greenhouse gases in the transport sector as a whole, it is necessary to take measures for each genre of passenger cars, heavy commercial vehicles, and motorcycles.

For the introduction of electrified vehicles, HEVs that can actively utilise biofuels without being restricted by infrastructure should be introduced in the short term. Along with the development of charging infrastructure, PHEVs should be introduced in the medium to long term.

Currently, the introduction cost of electrified vehicles is high. As a solution to this, incentives should be given to reducing vehicle acquisition taxes and introducing electrified vehicles by strengthening taxation on existing vehicles.

Motorcycles are mainly used for short trips in cities and are suitable for electrification. Since there are many registered vehicles in the Association of Southeast Asian Nations (ASEAN) region, we should actively promote electrification.

Natural gas is a promising alternative to petroleum diesel fuel for heavy duty commercial vehicles, where it is difficult to take environmental measures by electrification. Since natural gas can also be used as a fuel for civilian use, the development of supply stations should be planned, together with the development of urban infrastructure.

The effect of reducing greenhouse gas emissions by electrified vehicles strongly depends on the energy composition of power generation. Breaking away from coal-fired power is the key to success.

The introduction of biofuel is effective in reducing GHG emissions and oil consumption. Combined with the electrification of vehicles, a synergistic effect can be obtained. In order to be competitive in terms of price, it is necessary to continue to consider incentives for biofuel supply and the reduction of fuel tax for consumers.

The current electrification of vehicles is mainly to replace gasoline passenger cars. As the replacement of diesel vehicles with electrified vehicles progresses, it is expected that the demand for biodiesel fuel will change to bioethanol fuel. In response to changes in demand for biofuels, it is necessary to balance production and inventory in domestic markets and import and export in ASEAN to balance the supply and demand.

The next-generation fuel, lignocellulosic ethanol, has not yet been fully optimised for production processes or demonstrated on a commercial scale. In the future, we should search for biomass resources that bring about high productivity, establish energy-efficient production processes with high production efficiency, reduce energy consumption in production processes by using by-products (lignin), and create production sites to ensure economic efficiency. It is necessary to consider economic improvement by site selection and combined use of first-generation raw materials to improve productivity.

Instead of plantation development, which sometimes causes environmental damage, we must consider the use of agricultural and forestry waste.

The electrification of vehicles and the introduction of biofuels should be promoted according to a firm policy based on a medium- to long-term perspective that is not influenced by the political situation at the time. Accurate data collection from the transport and agriculture and forestry sectors are also essential for the calculation when formulating policies.

Chapter 1

Introduction

1. Background and Objectives

The electrification of mobility is now in fashion and some European countries have announced a ban on internal combustion engines in the future. From the perspective of production to energy consumption, electric vehicles are not necessarily zero-emission vehicles when electricity is supplied from fossil resources. In addition, the spread of electric supply stations is indispensable to the introduction of electric vehicles. However, the rapid expansion of infrastructure such as supply stations is difficult.

On the other hand, vehicles with improved fuel efficiency like hybrid and plug-in hybrid cars have appeared and those cars are also effective for the reduction of greenhouse gas (GHG) emissions. Conventional infrastructure is available for these vehicles, and GHG emissions reduction can be expected by promoting the use of biofuels produced from domestic resources in the East Asia Summit (EAS) countries. In order to introduce electrified vehicles, it is realistic to proceed step-by-step depending on the characteristics of vehicles and the development of infrastructure. However, it is not always clear whether the current electrified vehicle introduction plan is effective in reducing the environmental load.

In this study, we set up multiple scenarios in consideration of the introduction of policies of electrified vehicles in each country, and calculated by simulation the energy consumption, global warming gas emissions, and biofuel demand in each case. Based on the results, the best way to introduce electrified vehicles to reduce GHG emissions was clarified. We also held policy dialogues with government policymakers and industry representatives to exchange opinions on the research results. With these opinions in mind, we made recommendations on future environmental measures and biofuel policies in the transport sector. Regarding next-generation bioethanol produced from non-conventional resources, we have identified the challenges for commercial-scale supply.

The results of this research will contribute to the EAS energy research roadmap (Pillar 3: ASEAN Action Plan for Energy Cooperation 2016–2025 Climate Change Mitigation and Environmental Protection) 3.5 Program Area No. 5: Regeneration Energy and 3.6 Program Area No. 6: Regional Energy Policy and Planning).

2. Methodologies

A working group was established and operated with invited experts of energy policy makers, energy engineering scientists, amongst others, from each country. This study covered the simulation of the GHG emissions reduction effect by the electric vehicle based on the electric power situation and the fuel efficiency improvement vehicles using biofuel, and the estimation of the biofuel supply potential including the biofuel derived from non-conventional biomass resources needed in the high concentrated use of biofuels by vehicles. In the first step, the current supply and demand situation of electric power and biofuels in some ASEAN countries were investigated. Policies on the introduction of electrified vehicles of each country were also investigated. Based on collected data, well-to-wheel CO_2 emissions were estimated in the second step. Finally, the reduction effect of CO_2 emissions by electrification was calculated by a simulation and effective plans for mobility electrification were proposed. In addition, the amount of non-conventional biomass resources and the productivity of the next generation biofuels were investigated, and the biofuel supply potential was made clear to correspond to the high concentrated use of biofuel in vehicles.

3. Research Schedule

In 2019, we held two working group meetings. Members from India, Indonesia, and Thailand reported on national policies regarding the introduction of electrified vehicles. In addition, scenarios were set up to simulate the impact of introducing electrified vehicles on energy consumption such as oil consumption and the reduction of environmental impact. In addition, as demand for bioethanol is expected to increase with the growth of electrified gasoline vehicles such as hybrid electric passenger cars, we conducted a survey on the use of non-conventional resources and lignocellulosic ethanol. In 2020, based on the simulation results of the first year, we discussed the effective introduction of electrified vehicles that contribute to energy consumption reduction and GHG emissions reduction, and summarised policy recommendations. We invited government officials and representatives of industry in India, Indonesia, and Thailand to hold policy dialogues, make policy recommendations, and exchange opinions.

The outline of the events is shown below, and details are summarised in the appendix at the end of this report.

3–6 December 2018	Field Surveys in India, Thailand, and Indonesia
30–31 January 2019	FY2018 First Working Group Meeting in Bangkok, Thailand
8–9 May 2019	FY2018 Second Working Group Meeting in Yogyakarta, Indonesia
10 May 2019	Management Discussion in Jakarta, Indonesia
15 January 2020	FY2019 First Working Group Meeting in Koriyama, Japan
25 February 2020	Policy Dialogue in Bangkok, Thailand
3 March 2020	Policy Dialogue in Yogyakarta, Indonesia
13 March 2020	Policy Dialogue in New Delhi, India

Chapter 2

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

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

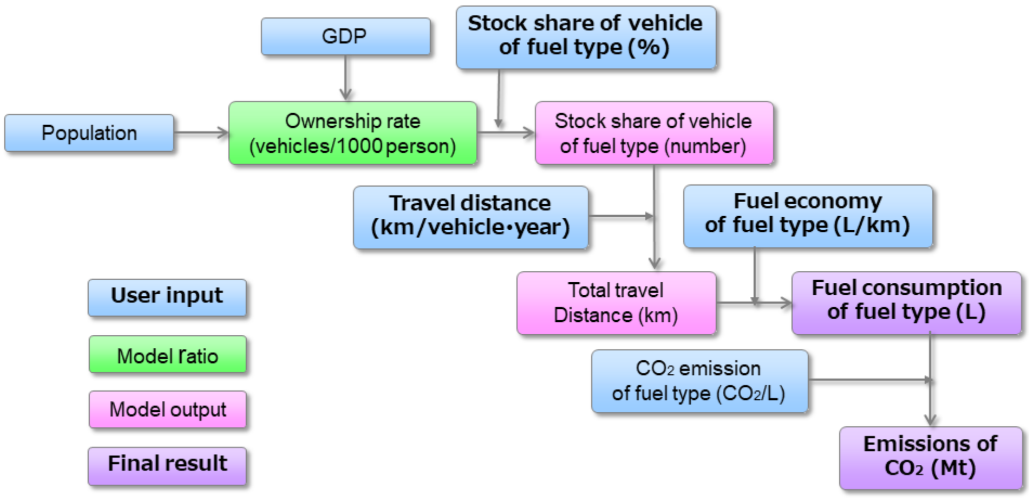
The objective of this study is to propose the most appropriate measure for mobility electrification, based on the investigation of effectiveness of xEV mix scenarios together with the use of alternative fuels. The study covered three countries of India, Thailand, and Indonesia as the governments of these 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	-	-	-	-	-

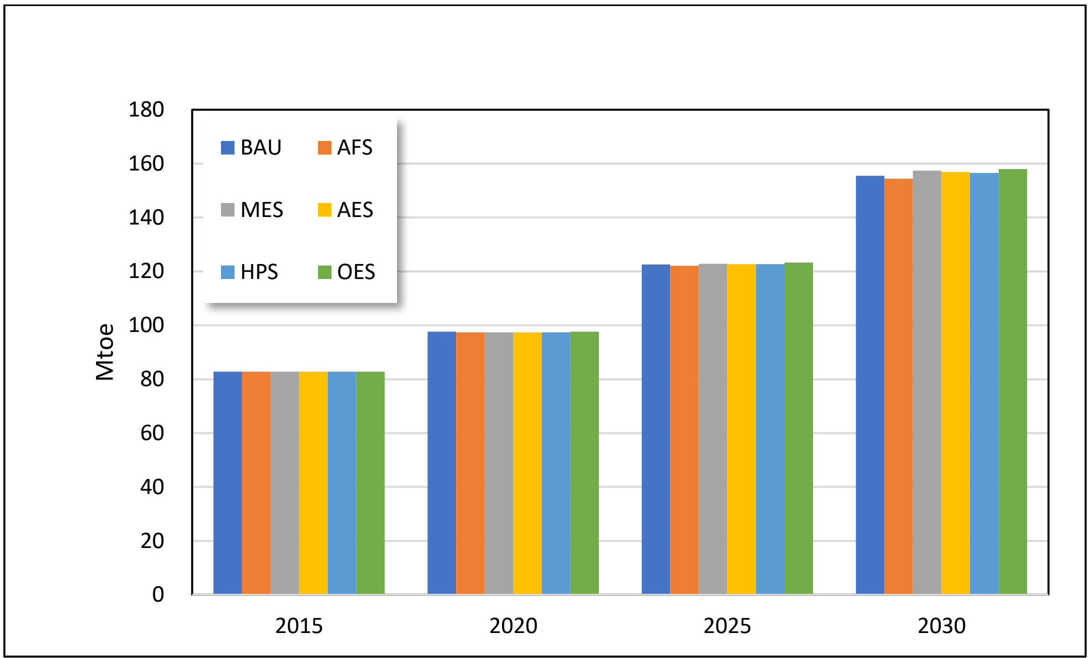
- stands for negligible.
CNG = compressed natural gas, OES = Only Electrification Scenario.
Source: Authors.

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

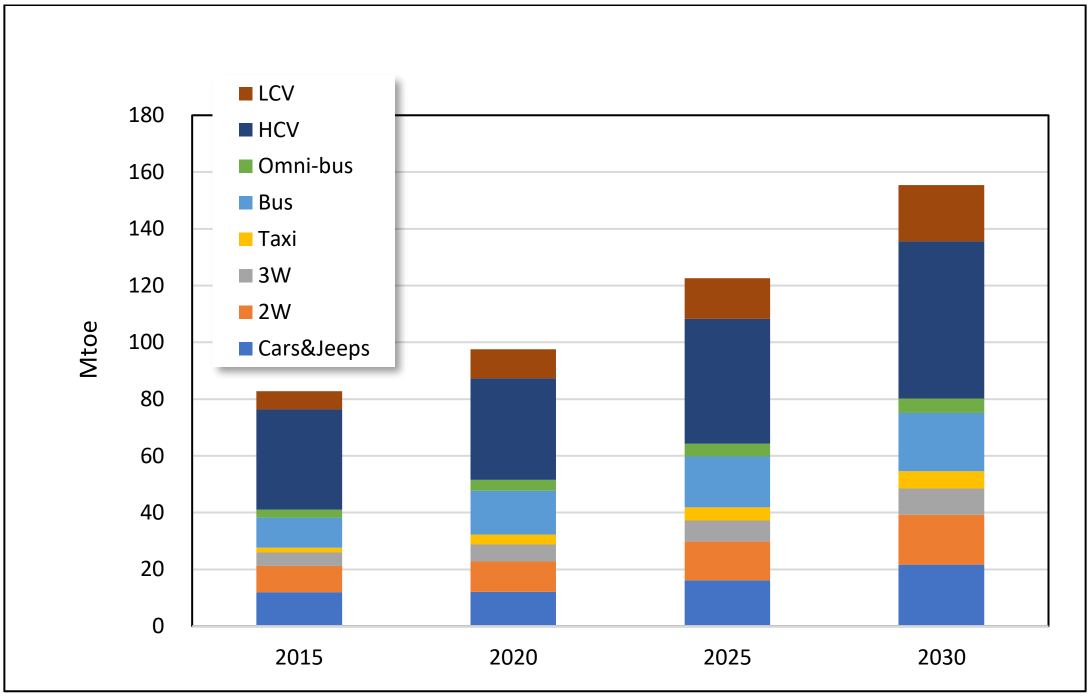


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, Mtoe = million tons of oil equivalent, OES = Only Electrification Scenario.
Source: Authors.

Energy Demand by Vehicle Type

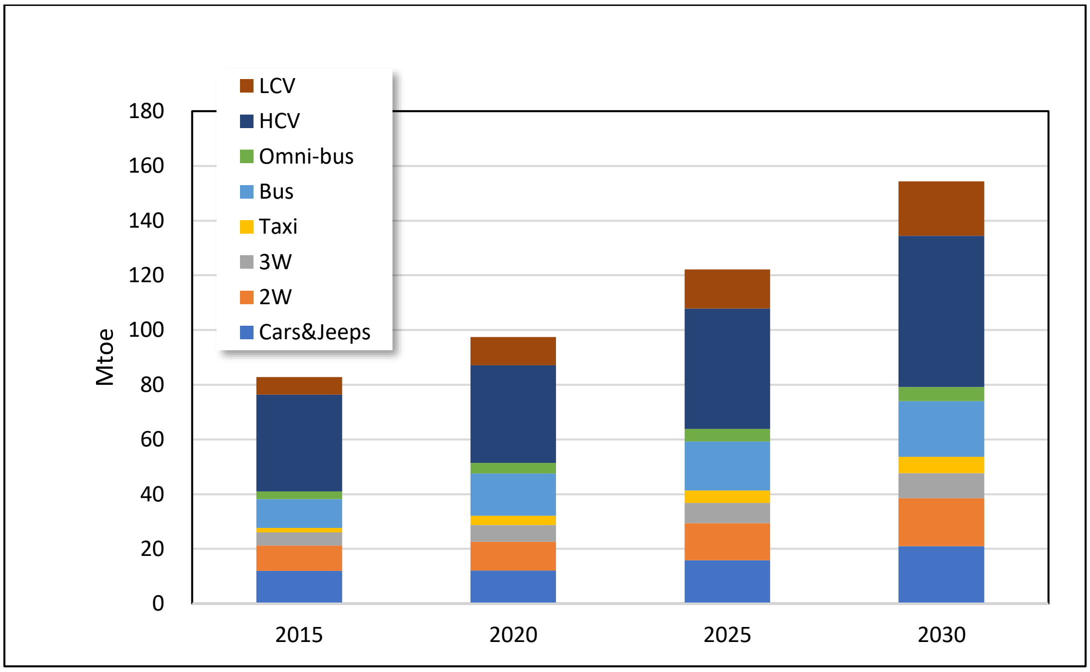
In the BAU scenario, the model results suggest that by 2030, HCVs will consume the highest amount of energy (55.3 Mtoe), thus contributing to around 36% of the final energy consumption by 2030. This is followed by cars and jeeps at 14% (21.7 Mtoe) accounting for 14%, and buses accounting for 13% (20.5 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



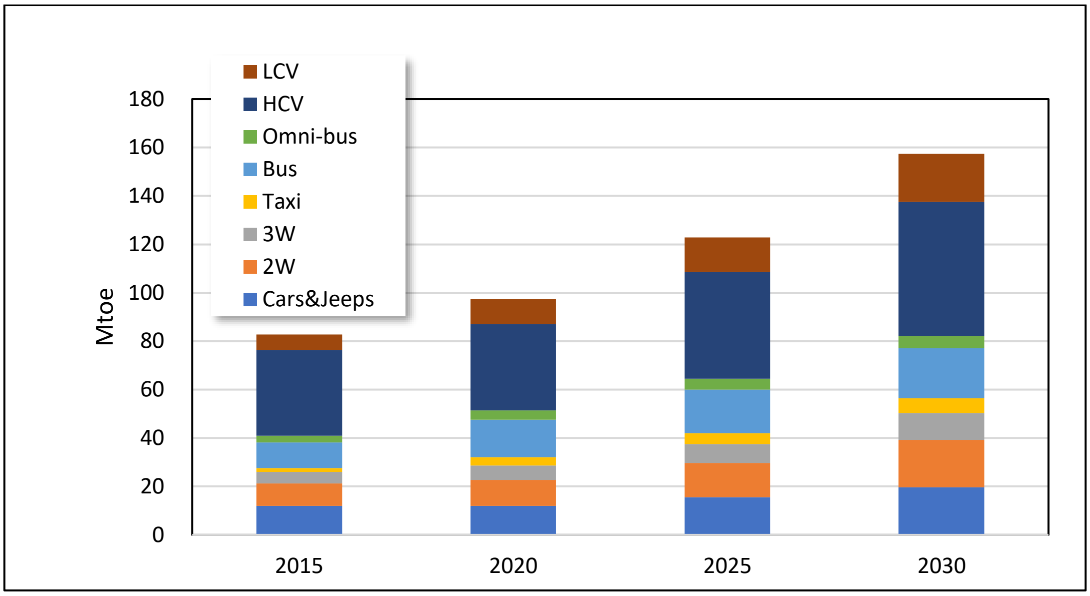
2W = two-wheeler, 3W = three-wheeler, BAU = business as usual, HCV = heavy commercial vehicle, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.4. Energy Demand by Vehicle Type in AFS



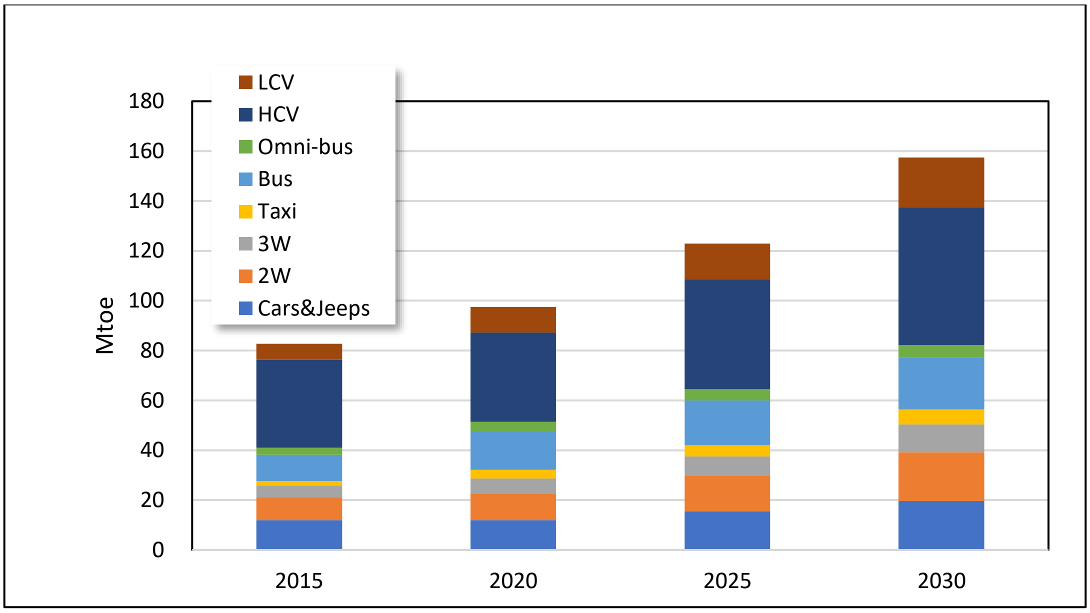
2W = two-wheeler, 3W = three-wheeler, AFS = Alternative Fuels Scenario, HCV = heavy commercial vehicle, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.5. Energy Demand by Vehicle Type in MES



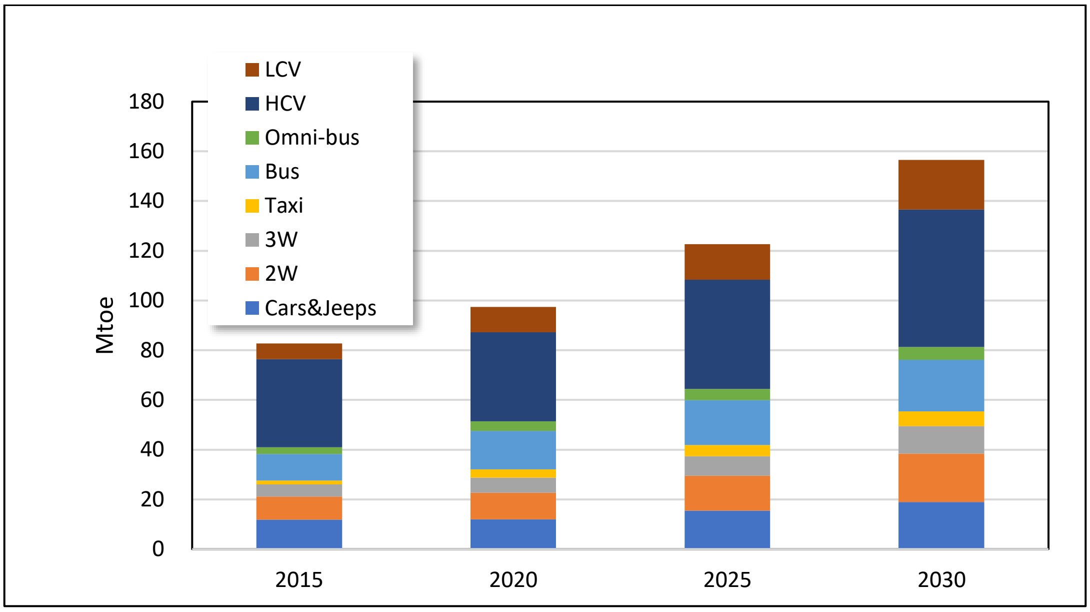
2W = two-wheeler, 3W = three-wheeler, HCV = heavy commercial vehicle, LCV = light commercial vehicle, MES = Moderate Electrification Scenario, Mtoe = million tons of oil equivalent.
Source: Authors.

Figure 2.6. Energy Demand by Vehicle Type in AES



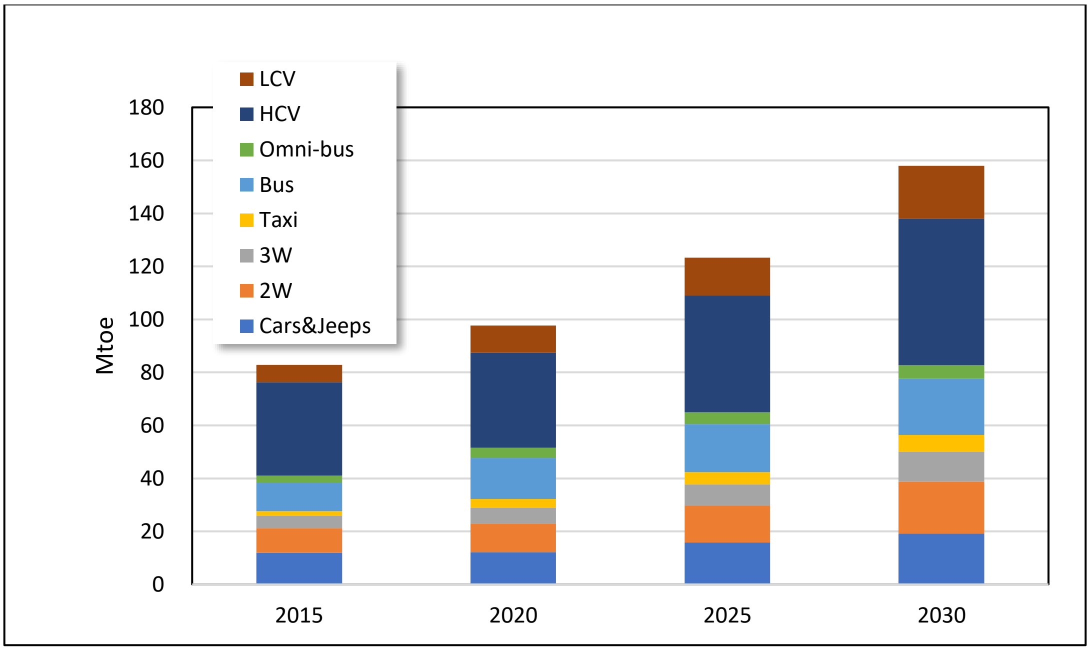
2W = two-wheeler, 3W = three-wheeler, AES = Aggressive Electrification Scenario, HCV = heavy commercial vehicle, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

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



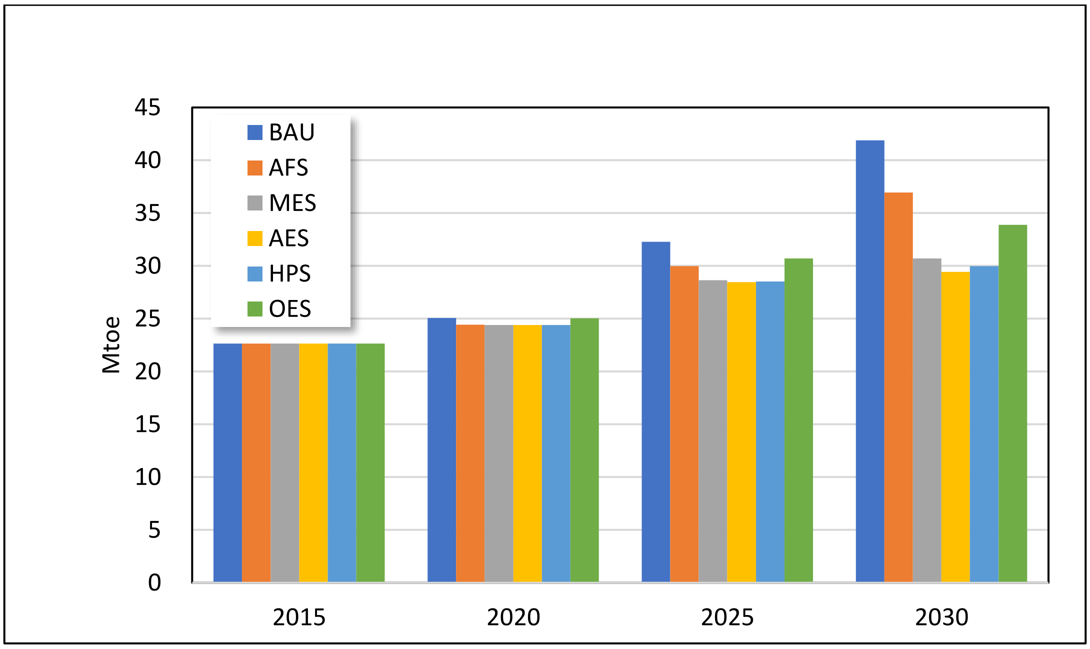
2W = two-wheeler, 3W = three-wheeler, HCV = heavy commercial vehicle, OES= Only Electrification Scenario, LCV = light commercial vehicle, Mtoe = million tons of oil equivalent.
Source: Authors.

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



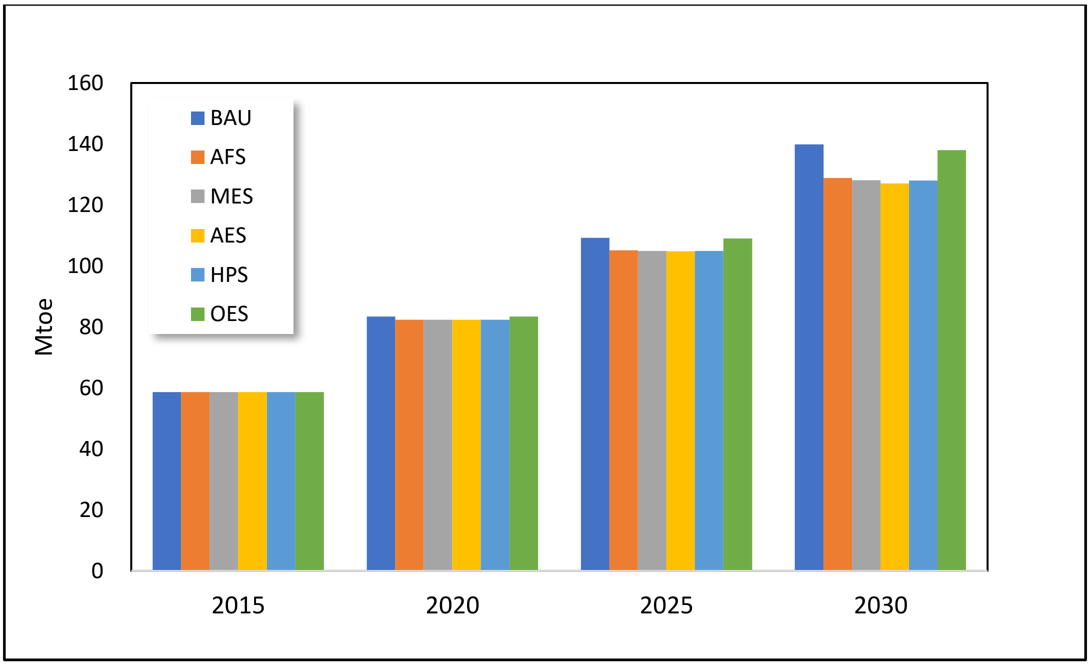
BAU = Business as Usual, AFS = Alternative Fuels Scenario, AES = Aggressive Electrification Scenario, MES = Moderate Electrification Scenario, HPS = Moderate Electrification cum Hybrid Promotion Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

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

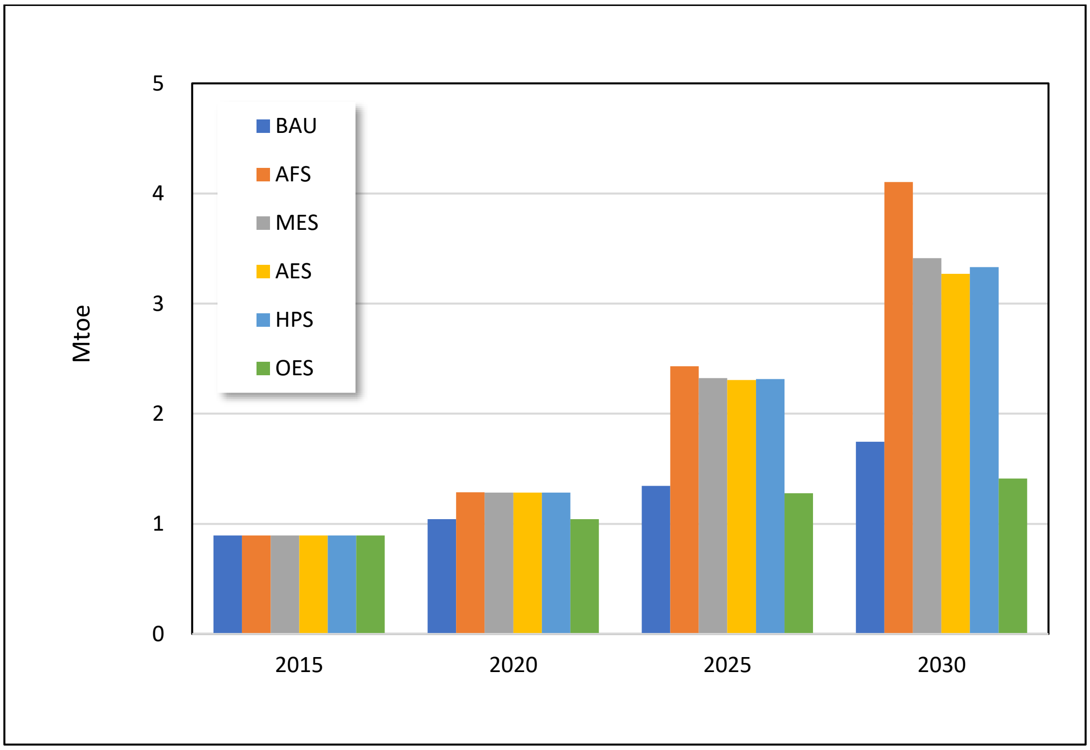


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

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

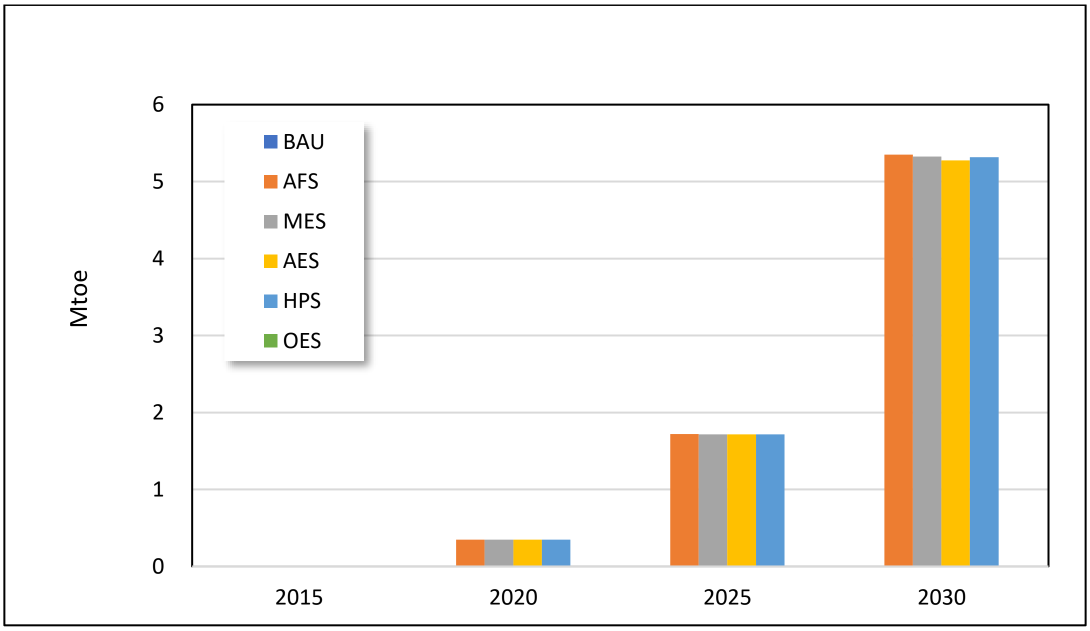


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

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



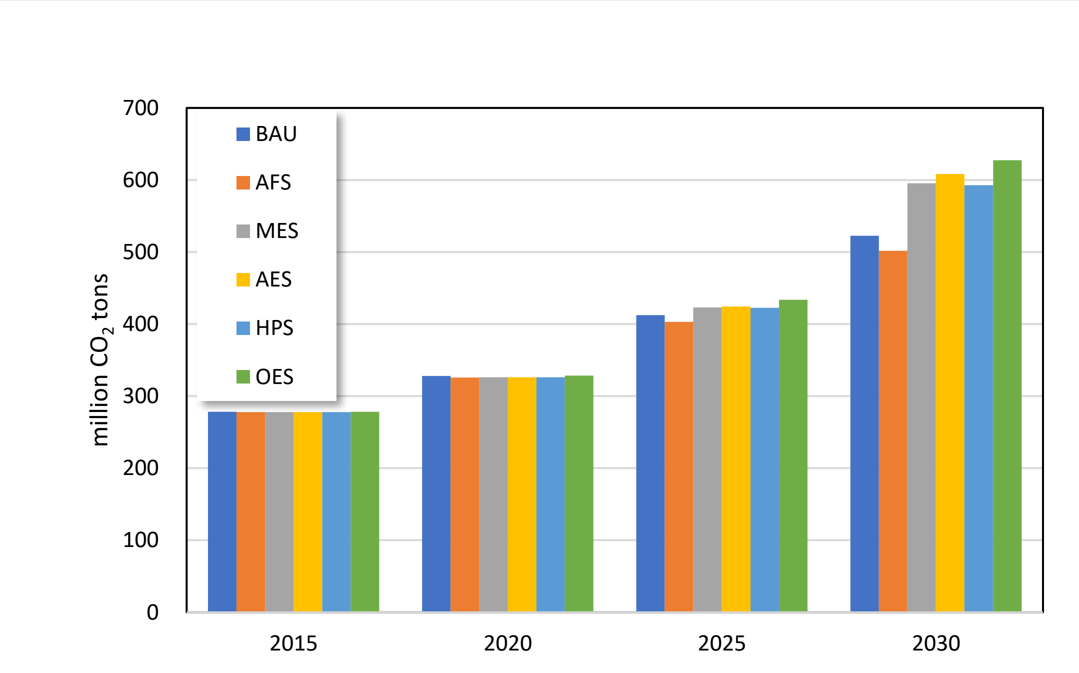
AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

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)

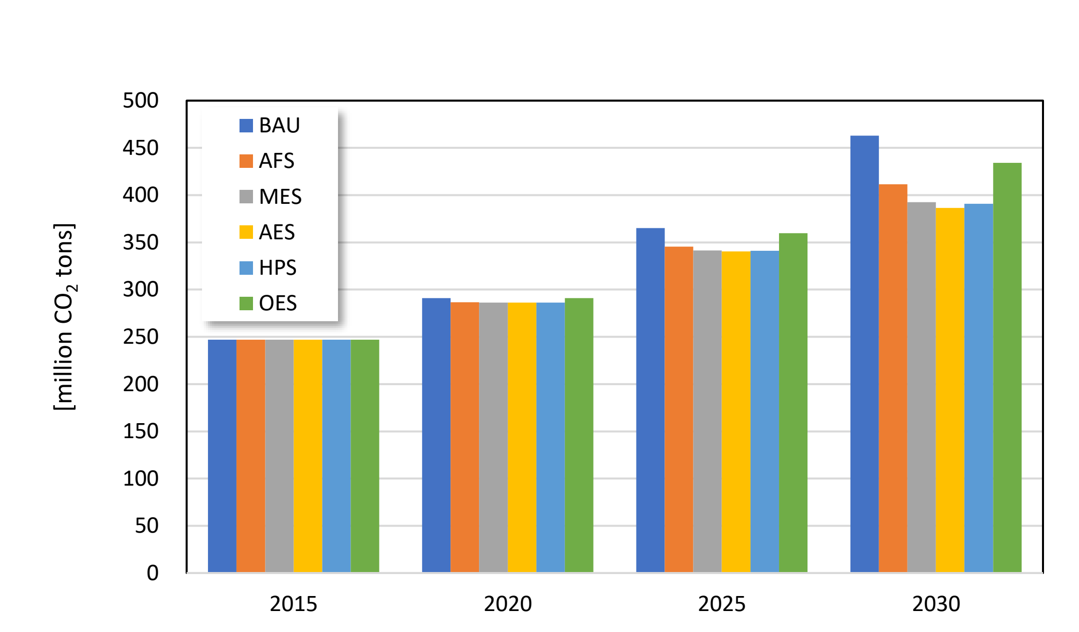


AES = Aggressive Electrification Scenario, AFS = Alternative Fuels Scenario, BAU = Business as Usual, HPS = Moderate Electrification cum Hybrid Promotion Scenario, MES = Moderate Electrification Scenario, OES = Aggressive Electrification Condition and Only Electrification Scenario.
Source: Authors.

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.

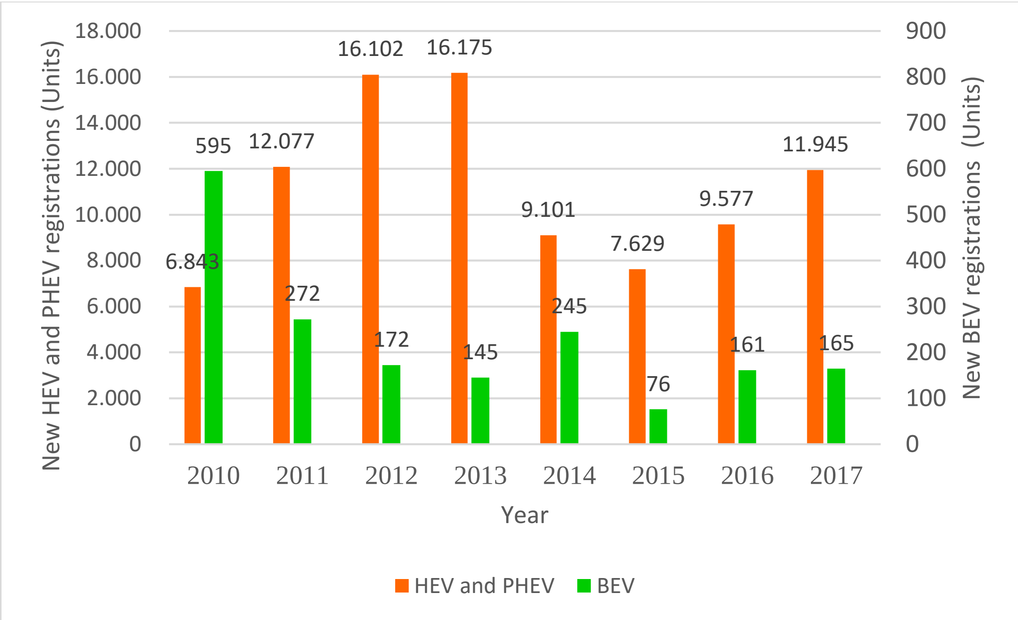
The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. Under the original plan, the government aimed to achieve a total installed solar capacity of 20 GW by 2022. 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.

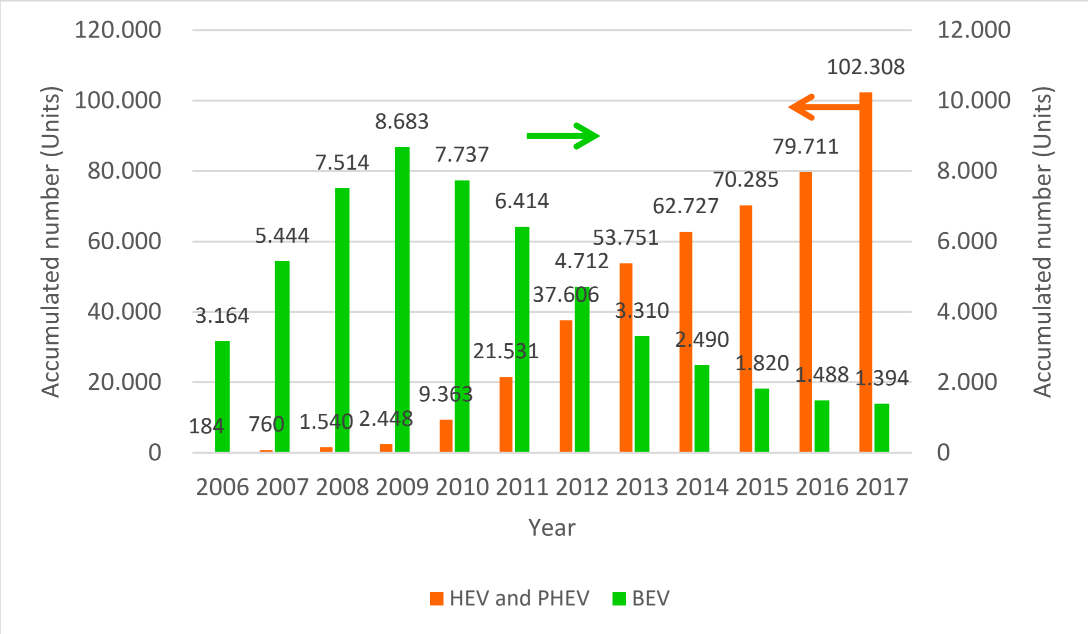
Figure 2.15. Statistics of New xEV Registrations in Thailand



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/

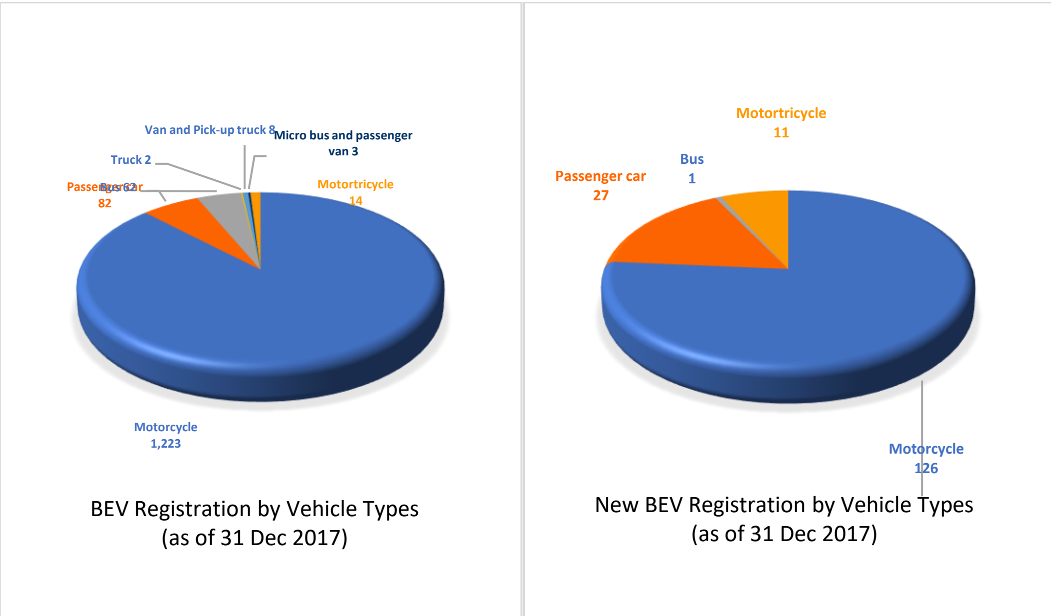
Figure 2.16. Statistics of Accumulative xEV Registrations in Thailand



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

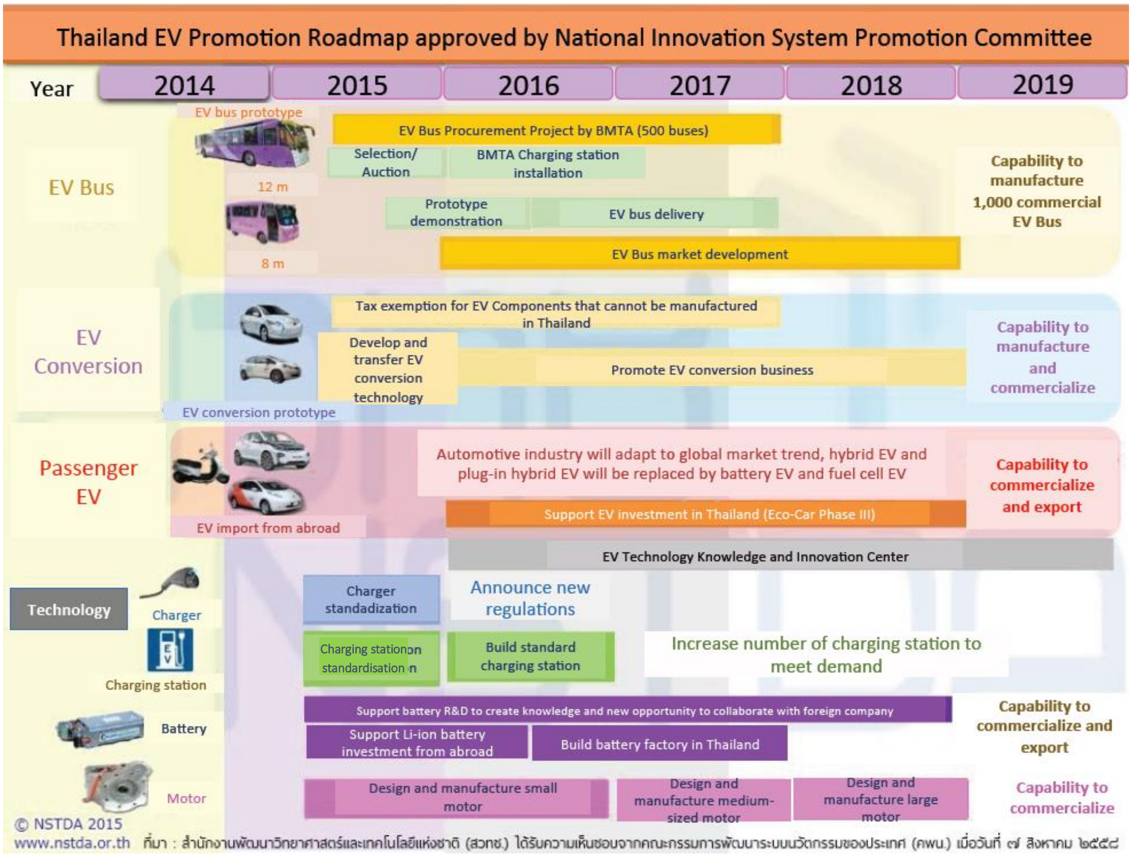
Source: Collected by Electric Vehicle Association of Thailand from data of the Department of Land Transport. https://web.dlt.go.th/statistics/

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).

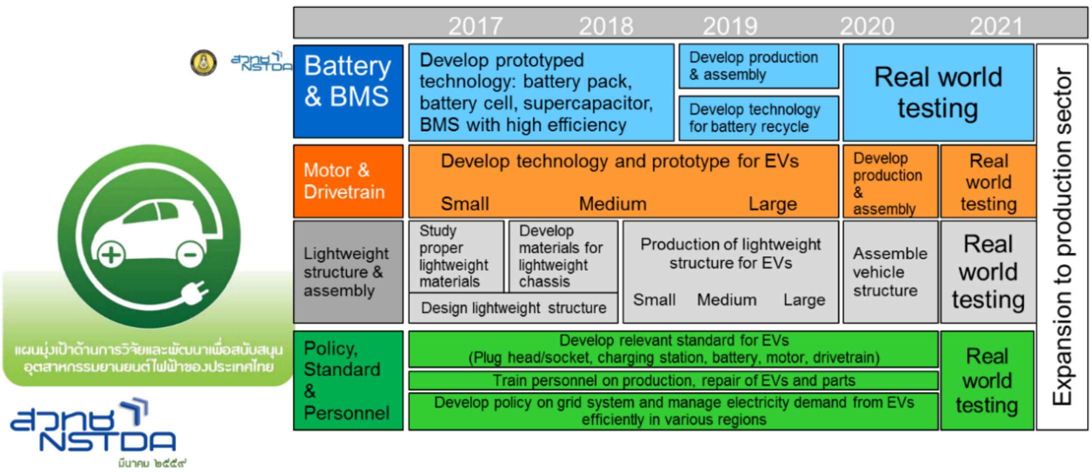
Recently, two funding agencies, the Energy Conservation Fund and the National Research Council of Thailand have dedicated a research budget for EVs and for energy storage for EVs.

Figure 2.18. Thailand's EV Promotion Roadmap



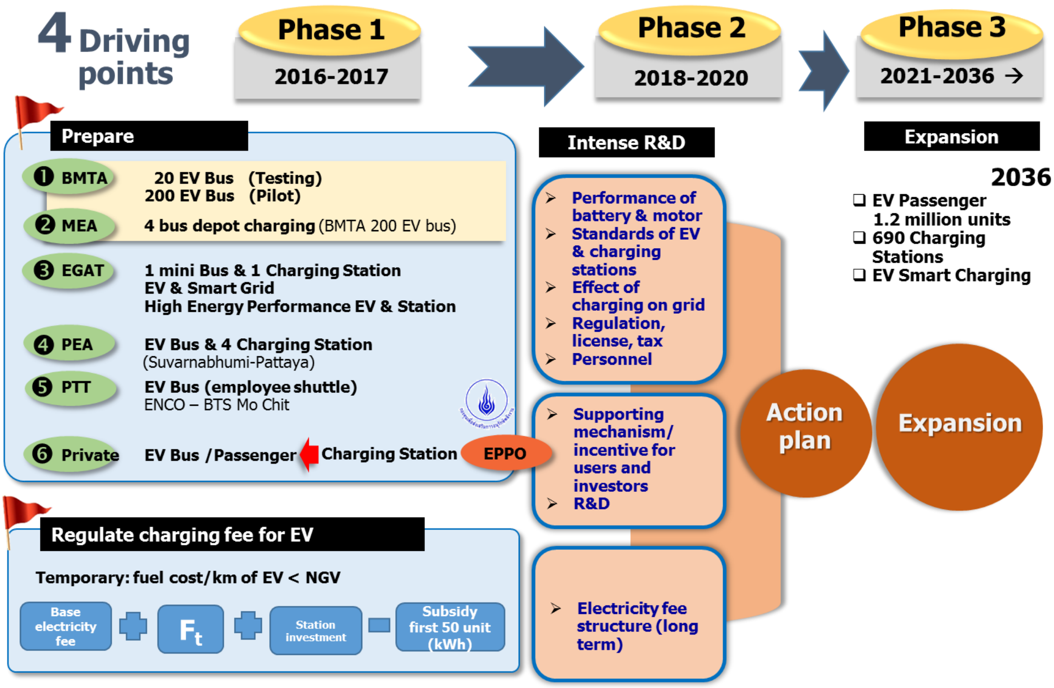
BMTA = Bangkok Mass Transit Authority, EV = electric vehicle.
Source: National Science and Technology Development Agency (2015). https://www.nstda.or.th/th/nstda-r-and-d/561-electronic-vehicle

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

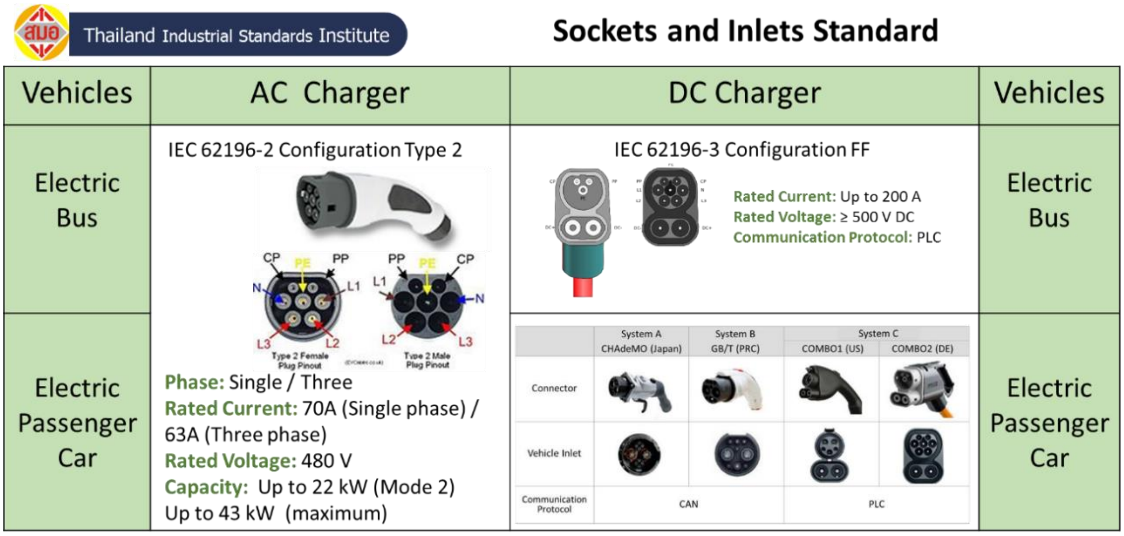


BMTA = Bangkok Mass Transit Authority EV = electric vehicle, NGV = natural gas vehicle
Source: National Science and Technology Development Agency (2015). https://www.nstda.or.th/th/nstda-r-and-d/561-electronic-vehicle

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.

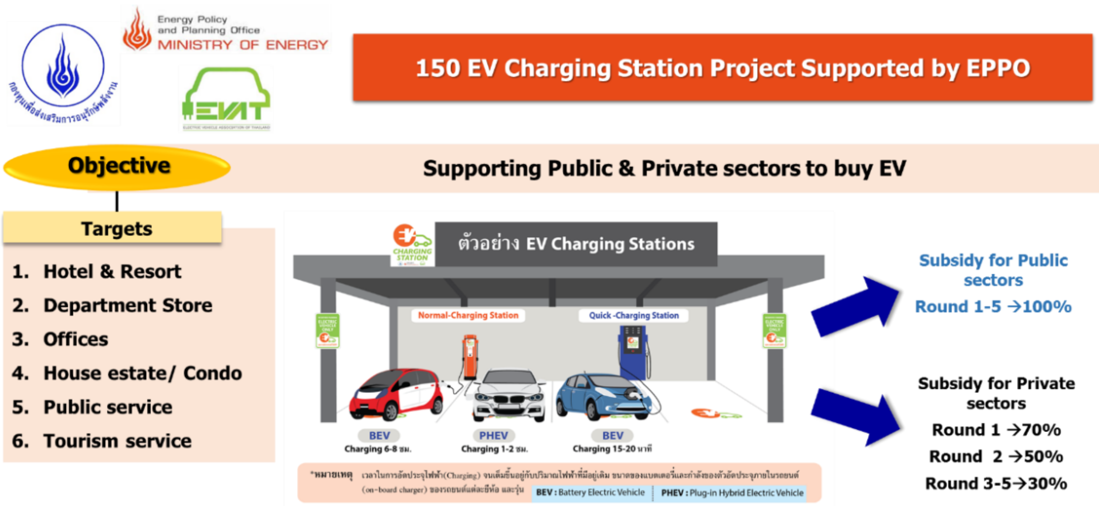
Figure 2.21 shows the Thai standard for EV charging protocol on both normal and quick charges for passenger car and bus. In addition, EPPO has contracted the Electric Vehicle Association of Thailand to conduct a charging station subsidy programme (EVAT, 2018). As shown in Figure 2.22 and Table 2.11, 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 (cm³)	Powertrain	Fuel used	Clean – Eco [CO_2 emission, g/km]	Safety certificated			Excise tax rate (%)
					R13H w/ABS&ESC	R94	R95	
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 (cm³)	Powertrain	Fuel used	Clean – Eco [CO_2 emission, g/km]	Safety certificated			Excise tax rate (%)
					R13H w/ABS&ESC	R94	R95	
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 (cm³)	Powertrain	Investment supported measure (BOI)	Clean – Eco [CO_2 emission, g/km]	Safety certificated			Excise tax rate (%)
					R13H w/ABS&ESC	R94	R95	
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

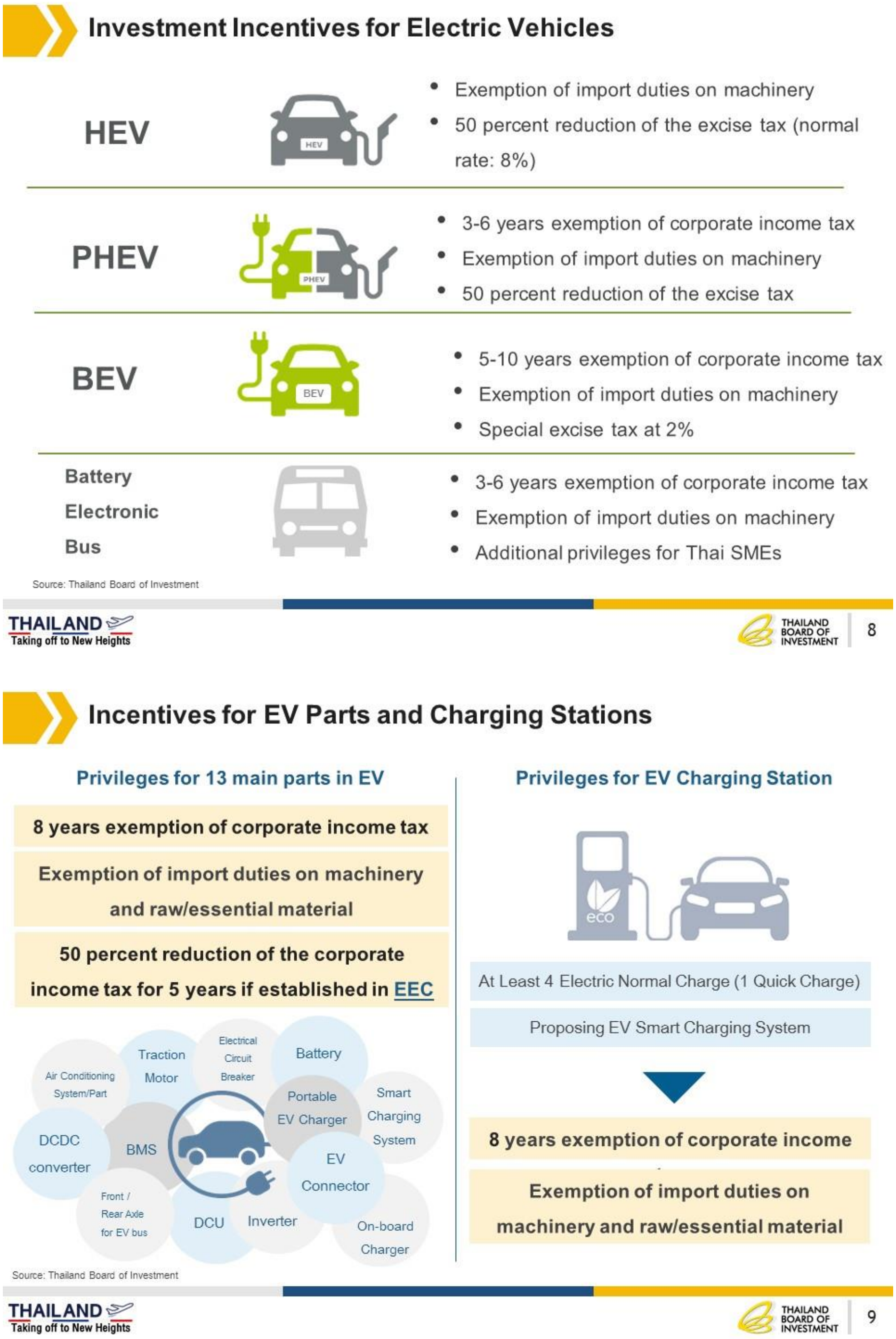
CAR - xEVs

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

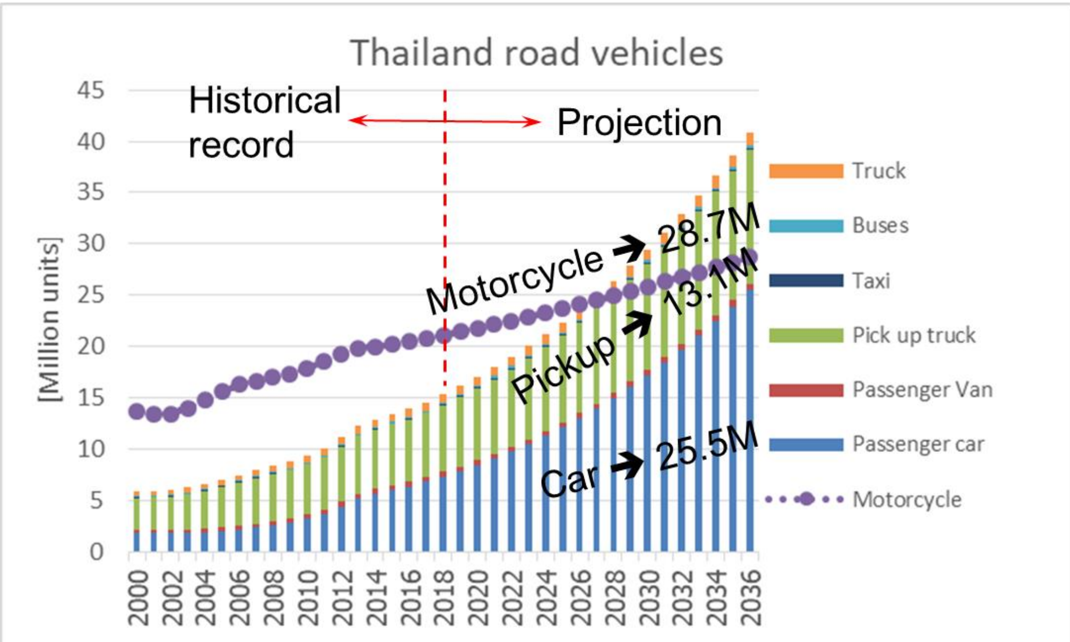
(c) Vehicle type	%	Ex-factory	Tax %	Tax (฿)	Owner price (฿)	∆Tax (฿)
ICE	100	668,853	-	130,847	799,701	0
HEV	126	842,755	4	33,710	876,465	-97,137
PHEV	156	1,043,411	4	41,736	1,085,148	-89,111
BEV	200	1,337,706	2	26,754	1,364,461	-104,093

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

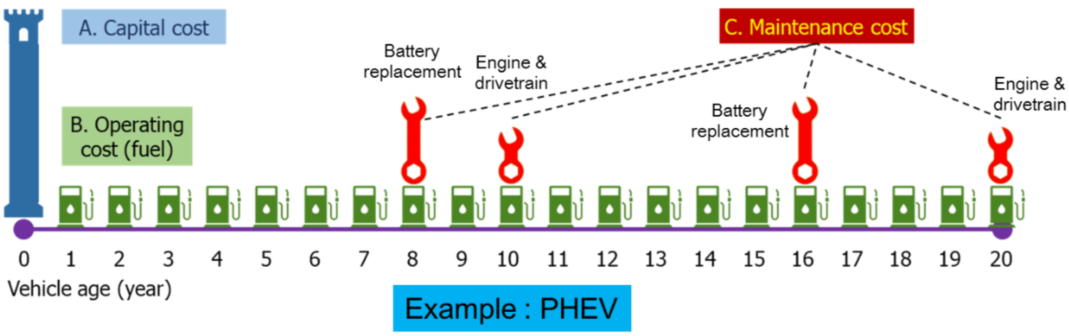
VKT = vehicle kilometres travelled.
Source: Authors.

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	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%]			
	BEV	1.92	(10% lower for B100 and 2% for B20)		
*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
GASOHOL91	17.4408	26.0958	1.8267	27.9225	1.8295	0.1281	29.88
GASOHOL95 E20	18.2991	23.3391	1.6337	24.9729	2.0254	0.1418	27.14
GASOHOL95 E85	20.8301	15.6226	1.0936	16.7162	4.3213	0.3025	21.34
H-DIESEL	17.5907	24.4687	1.7128	26.1815	1.8771	0.1314	28.19

http://www.eppo.go.th

Baseline gasoline price (30.15); E20 (27.14); E85 (21.34); Baseline diesel price (28.19)

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

estimated in this work

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

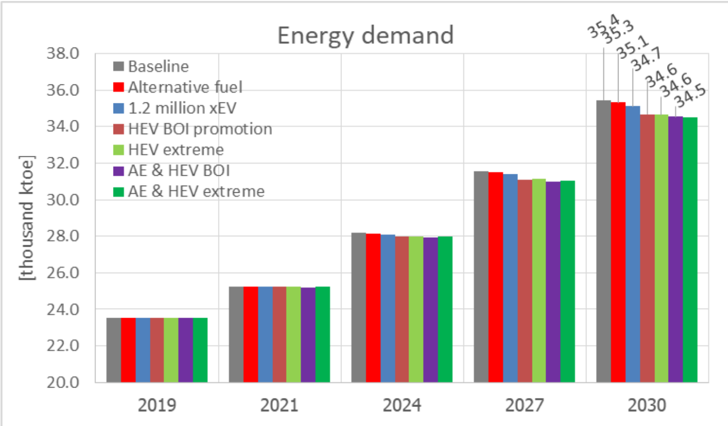
Combination Scenarios

- 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.

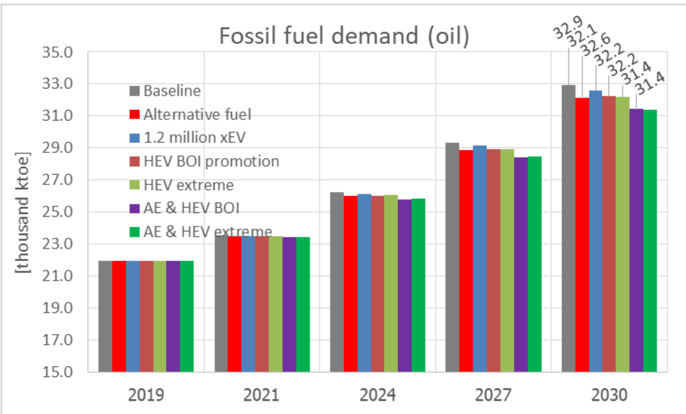
Figure 2.26. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Energy Demand Reduction



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.

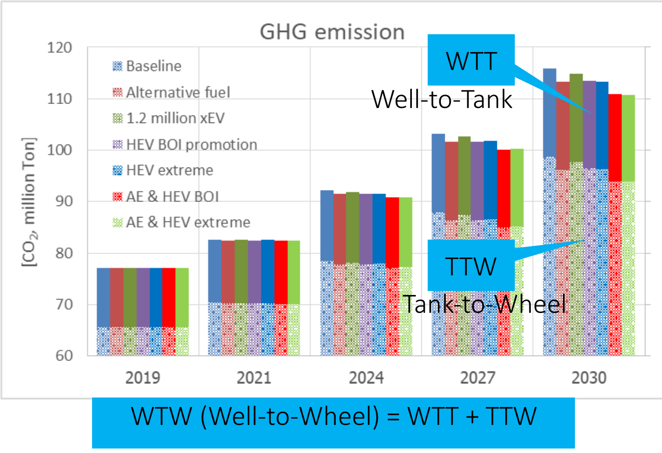
Figure 2.27. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Fossil Fuel Reduction



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.

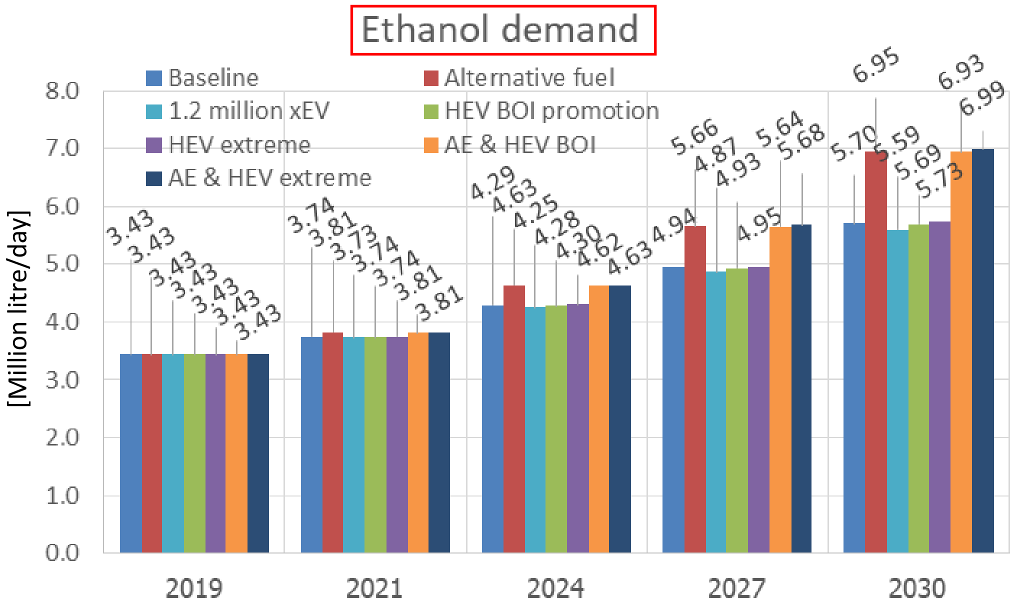
Figure 2.28. Simulation Results for Six Scenarios with BAU Scenario (Baseline), Greenhouse Gas Emissions Reduction



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%

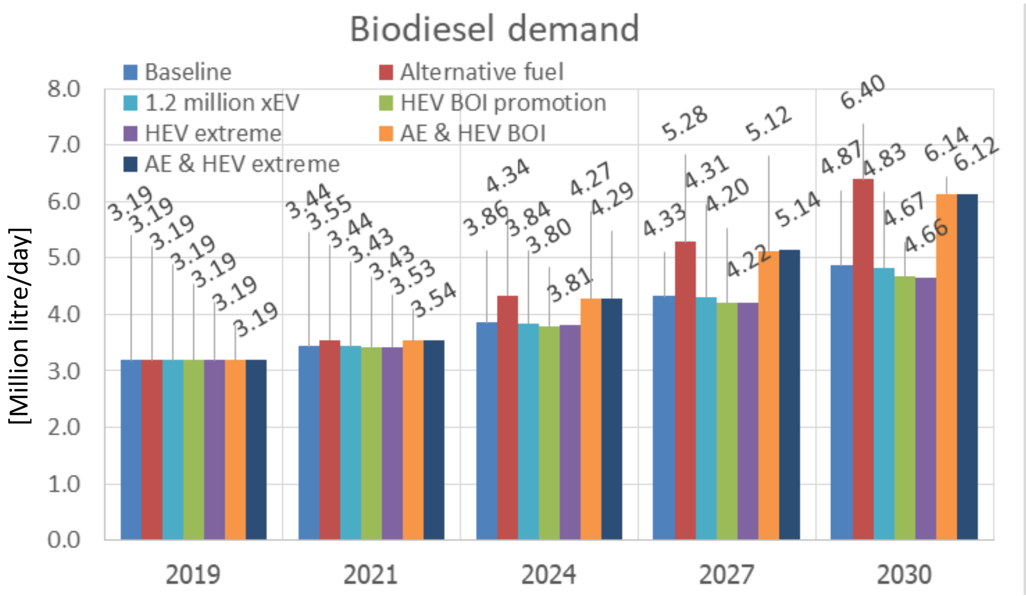
AE = alternative fuels, BAU = business as usual, BOI = Board of Investment, HEV = hybrid electric vehicle.
Source: Authors.

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



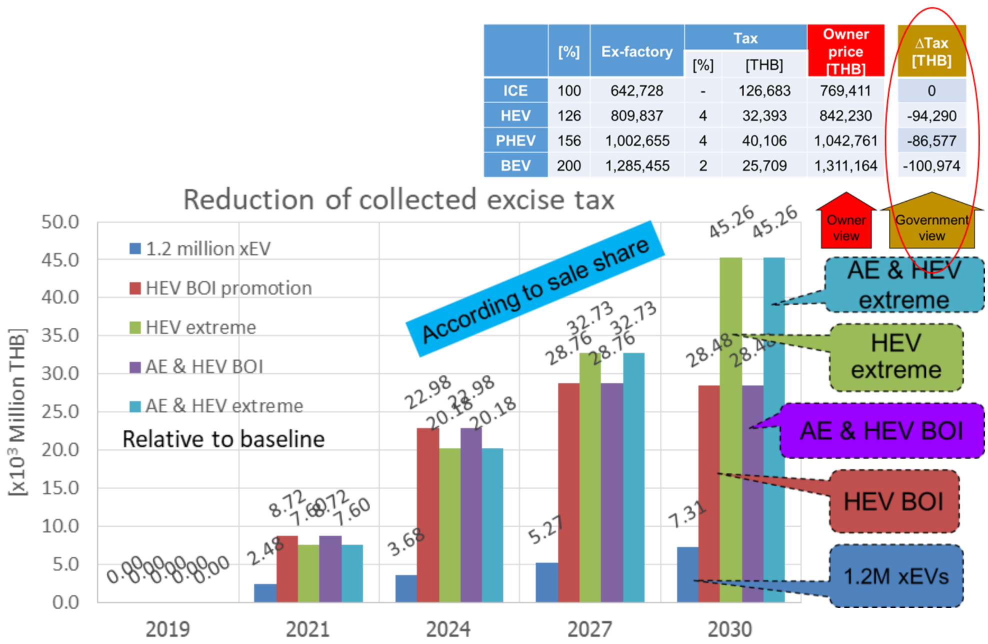
AE = alternative fuels, BAU = business as usual, BOI = Board of Investment, HEV = hybrid vehicle.
Source: Authors.

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.

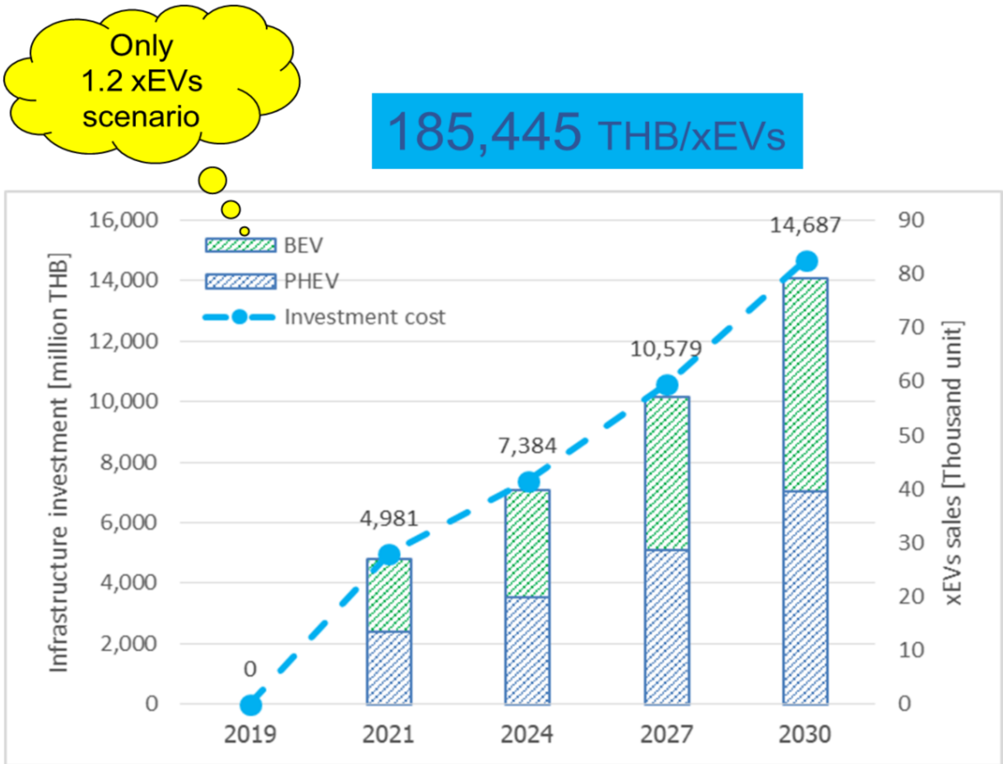
Figure 2.31. Simulated Cost Results for Six Scenarios with BAU Scenario (Baseline), Excise Tax Reduction



	[%]	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

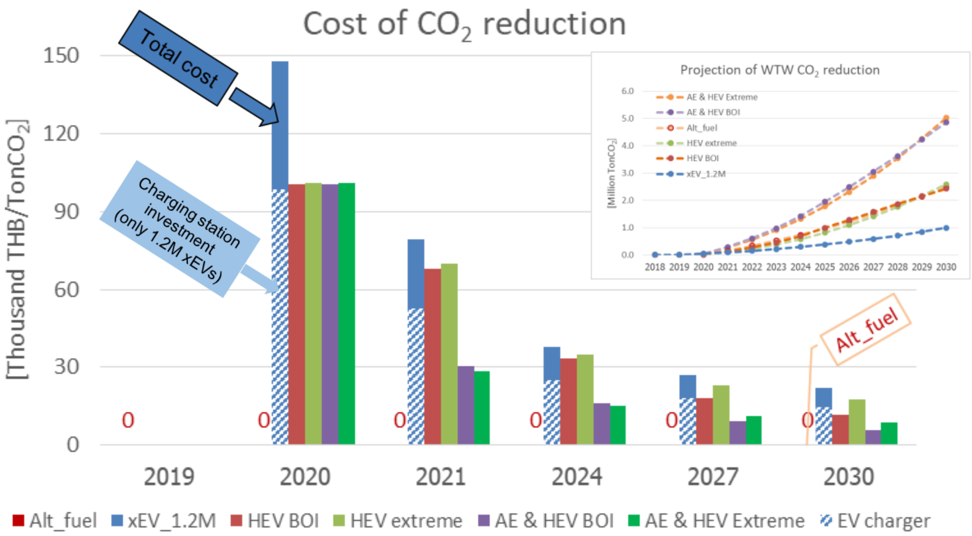
AE = alternative fuels, BAU = business as usual, BEV = battery electric vehicle, BOI = Board of Investment, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Authors.

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



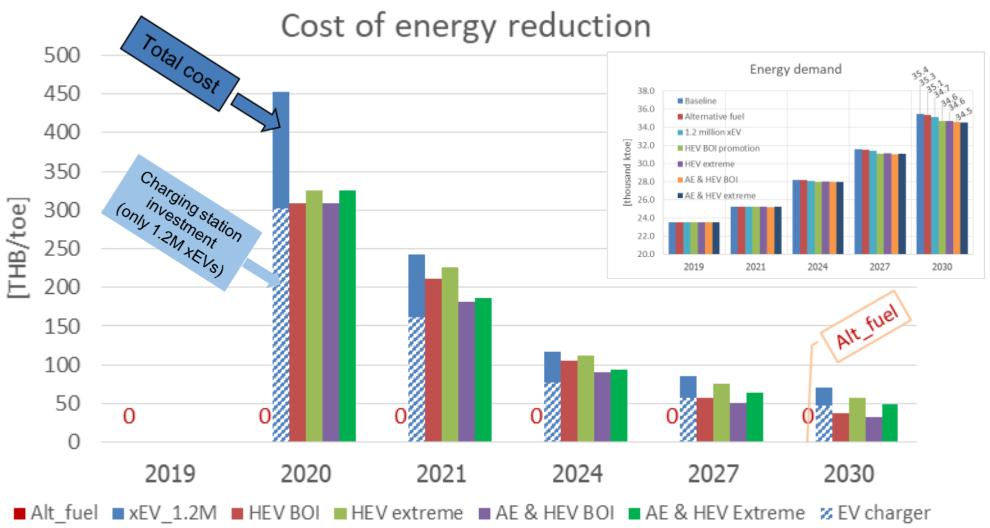
BEV = battery electric vehicle, BOI = PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

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



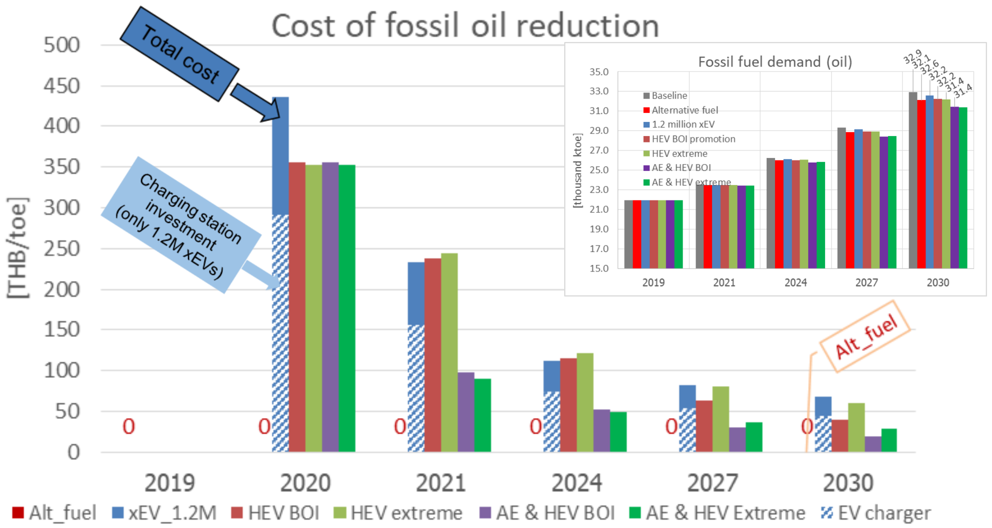
AE = alternative fuels, BOI = Board of Investment, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

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



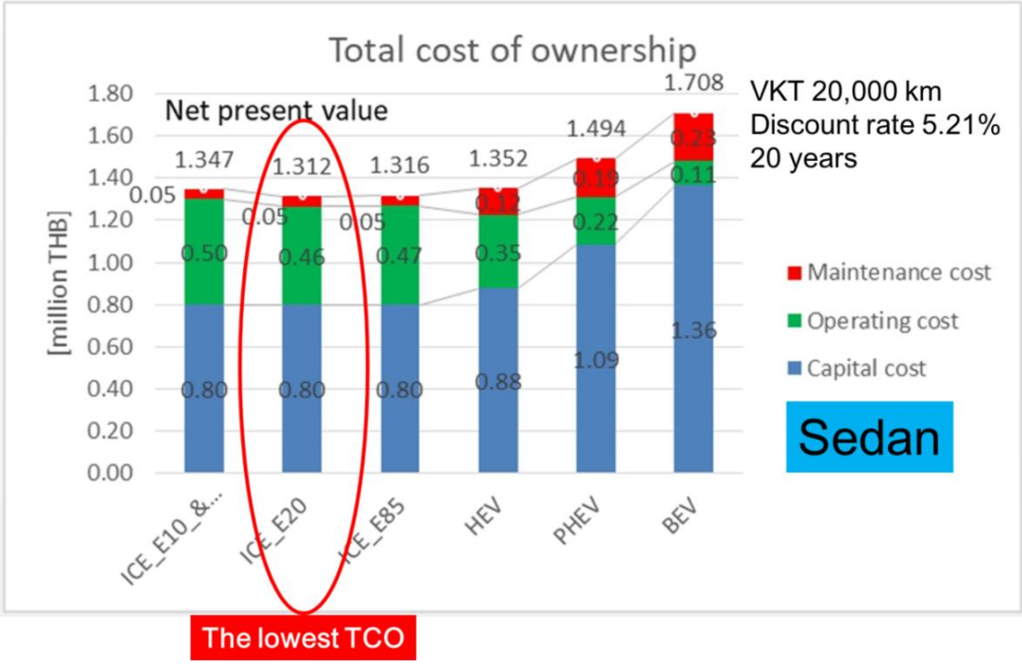
BEV = battery electric vehicle, BOI = PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

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



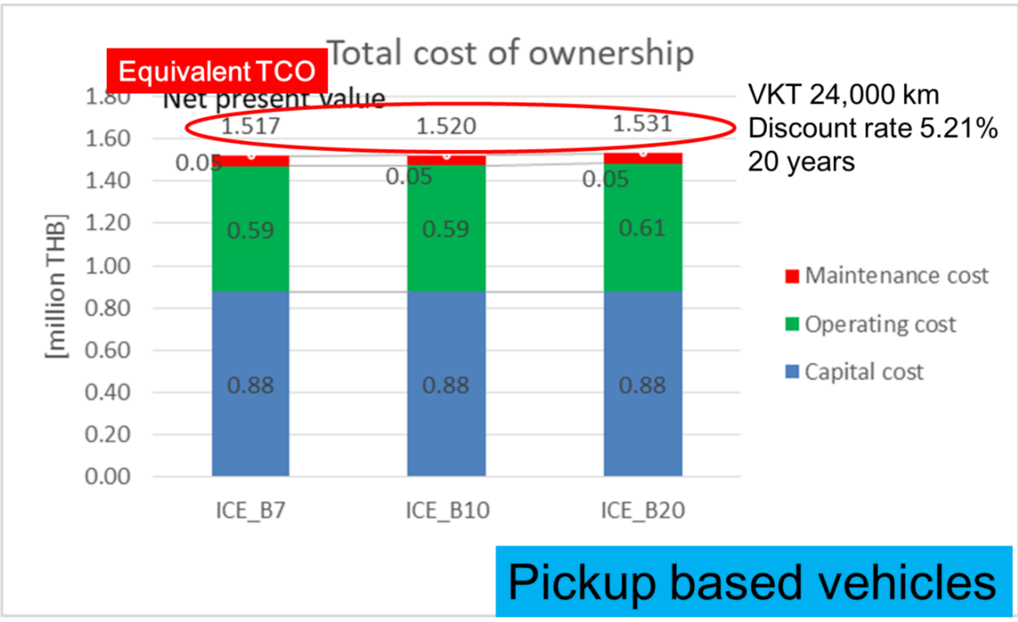
BEV = battery electric vehicle, BOI = PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: Authors.

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

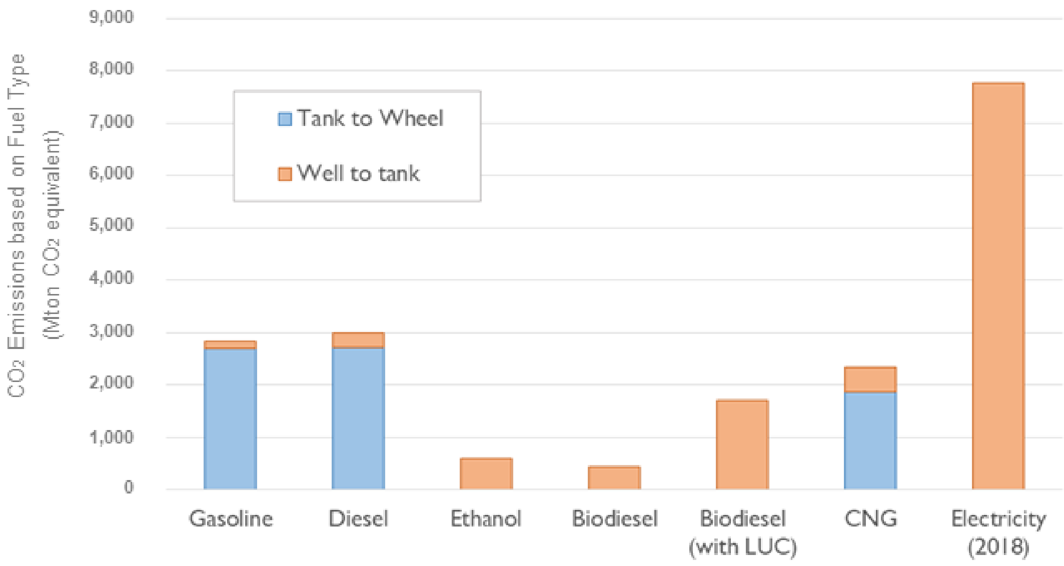
Vehicle type – Fuel type	Fuel Economy (km/L)	Remarks
Passenger car – gasoline	9.1	
Passenger car – diesel	10.3	
Bus – diesel	5.9	
Truck – diesel	5.9	
Motorcycle – gasoline	26.8	
Passenger car – CNG	9.8	Based on ratio of FE, 2015 Civic CNG and gasoline
Bus – CNG	5.9	Assumed to be similar to bus – diesel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

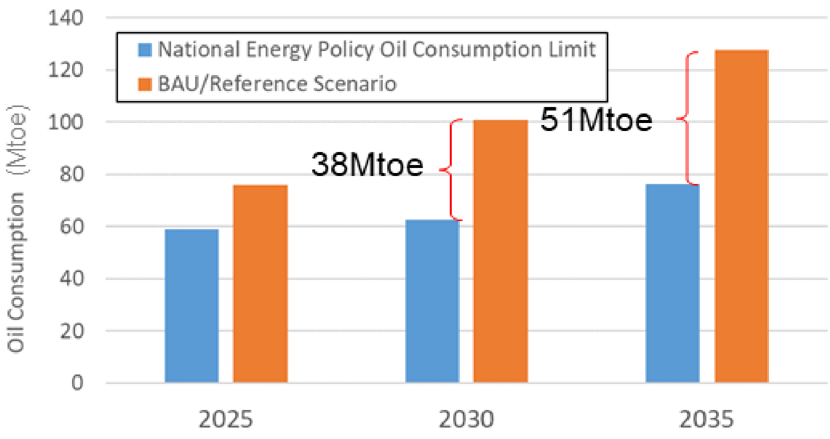
4.4. Study Results (oil consumption, CO_2 emissions, and cost of implementation)

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)

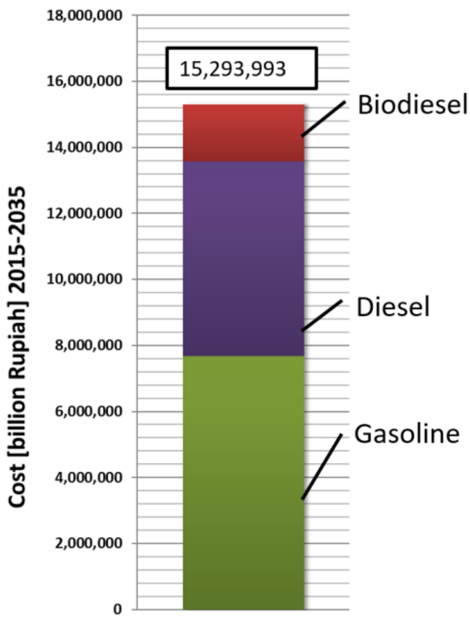


BAU = business as usual, Mtoe = million tons of oil equivalent, NEP = National Energy Policy.
Source: Authors.

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

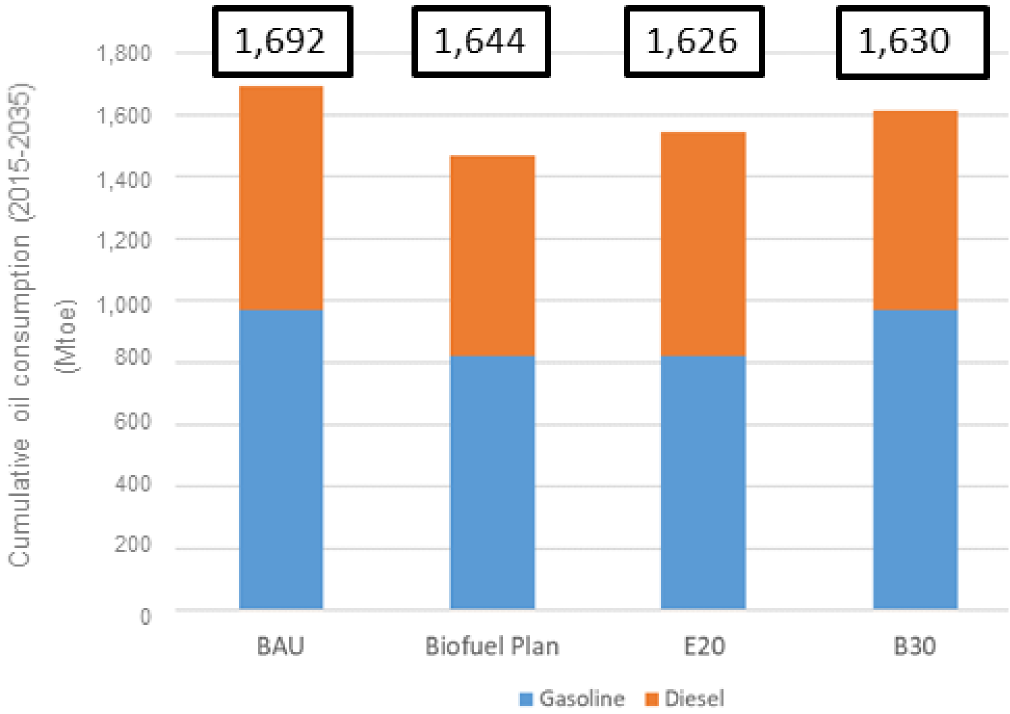


Source: Authors.

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%.

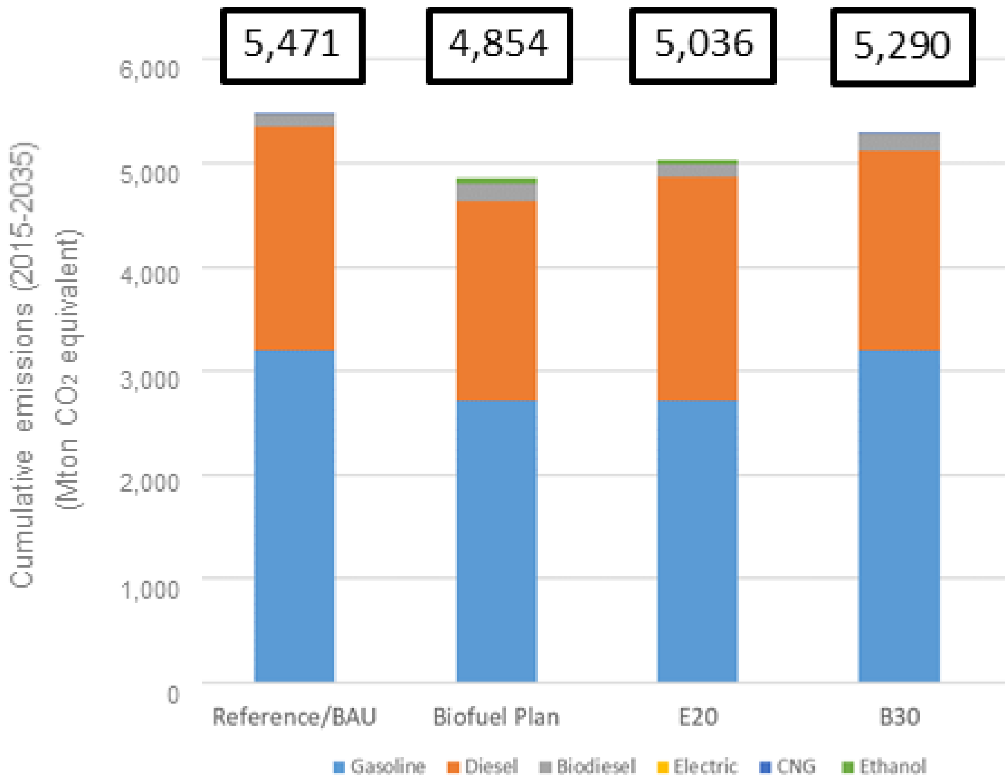
Figure 2.41. Comparison of Oil Consumption from 2015 to 2035 of Biofuel Scenarios and BAU



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

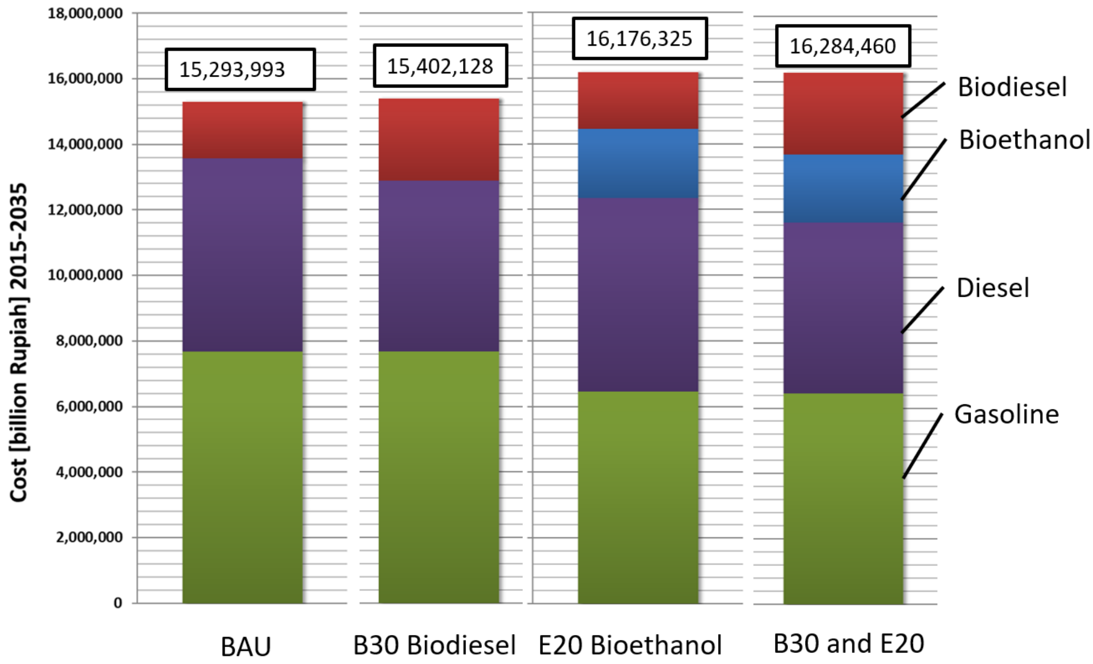


BAU = business as usual, CNG = compressed natural gas.
Source: Authors.

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



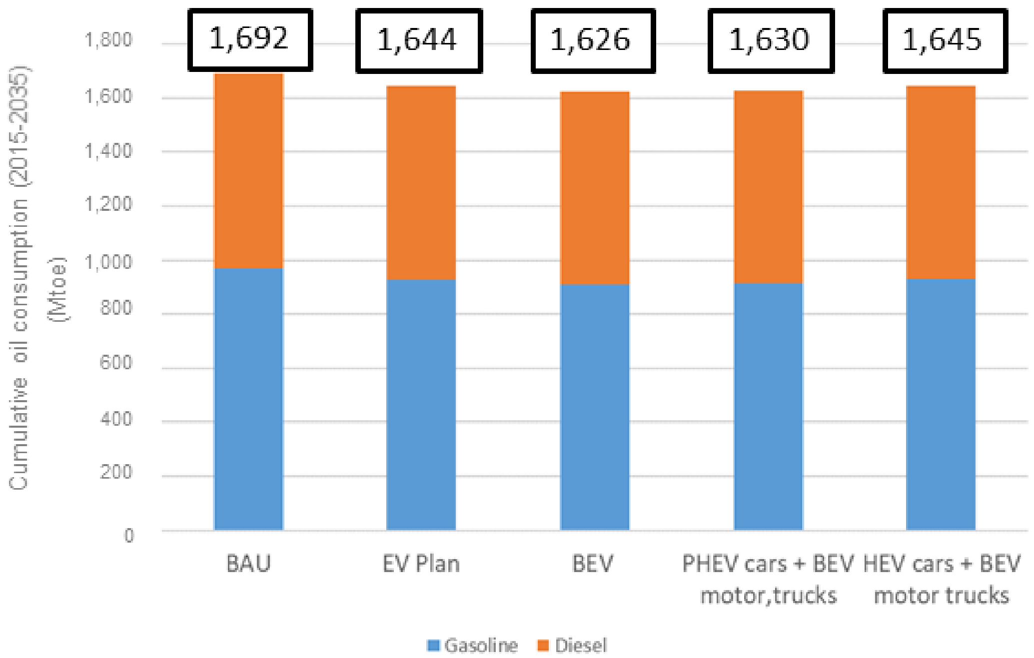
BAU = business as usual.
Source: Authors.

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.

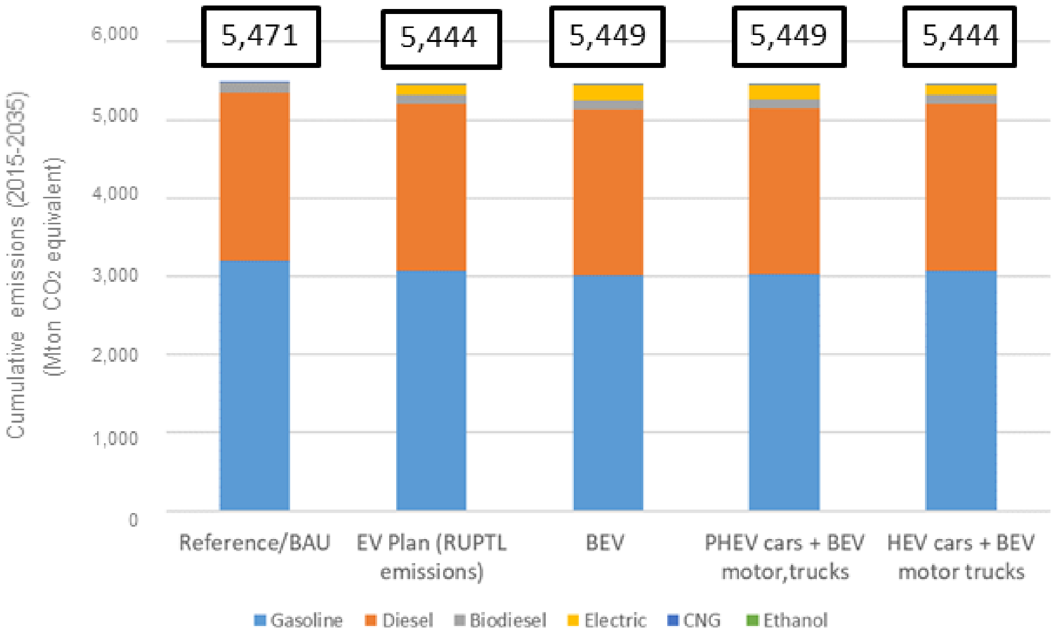
Figure 2.44. Comparison of Oil Consumption from 2015 to 2035 of xEV Scenarios and BAU



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.

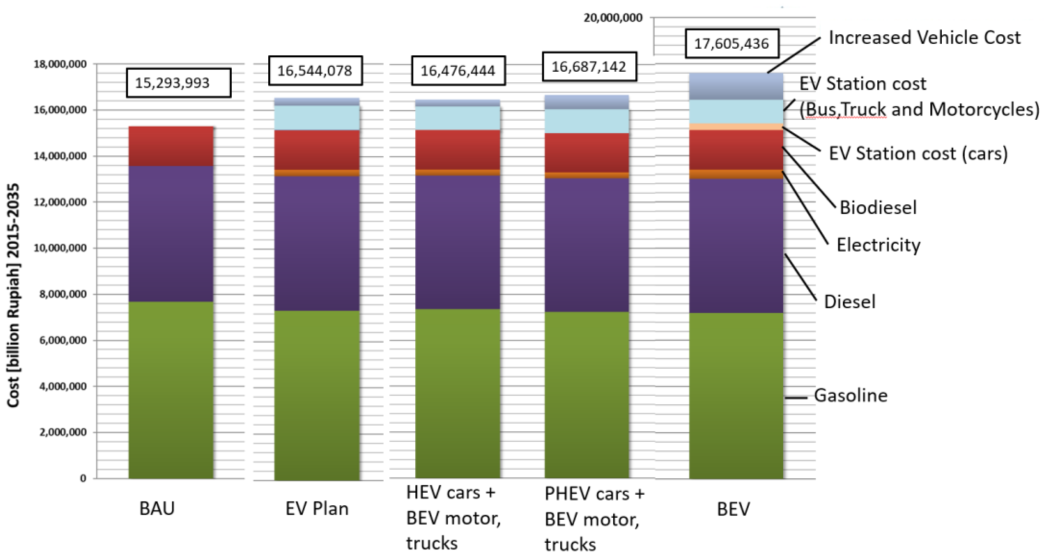
Figure 2.45. Comparison of Carbon Emissions from 2015 to 2035 of xEV Scenarios and BAU



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.

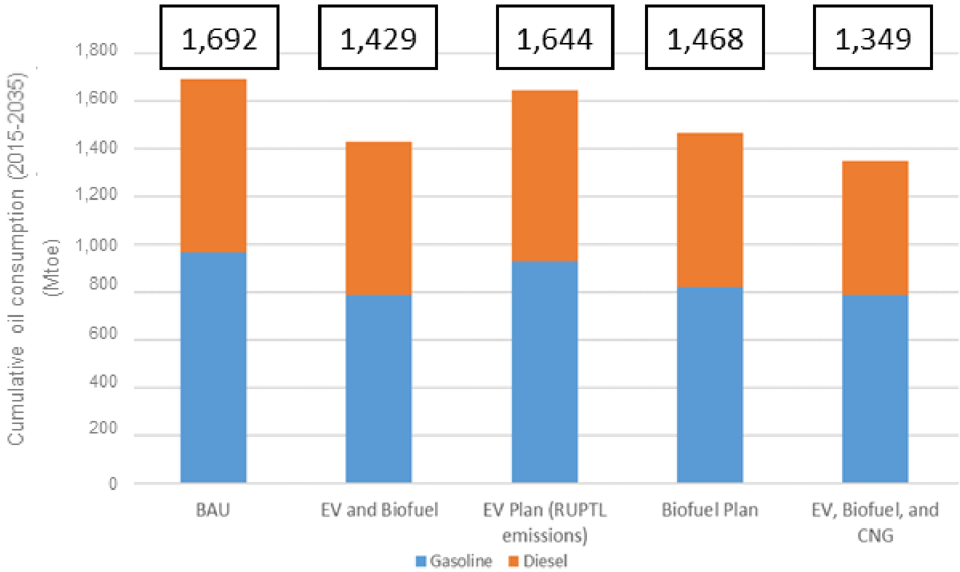
A large portion of the cost is to accommodate charging stations for electric buses, trucks, and motorcycles, which will grow significantly according to the production numbers specified by the EV plan. By 2035 there will be more than 35 million electric motorcycles, while electric buses and trucks will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

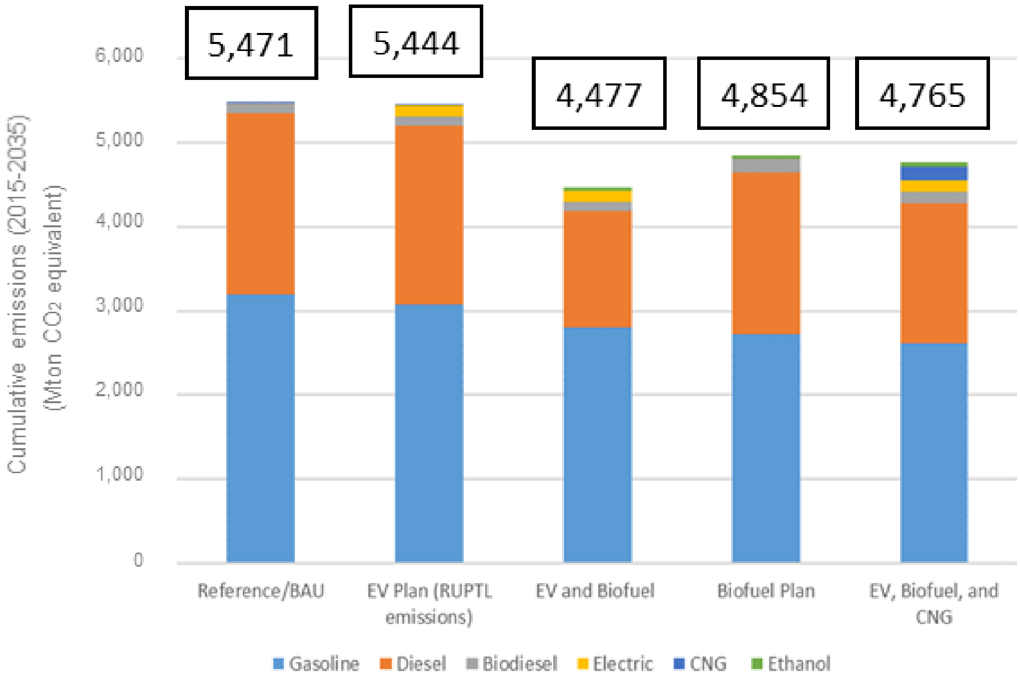
Figure 2.47. Comparison of Oil Consumption from 2015 to 2035 of CNG Implementation Scenario Combined with Other Scenarios and BAU



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

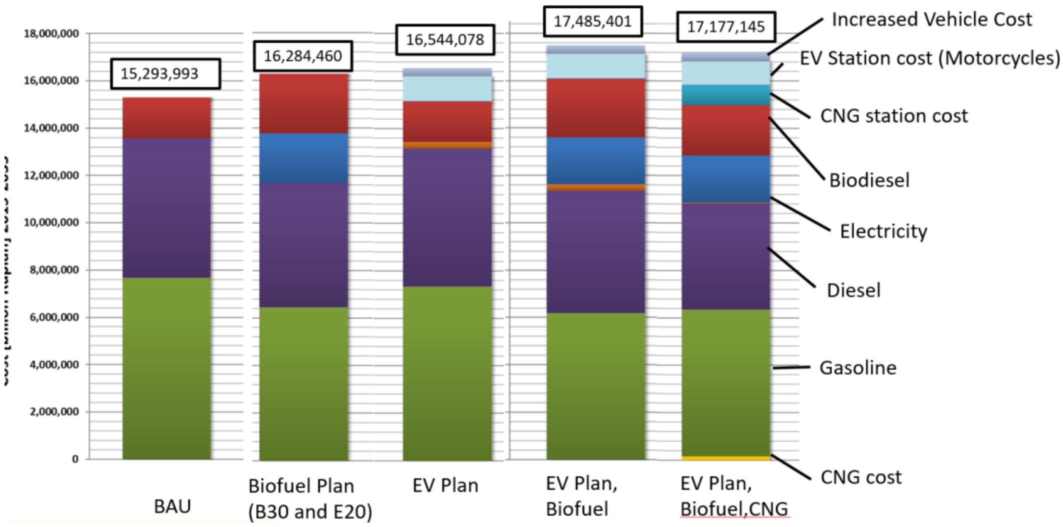


BAU = business as usual, CNG = compressed natural gas, EV = electric vehicle, Mton = million ton, RUPTL = Rencana Umum Penyediaan Tenaga Listrik.
Source: Authors.

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.

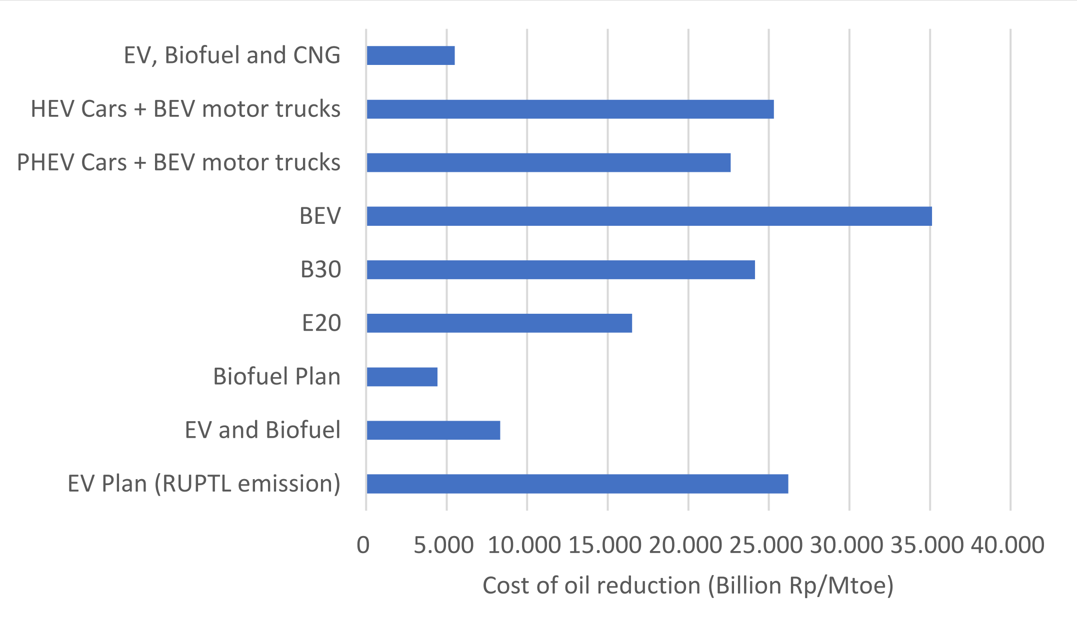
Figure 2.49 displays the cumulative costs for the combined scenarios in comparison to BAU and the isolated EV plan and biofuel plan. All plans have an increased cost compared to the BAU scenario: biofuels will cost more than fossil fuels, the EV plan will have an increased vehicle cost, and both the 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

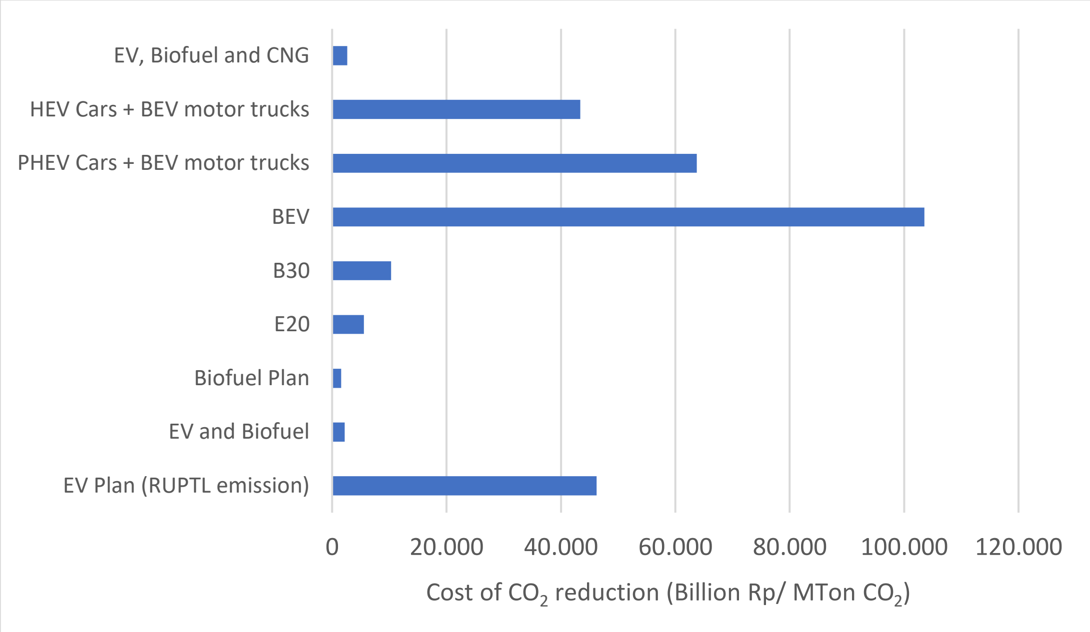


BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, Mtoe = million tons of oil equivalent, Mton = million ton, = million tons of oil equivalent, PHEV = plug-in hybrid electric vehicle, RUPTL = Rencana Umum Penyediaan Tenaga Listrik.
Source: Authors.

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.

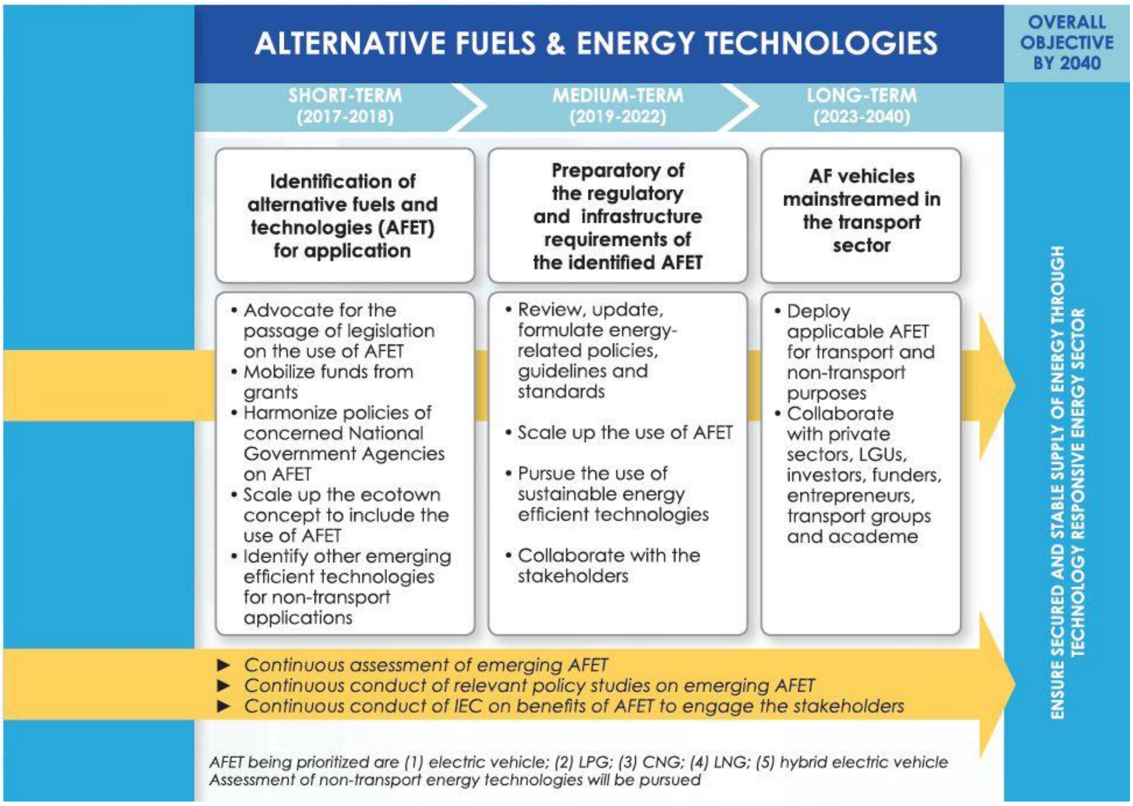
To ensure the proper use of the vehicles donated by the Government of Japan that were distributed to various NGAs, the DOE has issued Guidelines on the Use of Next Generation Vehicles. These guidelines cover the proper monitoring of performance data, which shall be used in validating energy efficiency 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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Chapter 3

Supply Potential of Next-Generation Biofuels from Non-Conventional Resources

1. Non-Conventional Biomass as Feedstock for Transportation Fuel Potential for Indonesia

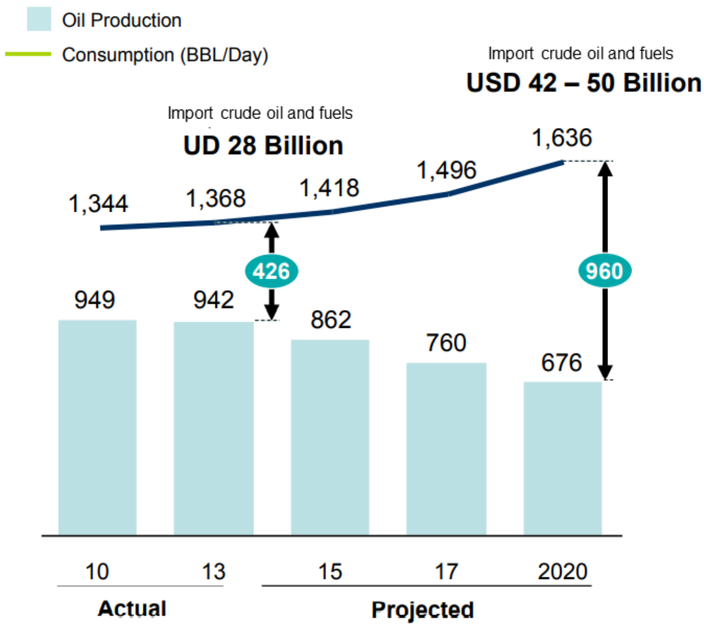
Background of Renewable Energy Sector of Indonesia

Being a densely populated country (237.4 million people) with an annual gross domestic product of US$878.3 billion in 2014 (BPS, 2015). Indonesia is set to be the largest consumer market in Southeast Asia, a member of the Group of 20, and has a growing and solid industry. Its sustained economic growth of 5–6% for the past 10 years has put pressure on the energy offer and environmental issues. Implementing sustainable bioenergy solutions, particularly from biomass, can overcome bottlenecks to economic growth whilst mitigating climate change impacts.

In addition to being rich in fossil energy, Indonesia's renewable energy sources are also considerable. Overall energy consumption in 2017 including biomass, was 1.23 billion barrels of oil equivalent (Boe), whilst the final commercial energy consumption was 927 million Boe (Center for Data and Information Technology, 2017). The use of traditional biomass, however, is prevalent for basic cooking and thermal purposes amongst millions of rural households in Indonesia. The share of final commercial energy consumption is divided into the sectors of industry (29.86%), households (15.45%), transport (46.58%), commercial use (5.43 %), and other sectors (2.68%). Although the industry sector previously was a major energy-consuming sector, the transport sector has overtaken to be the largest energy consumer since 2012.

The national fossil-fuel balance, however, does not fare well as fuel products and crude oil are imported (Figure 3.1). Oil production will reduce significantly, whilst product demand is increasing at 4–5% per year. Indonesia's fuel import could reach 1 million barrels/day in 2020. The inadequate oil refinery capacity has exacerbated the situation. These have contributed to the rapid increase of the national current account deficit. It is important, therefore, to explore other means to facilitate mobility for the people or alternative renewable fuel to substitute fossil fuel. Several alternatives are readily available including the use of electric mobility and utilising biofuels, particularly from non-conventional biomass.

Figure 3.1. Actual and Projected Domestic Crude Oil Production and Fuel Products Consumption

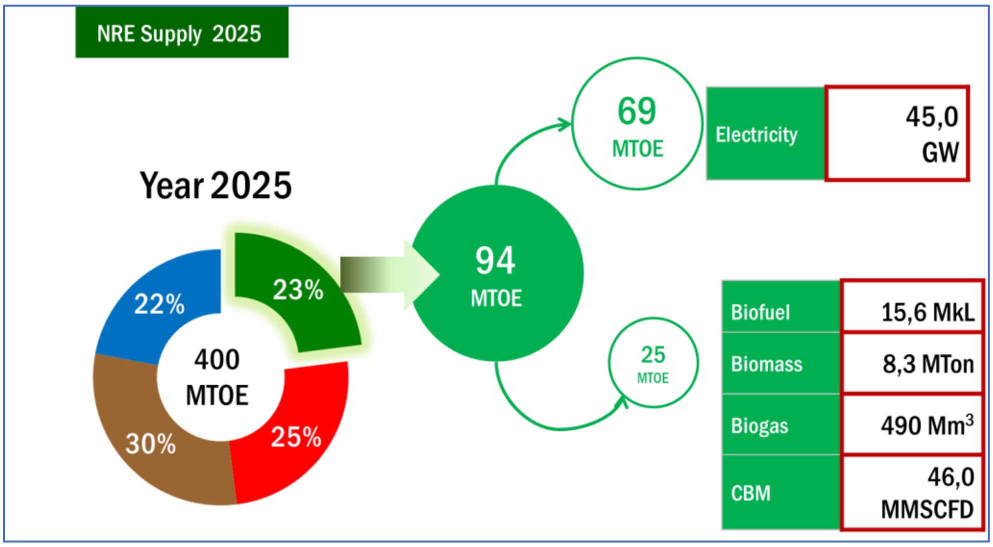


Source: Pertamina.

Presidential Decree No. 5/2006 on National Energy Policy (Kebijakan Energi Nasional, or KEN) is the Indonesian government's strategy on the energy sector. KEN was revised in 2014 by Regulation No. 74/2014, setting a larger target for new and renewable energy at 23% of the energy mix, with oil at 25%, gas 22%, and coal 30%, for a total of 400 million tons of oil equivalent (Mtoe) by 2025 (Government of Indonesia, 2014). To meet the target of renewable energy, the National Energy Council set that biofuel is projected to contribute 15.6 million kilo litres, biomass as a solid fuel would be 8.3 million tons, and biogas to be 490 million cubic metres. The biofuel is mainly for the transport sector, whilst biomass solid fuel and biogas are intended for electricity production. Figure 3.2 presents a visual presentation of renewable energies to meet the new and renewable energy target in 2025.

There is an untapped potential for bioenergy, about 246 million tons per year (Conrad and Prasetyaning, 2014), using dedicated crops and residual flows such as forestry and agricultural residues, organic municipal solid organic waste, offal, sewage sludge, and landfill gas. In the meantime, the total biomass consumption in 2017 is 306 million Boe or 18.6% of the total energy mix (Center for Data and Information Technology, 2017). The majority is used in the household sector followed by the industry sector. The use of biomass is also an attractive option for the electricity generation, particularly biomass derived from waste and oil palms.

Figure 3.2. Forms of Renewable Energies to Meet the New and Renewable Energy Target in 2025



CBM = coalbed methane GW = gigawatt, MkL = metric kilo litre, Mm^3 = metric cubic metre, MMSCFD = million standard cubic feet per day, Mtoe = million ton of oil equivalent, Mton = million ton.
Source: Dewan Energi Nasional (2017).

To speed up the development of biomass-based power plants, the government has issued Presidential Regulation No. 18/2016 to build waste to energy (WTE) plants for seven major cities including Jakarta, Bandung, and Surabaya. Given the significant share of biomass-derived renewable energy, it is also equally important to explore the source of biomass, whether they are in the form of conventional biomass such as vegetable oil or non-conventional biomass including forest residue, agricultural and municipal solid waste, and novel biomass feedstock such as algae.

Non-Conventional Biomass Supply

(1) Forest Residue

An analysis of the 2012's forest cover status showed about 128.4 million hectares (ha) or 68% of Indonesia's land area were state-owned forest areas (Ministry of Forestry of Indonesia, 2014). Of this forest area, limited and permanent production forests were about 58.1 million ha, which consists of a primary forest of 14.5 million ha, a secondary forest of 23.2 million ha, plantations of 2.5 million ha, and area without forest cover of 17.8 million ha. The primary forest here is a virgin forest or an old-growth forest – an untouched forest within the context of logging activities, whereas a secondary forest is a forest that has already been logged and must be left idle for 35 years for regrowth before a second cut is allowed. Most primary forests were located in Papua and Kalimantan, whilst secondary forests include the one in Sumatra.

Forest harvest residues come primarily from the harvesting of natural production forests and industrial forest plantations. About 50.4% resulted from harvesting residues and 49.6% from wood processing residues. The estimated total potential forest biomass in Indonesia for bioenergy in the year 2013 was 7.26 million tons or 132.16 PJ (Simangunsong et al., 2017). Riau province has the largest potential bioenergy followed by Central Kalimantan, East Kalimantan, East Java, South Sumatera, Central Java, and Jambi, which altogether accounted for 87% of total potential bioenergy. Table 3.1 shows the Indonesia's estimated total potential bioenergy (GJ) from harvesting and wood processing residues in the year 2013.

Table 3.1. Estimated Total Potential Bioenergy (GJ) from Harvesting and Wood Processing Residues, 2013, by Province

No.	Province	Harvesting residues from		Total	Wood processing residues from production of				Total
		Natural production forest	Industrial Forest Plantations		Sawnwood	Plywood	Veneer	Chipwood	
1	N. Aceh Darussalam	0	0	0	0	0	0	0	0
2	Sumatera Utara	269,992	712,043	982,035	885,892	317,677	9,615	0	1,213,184
3	Sumatera Barat	244,157	3,810	247,967	0	0	0	0	0
4	Riau	119,112	24,438,107	24,557,219	341,776	757,612	0	20,726,068	21,825,455
5	Kepulauan Riau	0	0	0	0	0	0	0	0
6	Jambi	30,850	3,666,682	3,697,532	18,042	590,710	94,180	3,515,230	4,218,162
7	Bengkulu	0	0	0	0	0	64,202	0	64,202
8	Bangka Belitung	0	1,010	1,010	0	0	0	0	0
9	Sumatera Selatan	0	8,540,742	8,540,742	87,346	0	171,999	419,188	678,533
10	Lampung	0	0	0	0	0	206,497	34,976	241,473
11	DKI Jakarta	0	0	0	11,859	0	0	0	11,859
12	Jawa Barat	0	352,759	352,759	48,014	41,932	159,878	15,470	265,295

No.	Province	Harvesting residues from		Total	Wood processing residues from production of				Total
		Natural production forest	Industrial Forest Plantations		Sawnwood	Plywood	Veneer	Chipwood	
13	Banten	0	68,590	68,590	31,929	1,549,746	1,298	0	1,582,973
14	Jawa Tengah	0	524,219	524,219	1,926,103	3,290,916	2,295,963	0	7,512,983
15	D.I. Yogyakarta	0	0	0	0	0	0	0	0
16	Jawa Timur	0	772,195	772,195	3,191,752	5,007,771	2,155,114	0	10,354,637
17	Bali	0	0	0	104,394	0	0	0	104,394
18	Nusa Tenggara Barat	0	0	0	0	0	0	0	0
19	Nusa Tenggara Timur	0	0	0	0	0	0	0	0
20	Kalimantan Barat	520,913	275,575	796,488	149,594	1,918,509	319,424	114,804	2,502,332
21	Kalimantan Tengah	7,060,304	8,019,374	15,079,678	41,724	1,091,208	212,117	418,797	1,763,846
22	Kalimantan Timur	5,224,009	3,975,322	9,199,331	807,816	3,592,638	2,611	1,809,425	6,212,490
23	Kalimantan Selatan	37,552	16,375	53,927	70,961	2,818,678	96,169	0	2,985,809
24	Sulawesi Utara	0	0	0	0	0	0	0	0

No.	Province	Harvesting residues from		Total	Wood processing residues from production of				Total
		Natural production forest	Industrial Forest Plantations		Sawnwood	Plywood	Veneer	Chipwood	
25	Gorontalo	0	0	0	0	0	0	0	0
26	Sulawesi Tengah	0	0	0	0	0	0	0	0
27	Sulawesi Tenggara	0	0	0	0	0	0	0	0
28	Sulawesi Selatan	0	0	0	68,225	870,077	505,001	0	1,443,303
29	Sulawesi Barat	29,793	0	29,793	0	0	0	0	0
30	Maluku	0	0	0	3,443	779	23,405	0	27,626
31	Maluku Utara	0	0	0	0	0	0	0	0
32	Papua	1,261,937	0	1,261,937	393,738	1,291,378	0	66,409	1,751,525
33	Papua Barat	439,245	0	439,245	536,224	14,612	171,003	70,197	792,036
	Indonesia	15,237,863	51,366,803	66,604,666	8,718,833	23,154,244	6,488,478	27,190,564	65,552,118

Source: Simangunsong et al. (2017).

Using a conversion return approach, the economic value of forest biomass when it was pelletised was estimated to be about US$5.60 per ton of wood residues. The economic value of forest biomass is more sensitive to changes in the price of wood pellets than to changes in the collection and hauling cost of wood residues.

(2) Agricultural Waste and Municipality Solid Waste

Indonesia is the world's largest producer of crude palm oil an important feedstock for biodiesel – and the third-largest producer of rice. Other major agricultural products are cassava (tapioca), groundnuts, cocoa, coffee, and copra. Table 3.2 outlines potential non-conventional biomass for biofuel production.

Table 3.2. Biomass Potential from Agricultural Waste

Biomass	Waste (mton)*	Biofuel from Cellulose (mton)	Biofuel from Hemicellulose (mton)	Total Biofuel (mton)
Rice Straw	6.85	0.79	0.36	1.15
Rice Husk	5.19	0.56	0.23	0.80
Corn Stalk	2.32	0.27	0.17	0.44
Bagasse	0.51	0.07	0.03	0.09
EFB Palm	7.44	0.90	0.50	1.41
Palm Frond	12.62	1.13	0.49	1.62
Total				5.55

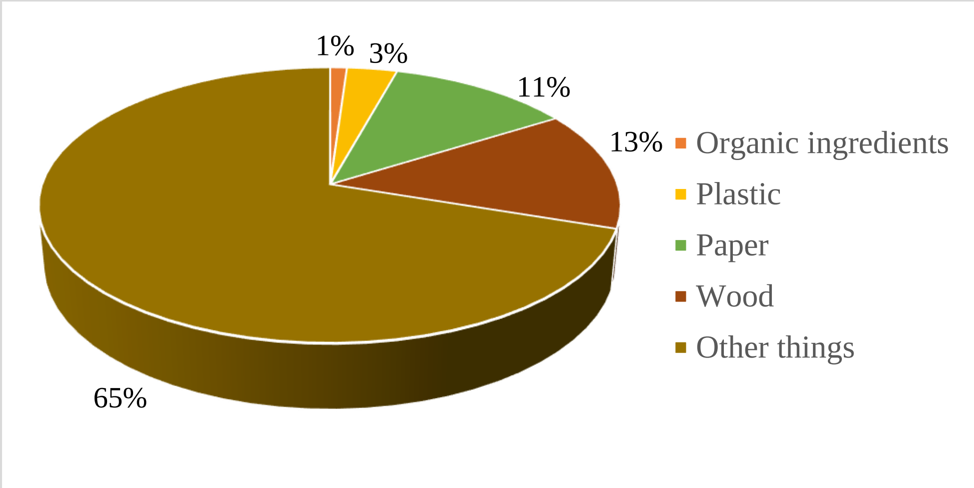
EFB = empty fruit bunch, mton = million ton.

Source: Authors (fuel production was calculated based on Badger, 2002).

Another potential option of renewable energy in urban areas is the utilisation of biomass for electricity production. One possible source is municipal solid waste (MSW), natural and biomass waste discharged from agriculture and forestry that has little economic value. The increase in population and economic growth will put a strain on municipal waste management. Several cities are experiencing difficulties in waste management as the public tends to dispose of waste without separation. The local authorities on the other hand, only organise the collection and transportation to final waste disposal sites without further treatment. As a result, the waste is left uncollected on the street curbs, which later poses dangers to human health and the environment. The current practices of open dumping in designated final disposal sites may cause serious impacts such as methane gas explosions, landslides, and air pollution due to open burning.

A survey by the Central Bureau of Statistics , revealed that the majority of MSW is organic waste that constitutes 65%. Figure 3.3 shows the overall composition.

Figure 3.3. Typical Municipal Solid Waste Composition



Source: Central Bureau of Statistics.

The composition for urban waste is slightly different; 70% of the waste is organic, 28% is inorganic, whilst 2% is classified as dangerous waste. Of the 70% organic waste, around 54% of it (38% of the total waste) is classified as degradable, thus potentially being composted or fermented.

Waste has become a major environmental issue since it produces methane gas (CH_4) and carbon dioxide (CO_2), besides being potentially dangerous to human health. The increasing population of Indonesia means an increasing volume of waste production. On the other hand, there is a limit on the capacity and lifetime of the existing landfill sites. Meanwhile, municipal solid waste has a potential of biomass energy that can be converted to electricity and this source of biomass can be developed in all regions of the country.

Table 3.3. Biomass Distribution Potential for Electricity

No.	Potential (MWe)	Unit	Sumatra	Kalimantan	Java–Bali–Madura	Nusa Tenggara	Sulawesi	Maluku	Papua	Total
1	Oil palm	MWe	8,812	3,384	60	-	323	-	75	12,654
2	Sugar cane	MWe	399	-	854	-	42	-	-	1,295
3	Rubber	MWe	1,918	862	-	-	-	-	-	2,781
4	Coconut	MWe	53	10	37	7	38	19	14	177
5	Rice husk	MWe	2,255	642	5,353	405	1,111	22	20	9,808
6	Corn	MWe	408	30	954	85	251	4	1	1,733
7	Cassava	MWe	110	7	120	18	12	2	1	271
8	Wood	MWe	1,212	44	14	19	21	4	21	1,335
9	Cow dung	MWe	96	16	296	53	65	5	4	535
10	Municipal Solid Waste	MWe	326	66	1,527	48	74	11	14	2,066
	Total potential	MWe	15,588	5,062	9,215	636	1,937	67	151	32,654

MWe = megawatt electric.
Source: Ministry of Energy and Mineral Resources (MEMR)

Table 3.4. Total Capacity of Power Plants using Biomass Derived Fuel, 2018

No.	Type	Quantity of Power Producer		Total Capacity (MW)		Total Investment (US$ million)	
		Proposal	Appointed	Proposal	Appointed	Proposal	Appointed
1.	Biomass	29	15	246.43	130.63	434.4	171.3
2.	Biogas	29	15	48.10	25.40	101.9	49.135
3.	Municipal Solid Waste	7	2	35.5	11	136.8	53.5

MW = megawatt.

Source: Ministry of Energy and Mineral Resources (MEMR)

(3) Algae

The production of biodiesel and bioethanol from algae is the most efficient way to produce biofuel. The main advantage of this system is that it has the efficiency of conserving higher levels of the photon (the factor of an increase in biomass production per hectare), can be harvested for most of the year, produce biofuels that are non-toxic and have high biodegradable capabilities (Schenk et al., 2008). Micro algae can grow ideally in tropical condition. Microalgae can grow ideally in tropical conditions. It can produce cellulose, flour, and oil efficiently and in large quantities (Sheehan et al., 1998). Some microalgae and cyanobacteria can produce bio-hydrogen under anaerobic conditions (Melis et al., 2000) and the fermentation process can produce methane (Schenk et al., 2008). Assuming a 20,000-kilometre-long and 1 kilometre wide beach coast of Indonesia used for algae growth, the potential of algae to oil in Indonesia is about 2 million barrels of oil per day (potential production of algae oil is predicted to be 10 times of palm oil production).

Several institutions in Indonesia are actively working on microalgae for biofuel. The venture of Universitas Gadjah Mada and Pertamina has been working with microalgae since 2015. They work on algae selection, cultivation, harvest, and algae oil extraction. The Indonesian Institute of Science is also actively working in this area, particularly algae oil extraction, in addition to their activities on producing bioethanol from lignocellulose material. LEMIGAS is also actively working with microalgae since 2014 in addition to its regular activities on first-generation biofuel testing. Some researchers of the Agency for the Assessment and Application of have also been working in this field. They have also been working on second-generation biofuel research since early 2010 in cooperation with Japan. The second-generation biofuel utilises biomass through liquefaction and gasification processes. Biodiesel is derived from biomass, including palm empty fruit bunches, midribs, and other agricultural waste.

Challenges

The challenges for using non-conventional biomass is to ensure a balanced allocation of biomass for fuel and electricity. As forest residues are exported in pellet form, they fetch a price of US$135 per ton as wood pellet price in the Republic of Korea, and a range of US$57 to US$249 per ton destined for Europe. Moreover, incentives to utilise biomass for biofuel are less attractive as the announced bioenergy projects in the Republic of Korea would further attract biomass imports from 2 million oven-dry metric tons (ODMT) to up to 12 million ODMT by 2024. Meanwhile the export of palm kernel shells to Japan and Singapore could reach 47 million ODMT by 2021. This trend has a drawback as Indonesia is exporting important chemical elements such as potassium and fibres that otherwise are needed for maintaining soil nutrients.

Besides, there are also challenges in the aspects of financing and investment. This is due to high initial investment costs related to a green field of renewable energy. Other challenges to guarantee the availability of raw materials and to provide adequate infrastructure such as the construction of electricity grids, charging station installation, and rewiring low voltage distribution.

Another issue is land use and land-use change for evaluating carbon emissions. Despite promising greenhouse gas, saving, and energy security, the growth of Indonesia's biofuel that relies on the domestic palm oil industry and sugar cane plantations is presenting enormous environmental and social costs. Given the recent expansion in oil palm plantation is at the expense of tropical forest (US EPA, 2012), the expansion of dedicated plantations for biofuels will likely follow such a trend. This plantation expansion suggests that the potential impact due to land-use change may occur. Instead of being renewable and environmentally friendly, this plan would potentially contribute significantly to greenhouse gas emissions along with other potential impacts such as diverting land from food crops to energy crops, de-afforestation, and social change. Moreover, potential conflicts could arise between local people and companies seeking to build dedicated biofuel feedstock plantations over land use. This could be solved by conducting a life cycle analysis for this biomass.

2. Biofuel Production from Non-Conventional Resources

Introduction

From the viewpoint of global environmental protection, the reduction of energy consumption and greenhouse gas (GHG) emissions in the transport sector is required worldwide. To realise this proposition, electrification of vehicles is being promoted, mainly in developed countries. The electrification of vehicles has many problems such as the construction of infrastructure for charging and the development of high-performance batteries. Therefore, rapid spread is difficult. Some countries in East Asia have a high proportion of coal-fired power generation, and electrification of vehicles may not necessarily reduce GHG emissions. The energy source of battery electric vehicles (BEV) is only electricity. GHG emissions reduction from BEV depends on reducing GHG emissions in power generation. On the other hand, there are abundant biomass resources in the East Asian region, and the introduction of biofuels made from these resources has realised the reduction of GHG emissions and the suppression of crude oil imports. In this area, it is expected that the combination of biofuels and high fuel efficiency vehicles such as hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV) will further enhance the reduction effect of GHG emissions.

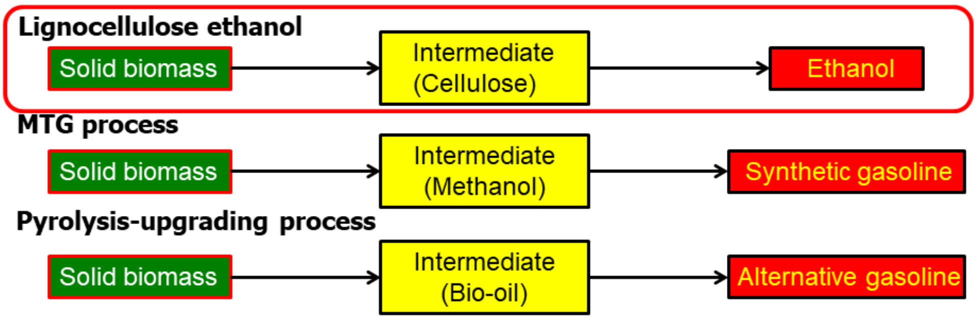
The current first-generation biofuels are limited in the species of raw materials and established manufacturing processes. Thus, it is possible to accurately estimate energy consumption and the amount of GHG emissions in fuel production. On the other hand, the species and production areas of biomass are diverse and methods for producing fuel have not established in the next-generation biofuel production using non-conventional biomass as raw materials. Therefore, it is difficult to accurately estimate energy consumption and the amount of GHG emissions. However, it is essential to use next-generation biofuels made from unconventional biomass to supply a sufficient amount of biofuels in the future.

As HEVs and PHEVs will be introduced mainly as substitutes for existing gasoline vehicles, we have considered how to reduce energy consumption and GHG emissions in the production of alternative fuels.

Biofuels as Alternative Gasoline

As a representative alternative gasoline, ethanol and hydrocarbon fuel produced by the gasification and pyrolysis of biomass and subsequent chemical synthesis and upgrading are known (Figure 3.4).

Figure 3.4. Alternative Fuels Production from Non-Conventional Resources



MTG = methanol to gasoline.
Source: Authors.

First-generation bioethanol is produced from sugar and starch crops as raw materials through the steps of saccharification and fermentation. The next generation bioethanol from non-conventional lignocellulosic biomass is produced through three steps of pre-treatment, saccharification, and fermentation. On the other hand, there are multiple methods for producing hydrocarbon-based bio-gasoline. Typical methods are the synthesis of methanol through gasification of biomass, followed by catalytic conversion to hydrocarbon (MTG process), and upgrading of bio-oil obtained by flash pyrolysis by deoxygenation to hydrocarbon. Amongst these methods, first-generation bioethanol is currently supplied commercially as a transportation fuel.

Energy consumption and GHG emissions are calculated based on first-generation bioethanol in the simulation of this project. In order to compare differences in energy consumption and GHG emissions using first-generation bioethanol with lignocellulosic ethanol as the next-generation biofuel, the estimation of energy consumption and GHG emissions associated with ethanol manufacturing was investigated.

Selection of Raw Materials

Various grass and woody biomass can be used as raw materials of lignocellulosic ethanol. This biomass can be classified into energy crops, biomass residues (agricultural wastes, forest residues, wood processing waste), and biomass waste. In producing ethanol from sugar crops and starch crops, biomass rich in sugars and starch is suitable for obtaining ethanol in high yield. In case of starch crops, crops with a starch content of 65%–75% (dry basis) are generally used for ethanol production. Table 3.5 shows the composition of biomass assumed as an ethanol source. The holocellulose content, which is the total amount of cellulose and hemicellulose, is 5%7–80%, excluding municipal solid waste. It is almost the same as the starch content of starch crops. Corn-derived residues and sugarcane bagasse are suitable as raw materials, although the composition of holocellulose is not constant. Amongst biomass obtained in large quantities in Southeast Asia, palm empty fruit bunch (EFB) is suitable as a raw material. Rice straw and wheat straw contain a large amount of hemicellulose. Ethanol can be produced with high yields if high-efficiency fermentation technology of pentoses is developed. Woody materials contain relatively large amounts of lignin. Since lignin is a substance that inhibits fermentation of sugars, it needs to be separated and removed for fermentation.

Table 3.5. Composition of Lignocellulosic Biomass

Lignocellulosic Biomass	Holocellulose (%)	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Miscanthus	60.0	39.0	21.0	24.5
Silver grass	57.0	33.3	23.7	24.5
Switchgrass	57.1	31.9	25.2	18.1
Corn cob	80.5	43.5	37.0	14.5
Corn cob	72.6	39.7	32.9	12.3
Corn stover	64.0	39.0	25.0	13.0
Oil palm empty fruit bunch	83.3	54.2	29.1	15.1
Rice straw	57.5	32.0	25.5	13.0
Rice straw	56.1	32.1	24.0	18.0
Rice straw	63.0	38.0	25.0	25.0
Sugarcane bagasse	67.0	45.0	22.0	31.0
Sugarcane bagasse	80.0	45.0	35.0	15.0
Sugarcane bagasse	68.4	42.3	26.1	22.4
Sugarcane bagasse	67.3	37.5	29.8	13.2
Sweet sorghum bagasse	62.0	39.5	22.5	17.5
Wheat straw	64.5	35.5	29.0	18.0
Wheat straw	80.0	30.0	50.0	15.0
Wheat straw	63.6	33.7	29.9	23.4
Softwood	66.0	28.5	37.5	27.5
Hardwood	70.0	22.5	47.5	22.5
Municipal solid waste	53.5	41.0	12.5	12.0
Newspapers	80.0	47.5	32.5	24.0

Note: holocellulose = cellulose+ hemicellulose.
Sources: Pandiyan et al. (2019), Loh, Kassim, and Bukhari (2018), Singh and Trivedi (2014), Nakanishi et al. (2018), Zabed et al. (2017).

Estimate of Lignocellulose Ethanol Yield

With regards to the yield of lignocellulosic ethanol, there are differences in the values reported because the production technology is at the development stage. Table 3.6 shows the standard yields reported in the literature. The ethanol yield per biomass unit weight (dry basis) is estimated to be 30%–40%.

Table 3.6. Ethanol Yield from Lignocellulosic Biomass

Biomass	Ethanol Yield (wt%/wt-biomass [dry])
Corn stover	35.5
Rice straw	37.9
Sugarcane bagasse	39.5
Wheat straw	31.6
Wheat straw	38.6
Molasses	22.0
Cassava	35.8

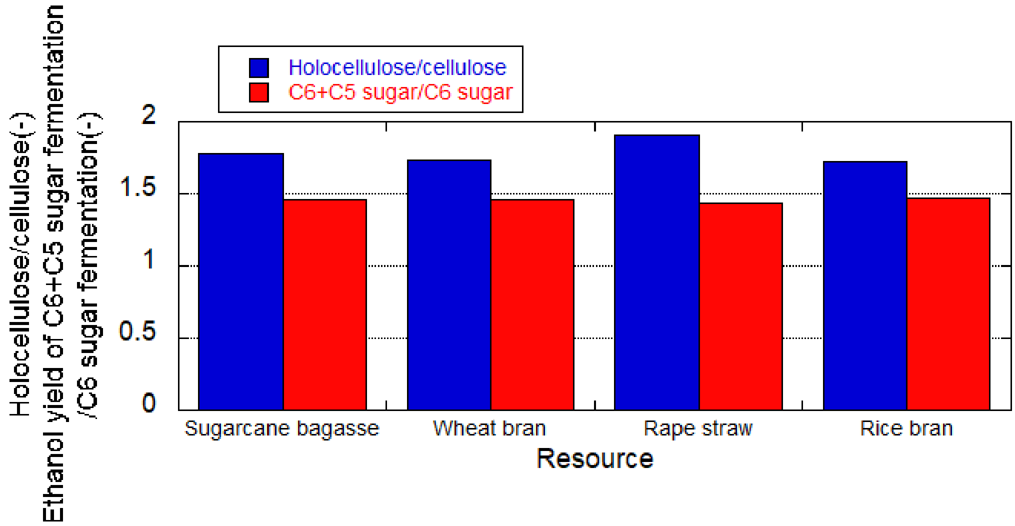
Sources: Pandiyan et al. (2019), Zabed et al. (2017).

Attempt to Improve Ethanol Yield

Research and development to improve the yield of lignocellulosic ethanol, saccharification and fermentation processes, enzymes, and removal technology of fermentation inhibitors have been investigated. Saccharification and fermentation are usually carried out following pre-treatment for the decomposition of the crystal structure of cellulose, which is performed to promote saccharification. The yield of ethanol is higher if these processes are performed simultaneously rather than in separate steps of saccharification and fermentation. It is reported that saccharification and fermentation are performed in separate steps, the ethanol yield based on sugar is 59%. On the other hand, when saccharification and fermentation are carried out simultaneously, the ethanol yield increases to 60%–72.5%. In this case, the ethanol yield increases to 75%–76% when coexisting with a pentose (C5 sugar) fermentation enzyme.

The main objective of the enzyme improvement is to improve the fermentation efficiency of pentoses. The ratio of holocellulose to cellulose contained in sugarcane bagasse, rice straw, wheat and rice husk is approximately 1.7 to 1.9. The ethanol yield improves by 1.4 to 1.5 times when the hexose (C6 sugar) and pentose are simultaneously fermented using multiple enzymes, compared to the ethanol yield when only hexose is fermented (Figure 3.5).

Figure 3.5. Effect of Pentose (C5 sugar) Utilisation on Ethanol Production

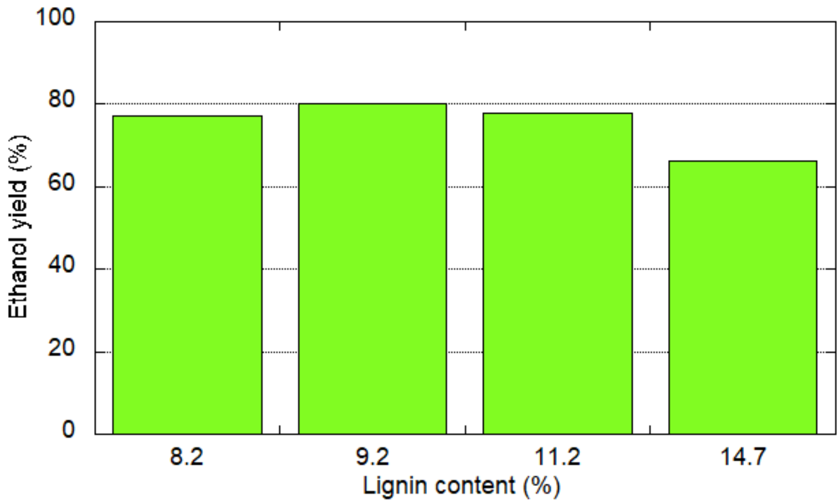


Source: Singh and Trivedi (2014).

The ratio of the hexose and the pentose simultaneous fermentation to only the hexose fermentation shows smaller than the holocellulose/cellulose ratio because the hemicellulose also contains the hexose. Fermentation of pentoses is essential to improve the yield of lignocellulosic ethanol.

The difference between sugar and starch crops and lignocellulosic biomass is that lignocellulosic biomass contains significant amounts of lignin. Because lignin has phenolic structures, it acts as an inhibitor of fermentation. Therefore, it is preferable to remove lignin in pre-treatment. The yield of ethanol obtained by saccharifying and fermenting of the delignified sugar cane bagasse which is obtained by decomposing and removing lignin with a chlorine-based oxidising agent is shown in Figure 3.6. The samples with lignin content 11.2% or less show high ethanol yield. However, it is not preferable to decompose and remove it when lignin is used as an energy source. So, it is preferable to develop lignin tolerant enzyme.

Figure 3.6. Effect of Lignin Content on Ethanol Production

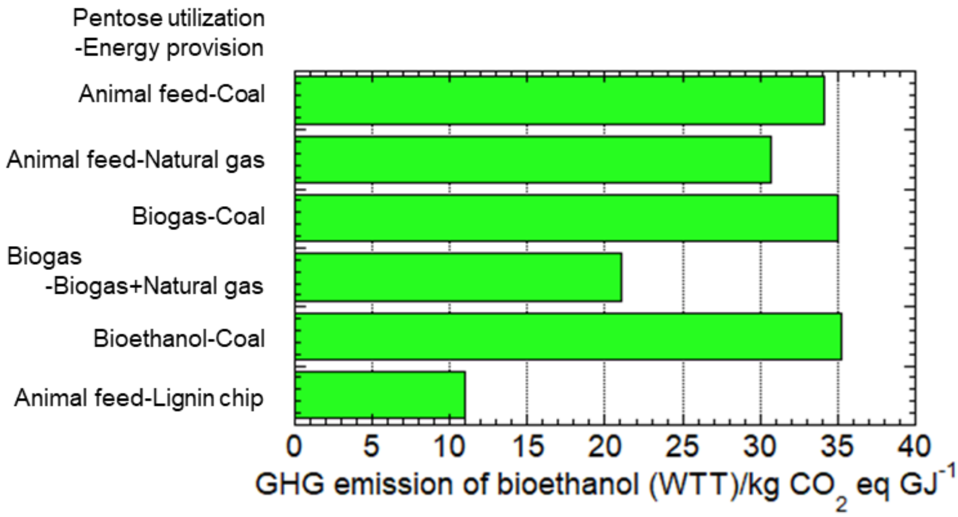


Source: Yu et al. (2018).

Reduction of Energy Consumption and Greenhouse Gas Emissions in Ethanol Production Process

In the production of ethanol from lignocellulose, the process of ethanol production is the largest energy consumption amongst crop cultivation, ethanol production, and transportation of raw materials and products. The ethanol production process requires external energy supply such as electricity and heat. If these energies can be covered by the use of by-products from ethanol production, it is possible to reduce the external energy supply. When fermentation of only hexoses is performed, hemicellulose-derived pentose can be used as an energy source. Comparing the case where pentose is used as animal feed and the case where it is converted to biogas and used as energy supply, it is possible to reduce GHG emissions by co-firing biogas (Figure 3.7). On the other hand, when lignin chips are used as energy sources such as heat (steam) or electricity generation, GHG emissions decrease significantly. When fermenting pentose to obtain ethanol, GHG emissions increase slightly compared to when it is used as animal feed. However, since the saving effect of energy supply by lignin is large, it is possible to satisfy both the improvement of ethanol yield and the reduction of GHG emissions.

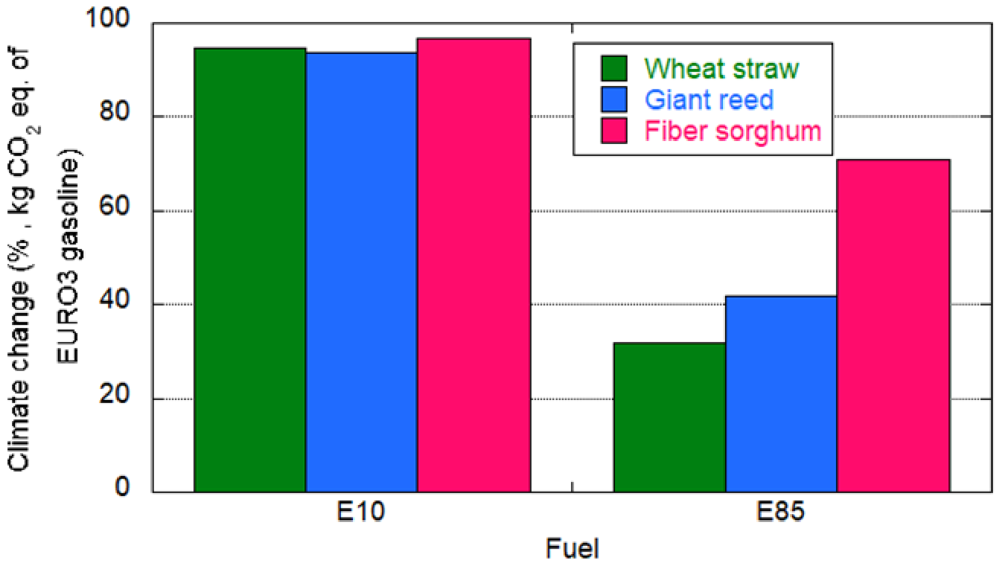
Figure 3.7. GHG Emissions from Ethanol Production



GHG = greenhouse gas. kg = kilogram, WTT = well-to-tank.
Source: Zech et al. (2016).

Differences in the energy consumption of cultivation and pre-treatment process of raw materials influence the amount of GHG emissions in ethanol production. In the case of using E10 fuel, there is no significant difference in the amount of GHG generated in well-to-wheel, (WtW) because the amount of the mixed bioethanol is small. However, when using E85, the difference in GHG emissions in ethanol production has a major impact on the amount of GHG emissions in WtW (Figure 3.8). Therefore, the selection of raw materials and the optimisation of the ethanol production process become more important.

Figure 3.8. Effect of Biomass species on GHG Emissions in WTW



GHG = greenhouse gas, WTW = well-to-wheel.
Source: Singh and Trivedi (2014).

Conclusion

There are many non-conventional biomass types that can be expected to yield ethanol comparable to starch crops. The productivity of lignocellulosic ethanol is difficult to estimate accurately because there are many development factors in the whole process. Many elemental technologies are currently under development. Estimated ethanol yield is 30%–40% of lignocellulosic biomass (dry base). By the utilisation of pentose (C5 sugar), the ethanol yield can be improved (1.4 times as compared with the case of using only hexose). In order to economically introduce lignocellulosic ethanol, it is preferable to improve the ethanol yield by a production process using conventional molasses and starch crops in the short and medium term. By utilising lignin, the environmental impact can be reduced and economics can be improved.

When lignocellulose ethanol is used at high concentrations, the effect of GHG emissions on ethanol production becomes larger. For ethanol production, it is more important to select optimal raw materials and processes with less environmental impact.

Based on the discussion, the following items are proposed as policy recommendations.

- The location of the fuel production facility should be considered in the biomass production area.
- Research and development of production technology of next-generation biofuel should be continued to provide data that can accurately estimate production efficiency, environmental compatibility, and economy.
- In the short term, energy production by sharing non-conventional biomass and fossil resources is a practical method (e.g. coprocessing in the refinery).

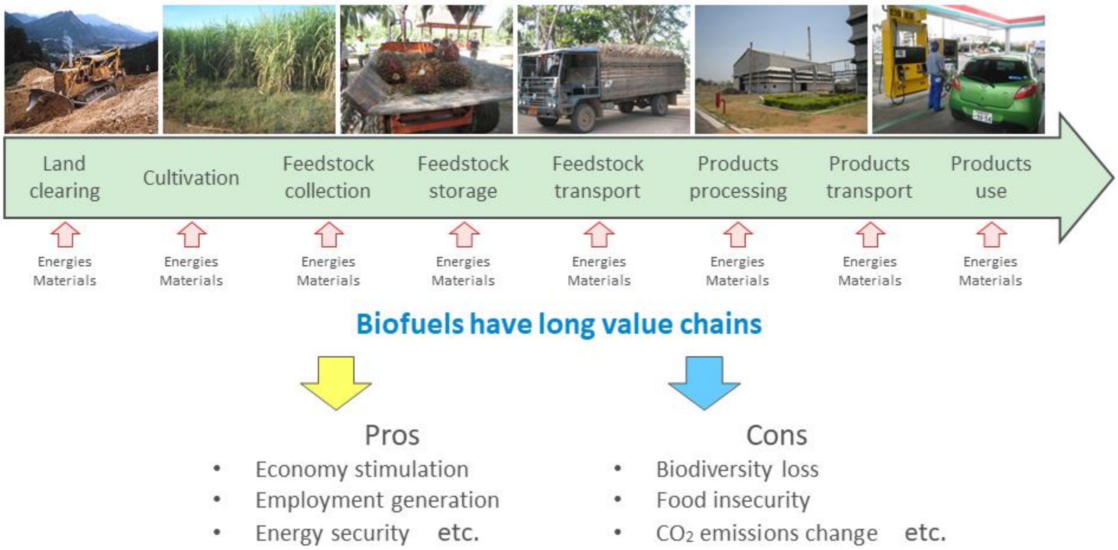
3. Life Cycle Assessment Study of Bioenergy Production

Introduction

East Asia Summit countries are abundant in biomass feedstocks and bioenergy produced from these feedstocks is expected to play important roles to diversify the current heavy energy dependence on imported oil and improve the environment in this region. One of the characteristics unique to bioenergy is that it has a long value chain (Figure 3.9) compared with other renewable energy resources and many stakeholders are involved in this value chain. This is why not only the environmental benefit (greenhouse gas [GHG] mitigation) but also economic (local economy stimulation, etc.) and social benefits (employment generation, etc.) can be expected by the deployment of bioenergy.

On the other hand, it should be noted that some negative impacts such as food insecurity and biodiversity loss may arise if the bioenergy and their feedstock production is not managed in a sustainable manner. Another negative impact that may affect the environment is the GHG/CO_2 emissions increase through the use of bioenergy. It is true that the direct CO_2 emissions from biomass combustion are counted as zero because the bioenergy is regarded as carbon neutral. However, various energy sources and materials necessary to operate the processes comprising the value chain induce indirect GHG/CO_2 emissions. It is reported that the value chain carbon footprint of biofuels sometimes becomes larger than the conventional automotive fuels (gasoline and diesel) if produced in an unsustainable manner.

Figure 3.9. Bioenergy Value Chain



Source: Authors.

Life Cycle Assessment of Bioenergy

The life cycle assessment (LCA) technique is frequently used to quantify the carbon footprint of the target bioenergy value chain. LCA is a useful tool to evaluate the environmental aspects and potential impacts associated with a product or service throughout its life span and the ISO-14040 series has been put forward as a framework of the internationally standardised LCA application method. To understand to what extent the LCA on bioenergy should cover, the 'GBEP Common Methodological Framework for GHG LCA of Bioenergy' (GBEP, 2010) that had been developed by the Global Bioenergy Partnership (GBEP) provides policymakers and bioenergy stakeholders with a harmonised methodological framework to assess the life cycle of GHG emissions of bioenergy. The methodological framework is a checklist that comprises 10 steps in the full LCA of GHG emissions from bioenergy production and use:

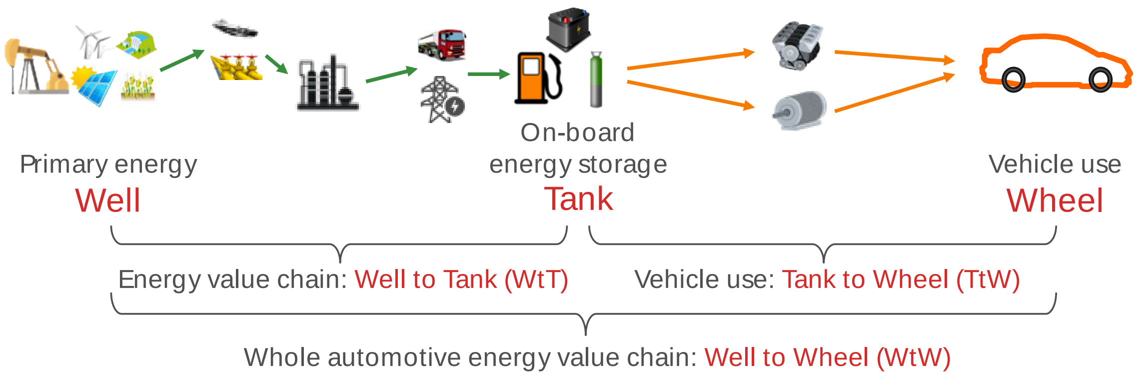
1. GHG covered
2. Source of biomass
3. Land-use changes (LUCs) due to bioenergy production
4. Biomass feedstock production
5. Transport of biomass
6. Processing into fuel
7. By-products and co-products
8. Transport of fuel
9. Fuel use
10. Comparison with replaced fuel

For each step, a set of questions was developed to ascertain which sources of emissions (or sinks) were considered and through which methods, and which assumptions were made. Since not all 10 steps will apply to all bioenergy systems, in some applications it will be necessary to skip one or more steps of the framework.

Definition of 'Well-to-Wheel'

The term 'well-to-wheel' has become well-known in the transport sector and currently various vehicle makers and automobile industry associations have set their long-term target to reduce the GHG/CO_2 emissions from well-to-wheel viewpoints. As shown in Figure 3.10, well-to-wheel is a specific LCA framework to evaluate the whole environmental emissions throughout the automotive energy value chain from extraction and collection of primary energy, energy transformation/refinery/transport, and consumption for vehicle use. The automotive energy value chain is called 'well-to-tank' and the vehicle use phase is called 'tank-to-wheel'. In other words, it can be said that well-to-wheel assesses the life cycle environmental emissions difference by the combinations of automotive energy (well -to-tank) and powertrain (tank-to-wheel).

Figure 3.10. Well-to-Wheel Analysis Outline



Source: Authors.

Examples of Bioenergy Life Cycle GHG/CO_2 Emissions

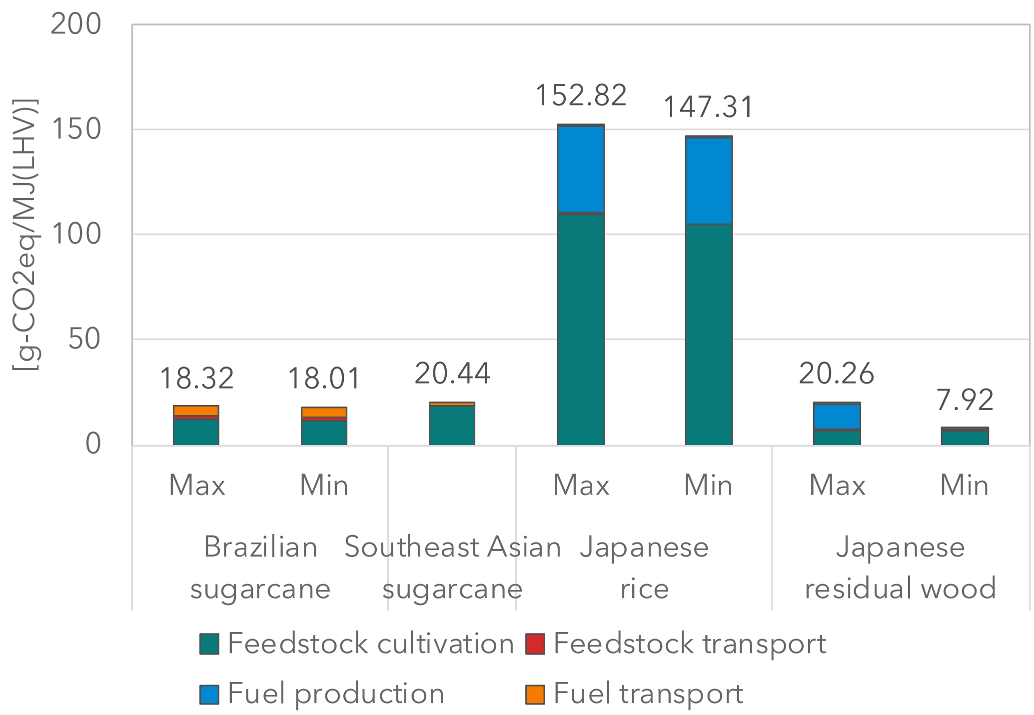
There are various studies that evaluated the life cycle of well-to-tank GHG/CO_2 emissions of bioenergy. All these cover some or most of the steps listed in the GBEP's framework (GBEP, 2010) but the results depend on the assumptions made for each study. To understand the carbon footprint profiles of both first- and second-generation bioenergy,[4] this article reviews the following four articles that are relevant to East Asia Summit countries or the emissions from non-conventional resources.

[4] First-generation bioenergy is the conventional and commercial bioenergy made from food crops, whereas second-generation or advanced bioenergy is produced from non-food biomass feedstock.

- Toyota and Mizuho (2008)

  In this report, Toyota Motor Corporation and Mizuho Information and Research Institute jointly assessed in detail the well-to-tank GHG emissions of bioenergy for Japanese transport use. Among the various bioenergy value chains considered in this report, Figure 3.11 shows the well-to-tank GHG emissions of ethanol production for transport use. Please note that the GHG emissions attributed to LUC (step 3 of the GBEP framework) were not included in the calculation. Imported ethanol to Japan produced from sugarcane showed low GHG emissions. The emissions from feedstock cultivation in Brazil tended to be smaller than in Southeast Asia due to higher sugarcane yield and different raw material in ethanol production system (cane juice in Brazil and molasses in Southeast Asia). The emissions from Japanese rice became far larger than those from sugarcane. The reason for the particular large emissions from feedstock cultivation was that rice is usually farmed in paddy fields and the methane emissions from paddy fields are large. It was also estimated that the emissions from residual wood could be almost the same level (maximum value) as imported ethanol from sugarcane, and the emissions could be reduced further by using bioelectricity instead of grid electricity in fuel production stage (minimum case).

Figure 3.11. Ethanol Well-to-Tank GHG Emissions Calculated in Toyota and Mizuho (2008)

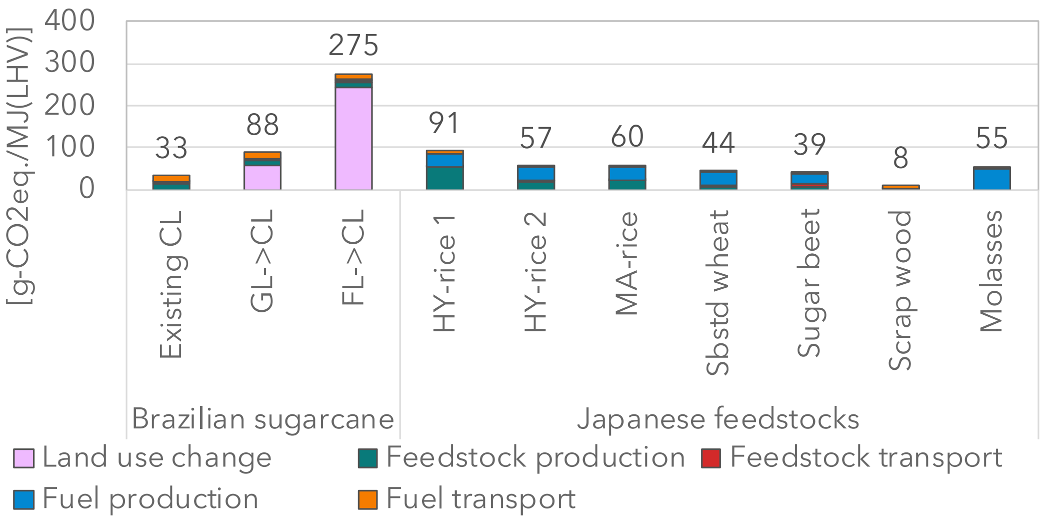


GHG = greenhouse gas.
Source: Toyota and Mizuho (2008).

- Ministry of Economy and Trade (2010)

  The Ministry of Economy and Trade (METI) study group calculated the ethanol well-to-tank GHG emissions from various pathways, which are shown in Figures 3.12. The difference from the Figure 3.11 assumption in the Toyota and Mizuho report (2008) was that Figure 3.12 included the direct LUC[5] (dLUC) emissions for Brazilian sugarcane-ethanol value chain. In this calculation, CO_2 emissions due to the above- and below-ground carbon stock change by converting the land to cropland were calculated and equally allocated over 20 years, which was found to be significant for Brazilian sugarcane case. It can be also confirmed from Japanese feedstock cases in Figure 3.12 that the emissions from scrap wood, one of the second-generation feedstocks, tended to be smaller than the other cases.

Figure 3.12. Ethanol Well-to-Tank GHG Emissions Calculated in METI (2010)



CL: cropland, GL: grassland, FL: forestland, HY-rice: high yield rice, MA-rice: minimum access rice, Sbstd wheat: substandard wheat

GHG = greenhouse gas.
Source: METI (2010).

- Silalertruksa and Gheewala (2011)

  Silalertruksa and Gheewala evaluated the GHG emissions from bioethanol production in Thailand. Cassava and molasses were selected as the target feedstock and the emissions from dLUC were included in their calculation. It can be confirmed from Table 3.7 that if the land use changes from tropical forestland (FL) and/or grassland (GL) to cropland (CL) were included, the GHG emissions could possibly increase from 1 to 10 times as compared to the case where LUC was excluded.

[5] Direct LUC accounts for changes in land used associated with the direct expansion of bioenergy feedstock production, such as the displacement of food or fiber crops, pastures and commercial forests or the conversion of natural ecosystems.

Table 3.7. Life Cycle GHG Emissions of Bioethanol in Thailand Calculated in Silalertruksa and Gheewala (2011)

Feedstocks	GHG emissions (g CO_2-eq/MJ bio-ethanol)			% Net avoided GHG emissions when comparing with gasoline[a]		
	Excluding LUC	Including LUC		Excluding LUC	Including LUC	
	Range	FL-CL	GL-CL	Range	FL – CL	GL – CL
Cassava	27[b]-91[c]	249-313	63-127	73%[b] - (-2%)[c]	(-178%) - (-249%)	30% - (-42%)
Molasses	28[d]-119[e]	292-380	71-158	77%[d] - (-33%)[e]	(-222%) – (-320%)	25% - (-73%)

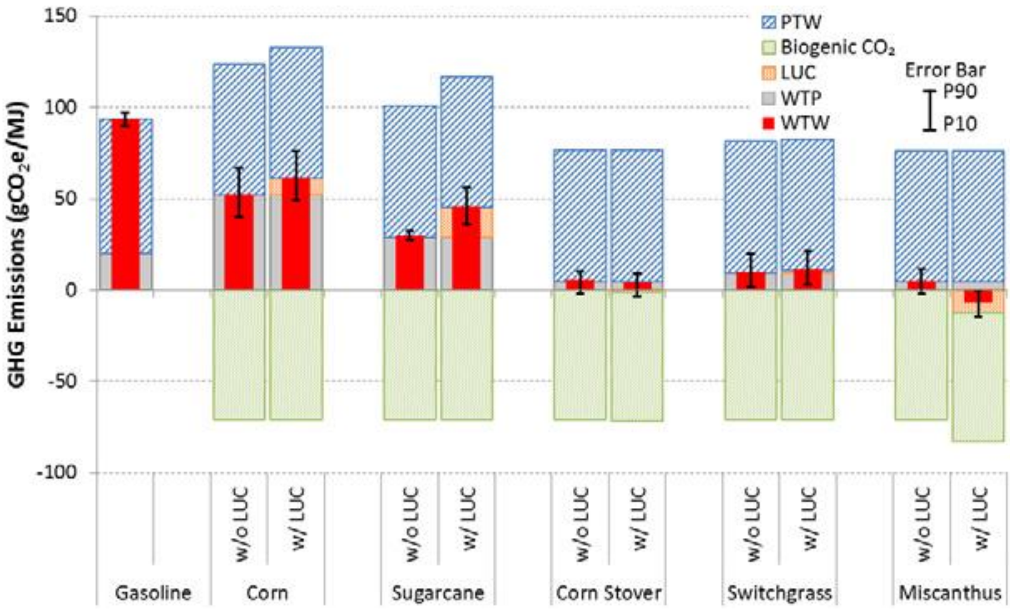
[a] % Net avoided GHG emissions are estimated based on gasoline fuel-cycle GHG emissions = 2.918 kg CO_2eq./L [7]
[b] Referring to cassava ethanol system in which ethanol plant uses biomass as fuel and recovered biogas are utilized (based on cassava yield = 34 ton/ha as policy target)
[c] Referring to cassava ethanol system in which ethanol plant uses coal as fuel and no recovery of biogas
[d] Referring to molasses ethanol system in which ethanol plant uses biomass as fuel and recovered biogas is utilized (based on sugarcane yield = 94 ton/ha as policy target)
[e] Referring to molasses ethanol system in which ethanol plant uses coal as fuel and no recovery of biogas

Source: Silalertruksa and Gheewala (2011).

- Wang et al. (2012)

  Wang et al. calculated well-to-wheel GHG emissions of gasoline and five bioethanol pathways in the United States as shown in Figure 3.13. The emissions were separated into well-to-pump (WTP, equivalent to well-to-tank), pump-to-wheel (PTW, equivalent to tank- to-wheel), biogenic CO_2 (i.e. carbon in bioethanol) and LUC GHG emissions. Figure 3.13 suggests that cellulosic bioethanol (ethanol from corn stover, switchgrass, and miscanthus) was projected to have larger GHG emissions reductions compared to gasoline than the current commercial bioethanol (ethanol from corn and sugarcane), even if the emissions from LUC were accounted.

Figure 3.13. Well-to-Wheel GHG Emissions of Gasoline and Bioethanol Pathways Calculated in Wang et al. (2012)



GHG = greenhouse gas.
Source: Wang et al. (2012).

- SCOPE (2015)

  In 2015, the Scientific Committee on Problems of the Environment (SCOPE) launched its report on 'Bioenergy and Sustainability: Bridging the Gaps' to answer the question whether modern bioenergy technologies can make a significant contribution to our future energy demands with positive contributions to the environment, and to social development.

  The report includes the discussion on the GHG/CO_2 emissions from LUC, which has been the most contentious issue in evaluating GHG effects of bioenergy. Among the LUC categorisation of dLUC and indirect LUC[6] (iLUC), the significance of iLUC had been regarded to be large enough to negate the GHG emission benefits of an otherwise low-emitting biomass-based fuel supply chain, as shown in Figure 3.12 and Table 3.7. Recently, it is deemed that this is no longer the case for ethanol crops due to the result of the reduction in the estimated magnitude of iLUC-induced emissions over time. Current trends relevant of iLUC observable in most parts of the world include ongoing improvements in the efficiency of feedstock production and conversion processes, decreased rates of deforestation, and more stringent regulation of agricultural practices.

[6] Indirect LUC comprises induced effects of biofuel feedstock expansion promoting land use changes elsewhere than where the expansion has taken place.

Findings for Bioenergy LCA

From the reviews of studies and reports in this section, the findings of bioenergy LCA can be summarised as follows:

- Bioenergy GHG/CO_2 results vary significantly amongst different bioenergy types and regions, and are affected by LCA methodology, technology modelling and data availability. This includes the system boundary settings, how the bioenergy co-products are treated, whether and how the LUC emissions are considered, and whether the technology advancement is considered or not.
- Second-generation bioenergy may have a higher life cycle GHG/CO_2 mitigation potential than the first-generation bioenergy.
- Emissions from LUC tended to have significant impact and there were still considerable uncertainty for the quantification of indirect LUC emissions, but in recent studies it is regarded that LUC emissions can be avoided if land demand for biofuels expansion is managed, if yield increase exceeds increase in demand and as long as deforestation rates are decreasing.

Last but not least, the selection of the right biomass feedstock, the right conversion technology, and the right LCA methodology become important to identify the role of bioenergy in GHG/CO_2 mitigation. Further reviews and continuous studies on bioenergy LCA are indispensable to achieve this goal.

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Chapter 4

Conclusion as Policy Recommendations

As we have stated, we have summarised policy recommendations through this study. In response to these recommendations, three policy dialogues were held, where we exchanged views with policymakers from the Indian, Indonesian, and Thai governments and representatives from relevant industries. In this discussion, in addition to evaluating our recommendations, we received valuable opinions on reducing energy consumption and reducing greenhouse gases in the transport sector. We would like to recap these and summarise the main points for future policymaking.

We have shown through simulation results that it is difficult to reduce energy consumption and greenhouse gas emissions only by electrifying automobiles, and it is effective to use biofuels, which is a renewable energy resource, together. Therefore, it is essential that future policies in the transport sector be promoted with the dual structure of electrification of automobiles and the introduction of biofuels. Therefore, the policies to be adopted in the future are roughly divided into the automobile policy and the biofuel introduction policy.

Electrified vehicles (xEV), which are currently being introduced, are mainly intended for passenger cars. As is clear from the results of the simulation and the opinions received, measures for passenger cars alone are not sufficient to reduce energy consumption and global warming gas emissions in the transport sector as a whole. Therefore, it is necessary to take measures for each genre of passenger cars, heavy commercial vehicles, and motorcycles. For passenger cars, introducing xEV is effective in reducing the environmental load. Therefore, the introduction should continue. However, in countries where the demand for diesel and coal is high in the energy composition of power generation, the introduction of xEV will have a very small effect on reducing the environmental impact unless it is changed to an energy composition with a lower environmental impact. Especially in the case of battery electric vehicles (BEV), which are 100% dependent on electricity, the effect is large. As a roadmap for introducing xEV, it would be effective to introduce hybrid electric vehicles (HEV) that do not rely on electricity in the short term and have a great effect of using biofuel together. If it is expected that the number of charging stations will increase or the electric power situation will improve over time, the introduction of plug-in hybrid electric vehicles (PHEVs) should be considered in the medium to long term. PHEVs will also have some benefits of using biofuels. In India and Indonesia, where coal-fired power generation is large, the amount of global warming gas emissions from power generation is high, and the advantage of introducing BEVs is small.

Next, we would like to mention the electrification vehicle introduction promotion policy. As shown in the cost estimation of the simulation, the introduction cost of electric vehicles is still high, and consumers have not yet actively supported it. In addition, old cars are often used in ASEAN member countries and India, and the proportion of new cars introduced is not high. Even if a country tries to promote the introduction of fuel-efficient cars to reduce the environmental load, it cannot be realised unless consumers can be motivated.

In order to promote the introduction of fuel-efficient cars, both ‘candy and whip’ policies should be implemented. The hurdle for introducing xEVs is the high introduction cost. In order for consumers to accept electrified vehicles, it is effective to give incentives such as a reduction of vehicle acquisition tax and eco-car subsidies. By giving incentives for each vehicle type according to fuel consumption and global warming gas emissions, it is possible to reduce costs at the time of introduction and increase consumers' willingness to purchase. If the number of registered vehicles is low, the incentive will be greatly promoted if it is raised to a level that does not differ from the cost of introducing existing internal combustion engine vehicles. When setting incentives, numerical standards for energy consumption and environmental load reduction are clearly indicated, and based on this, evaluation is made for each vehicle type. Automobile manufacturers should provide accurate numerical information to governments so that assessments can be performed accurately.

On the other hand, two points can be considered to promote the introduction of xEVs: environmental taxation and retirement policy for old-model cars. Environmental taxation includes building a carbon taxation system to promote environmentally-friendly efforts. For example, an ‘area taxation’ could be considered such as a taxation on cars entering urban areas where congestion occurs and for vehicles with poor fuel economy, and a seasonal taxation to control the number of vehicles when air pollution becomes serious.

By enacting a vehicle retirement policy and retiring old vehicles with poor fuel efficiency and high emissions of environmental pollutants, the effect of xEV introduction on oil consumption and emissions will be enhanced. In Japan, a tax is levied every 2 years through a vehicle inspection system, and it is obligatory to maintain the necessary parts. Also, the vehicle tax added every year will increase for vehicles that have passed a certain number of years since registration. This tax is disliked, and there is a demand for switching to new cars. Even if it is difficult to manage each individual vehicle, it will be possible to establish a vehicle retirement policy by methods such as regulations and strengthening taxation, by classifying vehicles by year.

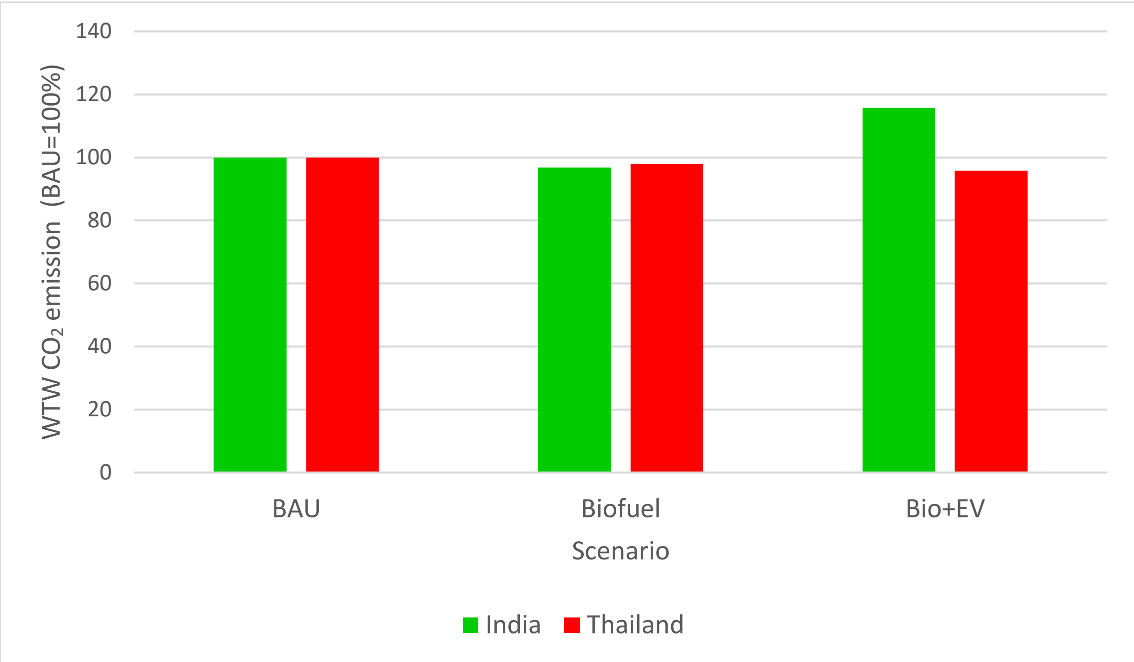
By enacting a vehicle retirement policy and retiring old vehicles with poor fuel efficiency and high emissions of environmental pollutants, the effect of xEV introduction on oil consumption and emissions will be enhanced.

The electrification of heavy commercial vehicles such as buses and trucks is currently difficult. In particular, heavy-duty trucks used for physical distribution transportation have a feature that they travel long distances, so that when they are electrified, it is inevitable they will need to be charged midway in the trip. It takes time to maintain charging stations, and the long charging times affect the transportation schedule.

As an environmental measure for heavy-duty vehicles, the use of fuel, which has a lower environmental load than petroleum diesel fuel, is considered. Liquefied natural gas (LNG) and compressed natural gas (CNG) are two options. Since the technology has already matured, the problem of developing infrastructure must be solved. Since natural gas can also be used as a fuel for civil use in the city, it is desirable that the supply stations be planned together with the infrastructure development of the city.

A problem closely related to the electrification of automobiles is the problem of energy composition of power generation. In this research, it is not correct to simply compare the simulation results because the values used for scenario setting and calculation differ from country to country. Based on this, the comparison of the well-to-wheel-based global warming gas emissions forecasts for 2030 in India and Thailand are shown in Figure 4.1. As bio scenarios, the results of the alternative fuels scenario in India (Fig.2.13) and those of the alternative energy scenario in Thailand (Fig.2.31) were compared. As a Bio+EV scenario, comparisons were made with the results of the moderate electrification scenario in India and the combination scenario in Thailand.

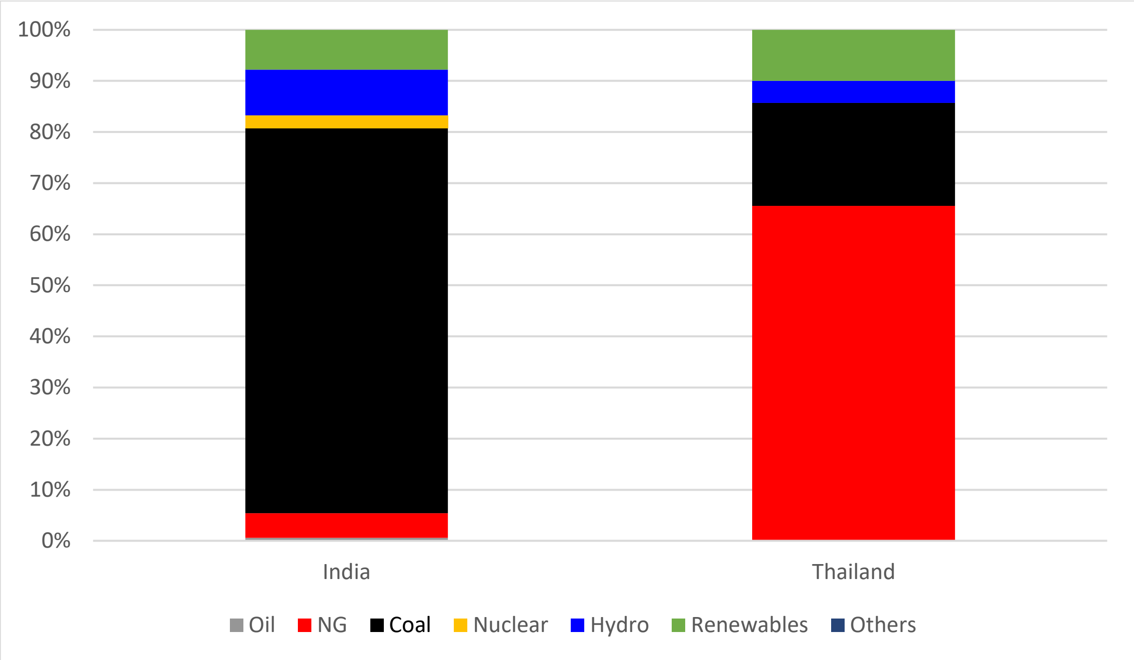
Figure 4.1. Well-to-Wheel CO_2 Emissions from Road Transport Sector (2030) Based on Simulation



BAU = business as usual, EV = electric vehicle, WTW = wheel-to-well.
Source: Authors.

In the biofuel scenario, CO_2 emissions are decreasing in both countries, indicating that they are effective in reducing greenhouse gas emissions. The magnitude of the effect is different because the policy target of the introduction amount is different in each country. On the other hand, when biofuel and electrification of automobiles are carried out in parallel, the synergistic effect appears in Thailand and the reduction effect is large, whereas it is increasing in India. Since the reduction effect of electrification appears in TtW (Fig. 2.14), it can be seen that the increase in electrification is due to WtT, that is, power supply. Figure 4.2 compares the energy composition of power generation in both countries. India has a large proportion of coal-fired power plants that emit a large amount of CO_2. This is considered to be the main reason why emissions of global warming gas cannot be reduced even by electrification, and it is pointed out that the reduction of environmental load by electrification of vehicles is meaningless unless they are combined with power generation improvement.

Figure 4.2. Energy Composition in Power Generation



Source: BP (2019).

The introduction of biofuels is effective in reducing greenhouse gas emissions and oil consumption, as was mentioned above. Based on the fact that biofuels are already widely distributed in the ASEAN market, we will summarise the points to be noted in the electrification of automobiles in the future.

As is clear from the results of this simulation, the introduction of biofuels can reduce oil consumption and greenhouse gas emissions. On the other hand, the big problem of introducing biofuel is its price. As the fuel for transportation is ridiculed as 'cheaper than water,' it is necessary to considerably reduce the selling cost from the standpoint of consumers. On the producer's side, it is desirable to maintain a price that can secure an adequate income to maintain production. To satisfy this conflicting position, government incentives for producers and reduced fuel taxes on consumers are essential.

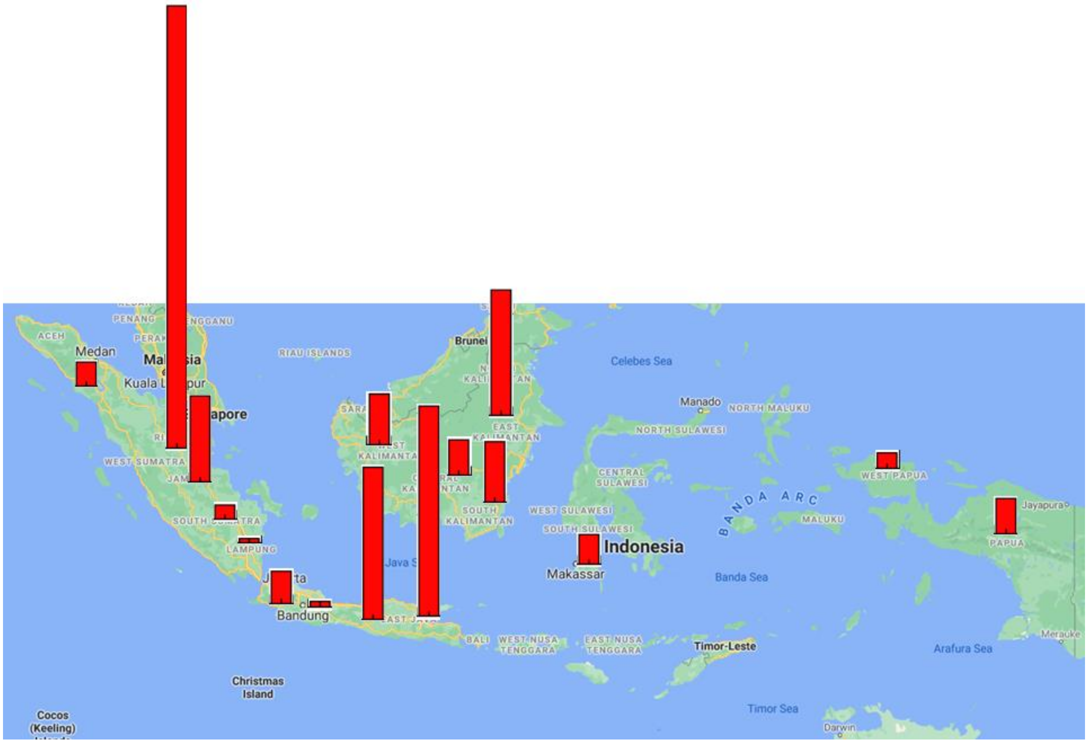
Electrified vehicles are mainly passenger cars, and they are being introduced mostly as an alternative to gasoline vehicles. The proportion of gasoline vehicles in passenger cars varies from country to country. In particular, when diesel vehicles will be replaced by electrified vehicles, it is expected that a shift in demand from biodiesel fuel to bioethanol will occur. As can be seen from Thailand's simulation results, the introduction of HEVs offsets the improvement in fuel consumption and growth in fuel demand, and the demand for bioethanol is almost flat. On the other hand, the conversion of diesel vehicles to electrified vehicles has reduced the consumption of biodiesel fuel compared to the BAU case. It is expected that the demand for biofuels will change in conjunction with the spread of electric vehicles in the future, so it is necessary to modify the supply plan flexibly according to the situation when carrying out a biofuel policy.

In order to meet the demand change of biofuels due to the spread of electrified vehicles, it is necessary to balance the supply and demand by domestic fuel inventory management in the region and import/export in the ASEAN region. It is hoped that a coordinated policy will be discussed at the energy conference held by the government officials of each country.

Industrial ethanol is in great demand not only as an automobile fuel, but also as a chemical raw material and a pharmaceutical. With the recent prevalence of COVID-19, the demand for disinfection has increased significantly and the price has also risen. In production from the current crops, it is expected that high-priced food (alcohol) and pharmaceuticals will be given priority, and low-priced fuel alcohol will be in short supply. The production of ethanol from unconventional raw materials will help solve this supply shortage. The production of ethanol from lignocellulose, which is an unconventional raw material, is currently low in productivity and the production process is not optimised. Only laboratory tests at the research stage, a life cycle assessment based on those values, or bench-scale manufacturing tests are performed. In order to commercialise the production of ethanol from lignocellulose, some technical hurdles must be cleared. These include (i) search for biomass resources that bring about high productivity, (ii) establishment of highly efficient and energy-saving production processes, (iii) energy consumption in production processes by using by-products (lignin) reduction, (iv) location selection of production areas to ensure economic efficiency, and (v) economic efficiency improvement by productivity improvement by using first-generation raw materials together. By deriving highly accurate numerical values through research and development, it becomes possible to more accurately calculate the environmental load and production cost by a life cycle assessment. Since it is difficult to make a profit as a corporate activity in the research and development stage, it is desirable that governments provide subsidies. Biofuel refineries are often small businesses. In order to improve economic efficiency, the integration of small-scale refineries should be considered.

For first-generation biofuels, fuel production has been carried out by setting up production plantations on newly reclaimed land. This led to environmental damage and became a problem. Traditional slash-and-burn agriculture has also caused haze problems. In order to produce next-generation fuel whilst suppressing environmental damage, it is desirable to use waste that does not require the production of new crops. This survey, which was compiled for Indonesia, shows that there are regional differences in the supply potential of lignocellulosic waste (Figure 4.3). In addition, some of the existing palm oil manufacturing plants are producing waste that can be used, such as EBF, waste at the stage of oil extraction, and old trees whose fruit production capacity has declined. In order to locate a manufacturing plant, it is necessary to conduct a resource survey on the type of biomass, the amount of biomass, and the regional characteristics.

Figure 4.3. Estimated Total Potential Bioenergy from Harvesting and Wood Processing Residue, Indonesia (2013)



Source: Created by the authors based on Simangunsong et al. (2017) and Google Maps.

Finally, we would like to argue that it is essential for policymakers to formulate solid medium- to long-term national energy plans that have carefully evaluated the outlook. Sometimes the policy may change midway due to political conditions, but the basic skeleton does not change, and we plan a policy that can flexibly respond to the 'branches and leaves' with minor modifications due to the spread of automobiles and the production status of biofuels. The policy needs to be multifaceted, as the fusion of technologies for electrifying automobiles and introducing biofuels is effective.

The formulation of such policies should be based on accurate data. In addition to collecting and enriching the statistical data of the current transport sector, which is the basis for trial calculation, reduce energy consumption and global warming in the trial transport sector by incorporating other factors such as travel demand management, mass transportation promotion, and eco-driving. An optimal solution for reducing gas emissions should be sought.

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Simangunsong, B.C.H., V.J. Sitanggang, E.G.T. Manurung, A. Rahmadi, G.A. Moore, L. Aye, and A.H. Tambunan (2017), 'Potential Forest Biomass Resource as Feedstock for Bioenergy and its Economic Value in Indonesia', Forest Policy and Economics, 81, pp.10–17. doi:https://doi.org/10.1016/j.forpol.2017.03.022

Appendix 1

Record of ERIA Working Group Meeting:

Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asia Summit Countries

First Working Group Meeting (2018–2019), 30–31 January 2019, Bangkok, Thailand

1. Opening Address

The first meeting (2018–2019) of the ERIA Working Group (WG) was held in Thailand, hosted by the MTEC (National Metal and Materials Technology Center). WG Leader Dr Toba from the National Institute of Advanced Industrial Science and Technology, Japan (AIST) and representative of host institute Dr Sumittra Charojrochkul gave the welcome address and expressed great appreciation for all WG members. This was followed by self-introductions of all WG members and observers.

Dr Toba explained the outline of this new ERIA Energy Project and the WG title 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asia Summit Countries'. The present ERIA project focuses on the following subjects:

1. Evaluation of CO_2 emissions reduction by mobility electrification as a main research theme of this project, which will discuss best scenarios of electrified vehicles' introduction based on the simulation of the CO_2 emissions reduction, energy consumption in the transport sector, and biofuel utilisation. It is headed by Mr Ichikawa from Toyota, Japan.
2. Supply potential of next-generation biofuels from non-conventional resources, which will investigate the resource quantity of non-conventional biomass, the production process of bioethanol from non-conventional biomass, and its environmental compatibility. It is headed by Dr Toba from AIST, Japan.

2. Session I: Evaluation of CO_2 Emissions Reduction by Mobility Electrification

The session started with an outline of the subject presented by Mr Ichikawa. The scope covered three countries: Thailand, Indonesia, and India. First, information on policies such as biofuel introduction, power generation, and electrification vehicle introduction targets in each country were investigated. In the next step, scenarios will be set for each country and the effects of reducing CO_2 emissions and energy consumption were clarified by the simulation. Finally, based on these results, the best scenario for introducing electrified vehicles will be proposed.

Professor Atul Kumar from TERI Studies of Advanced Science (TERI-SAS), India gave the 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification in India', in which he explained the current state of energy consumption in the transport sector, policies for realising low-carbon emissions, and plans for introducing electric vehicles in India.

Dr Nuwong Chollacoop from the National Metal and Materials Technology Center (MTEC), Thailand gave the 'Report from Thailand', in which he explained the energy situation, Thailand's Integrated Energy Blueprint (TIEB: 2015–2036) with emphasis on the Oil Plan, the Energy Efficiency Plan (EEP), and the Alternative Energy Development Plan (AEDP). Detailed information of bioethanol and biodiesel were shown with action plans and consideration of feedstock supply. Electrified vehicle (EV) policies and the current status of EV introduction were introduced.

Dr Adihika Widyaparaga from Universitas Gadjah Mada (UGM), Indonesia gave the 'Effect of Indonesia xEV Adoption Schedule on Carbon Emissions and Oil Consumption', in which he explained the energy situation and biofuel introduction roadmap in Indonesia. Government policies for low carbon emissions vehicle introduction were also explained. Leading estimates of energy consumption and CO_2 emissions were reported.

3. Session II: Research of Next-Generation Biofuels

In this session, Dr Arie Rahmadi from BPPT, Indonesia gave the 'Non-conventional Biomass as Feedstock for Transportation Fuel Potential for Indonesia' with biomass potential from forest residue and agricultural waste. Reports on recent research and the development of next-generation biofuels using lignocellulose, palm residues, and algae were presented.

Dr Toba presented the 'Fuel Production from Non-conventional Resources' on this subject. An overview of the types of next-generation biofuels produced from non-conventional resources and their production methods, factors that determine production efficiency, costs in bioethanol production, and examples of greenhouse gas emission calculations were presented.

All members were taken to visit the biodiesel upgrading test plant installed in Global Green Chemicals in Rayong.

Second Working Group Meeting 8–9 May 2019, Yogyakarta, Indonesia

1. Opening Address

The first meeting (2018–2019) of the ERIA WG was held in Indonesia, hosted by UGM. WG Leader Dr Toba from AIST, representatives of host institute Professor Dr Panut Mulyono (Rector) and Dr Deendarlianto (Director, Center for Energy Studies) gave the welcome address and expressed appreciation to all WG members.

Dr Toba explained the outline and progress of this ERIA Energy Project and the WG title 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asia Summit Countries'.

2. Session I: Evaluation of CO_2 Emissions Reduction by Mobility Electrification

A summary of the previous discussions, the issues at this meeting, and the reference values necessary for cost estimation were presented by Mr Ichikawa. Through discussions, the amount and timing of the introduction of electrified vehicles, what kinds of scenario will enable the achievement of the government's target of the introduction of electrified vehicles, and what effects biofuel introduction will bring were clarified.

Professor Atul Kumar from TERI-SAS, India set up five scenarios in addition to the business as usual (BAU) scenario and reported the results of simulating energy demand, fuel and biofuel consumption, and CO_2 emissions in India. According to a well-to-wheel's calculation, the introduction of biofuel had a good effect on reducing CO_2 emissions, but the introduction of electrified vehicles increased the emissions compared to the BAU case.

Dr Nuwong Chollacoop from MTEC, Thailand set up five scenarios in addition to the business as usual (BAU) scenario and reported the results of simulating energy demand, fossil fuel and biofuel consumption, CO_2 emissions, and economic analysis. It was clarified that the combined use of biofuel and electrified vehicles is extremely effective in reducing fossil fuel consumption and greenhouse gas emissions. It was shown that vehicles using biofuels and HEVs are more cost effective than battery electric vehicles (BEV).

Dr Adihika Widyaparaga from UGM, Indonesia presented the 'Effect of Indonesia xEV Schedule and Alternative Fuel Adoption on Carbon Emissions and Oil Consumption from Road Transportation'. Three scenarios were set up and compared with the BAU scenario based on the current biofuel condition. The EV plan alone has no significant effect on reducing crude oil consumption and CO_2 emissions, but using biofuels has been shown to have a greater reduction effect.

Ms Ruby de Guzman from the Philippines Department of Energy gave 'Updates on Electric Vehicles in the Philippines', in which she presented the government policy on electric vehicle introduction and activities in local communities to promote the introduction of electrified vehicles.

3. Session II: Research of Next-Generation Biofuels

Dr Toba presented the 'Fuel Production from Non-conventional Resources' details. The classification of non-conventional resources, the results of a survey on compatibility of biomass as a raw material for next-generation bioethanol production, technology for improving ethanol yield, and CO_2 reduction in the ethanol production process by using by-products were reported.

All members were taken to visit the Madukismo ethanol production facility, biogas digester facility at Gamping Fruit Market, and the UGM algae biofuel facility.

First Working Group Meeting 15–16 January 2020, Koriyama, Japan

1. Opening Address

The first meeting (2019–2020) of the ERIA WG was held in Japan, hosted by AIST. WG Leader Dr Toba from AIST and a representative of the host institute, Dr Masaru Nakaiwa (Director-General, Fukushima Renewable Energy Institute) gave the welcome address and expressed appreciation for all WG members.

Dr Toba explained the outline and progress of the ERIA Energy Project and the WG title 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asian Countries'. The items and issues for the compilation of policy recommendations were shown by the project leader based on the previous discussion.

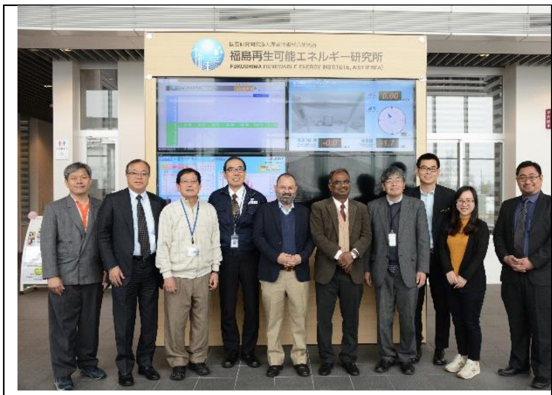
Professor Atul Kumar from TERI-SAS, explained the analysis results modified according to the provisional guidelines developed by the WG for policy recommendations.

Dr Nuwong Chollacoop from the MTEC, explained the analysis results modified according to the provisional guidelines developed by the WG for policy recommendations. The revised materials focused on reducing energy consumption and CO_2 emissions.

Dr Adihika Widyaparaga from UGM, explained the analysis results modified according to the provisional guidelines developed by the WG for policy recommendations. The revised materials show the analysis results that consider the CO_2 emissions associated with power generation, which were omitted in the previous discussion.

After the presentations, the WG leader suggested to the members what each policymaker, automobile user, and automobile manufacturer are expected to introduce electrified vehicles and requested that the proposals should be made with these items in mind. Based on the analysis results and discussion, the guidelines for policy recommendations were fixed, and each member made presentation materials for policy dialogue.

All members were taken to visit the Fukushima Renewable Energy Institute's renewable energy laboratory and mobile hydrogen stations supplying fuel cell vehicles.


福島再生可能エネルギー研究所

Appendix 2

Record of ERIA Working Group Policy Dialogue: Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asia Summit countries

Policy Dialogue, 25 February 2020, Bangkok, Thailand

1. Agenda

Organised by the National Metal and Materials Technology Center (MTEC) and the Department of Alternative Energy Development and Efficiency, Ministry of Energy (DEDE)

Venue: Mandarin A Room, Mandarin Hotel, Bangkok

Proceedings of the policy dialogue on 'Evaluation of CO2 Emissions Reduction by Mobility Electrification and Alternative Fuels Introduction in EAS Countries' organised by MTEC and DEDE in collaboration with ERIA on 25 February 2020, at the Mandarin Hotel, Bangkok.

Policy Dialogue on Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Fuels Introduction in East Asia Summit Countries

Mandarin A Room, Mandarin Hotel, Bangkok
Tuesday, 25 February 2020

09:00–09:30	**Registration**	
09:30–09:40	**Welcome address**	**Dr Venkatachalam Anbumozhi** Senior Economist Economic Research Institute for ASEAN and East Asia (ERIA), Indonesia
09:40–09:50	**Overview of ERIA project**	**Dr Makoto Toba** Leader, Non-conventional Carbon Resources Group, National Institute of Advanced Industrial Science and Technology (AIST), Japan
09:40–09:50	**Opening remarks**	**Mr Sarat Prakobchart** Department of Alternative Energy Development and Efficiency (DEDE)
09:50–10:00	**Group photo**	

10:00–10:15	**Coffee break**	
10:15–10:45	**Thailand presentation**	**Dr Nuwong Chollacoop** Leader, Renewable Energy Research Team National Metal and Materials Technology Center (MTEC)
10:45–11:15	**India & Indonesia presentation**	**Mr Shoichi Ichikawa** ERIA WG Sub-Leader
11:15–11:55	**Free discussion**	
11:55-12:00	**Concluding remarks**	**Mr Shoichi Ichikawa** ERIA WG Sub-Leader

2. List of participants

No	Organisations	First name	Last name
1	Department of Alternative Energy Development and Efficiency (DEDE)	Sarat	Prakobchart
2		Watcharin	Boonrit
3		Minta	Poowatanavong
4		Thanakit	Joyjinda
5		Nattapon	Cheyphuak
6		Sutharee	Kiatman
7		Chanettee	Sikhom
8		Supatchalee	Sophonthammaphat
9		Dechathon	Ruangkraikollakit
10		Mongkol	Prongjuntunk
11		Siroj	Kuhavichit
12		Chumlong	Mungkung
13		Settapol	Wattanasit
14		Pariwat	Rachakrae
15		Natikorn	Prakobboon
16		Pakamas	Chanmaneechot

No	Organisations	First name	Last name
17		Nantawipa	Bandit
18		Rungthip	Chumnumsit
19		Natchariya	Chaipanya
20		Angkana	Wisetsingh
21	Energy Policy and Planning Office (EPPO)	Supitr	Kamglad
22		Vichien	Tantiwisarn
23		Korakot	Phupaiboon
24		Juthamas	Kijjanuluck
25		Supatchaya	Chonchanachai
26	Department of Energy Business (DOEB)	Krittika	Tawonkeaw
27		Poonsook	Tapanasopon
28		Nipon	Tapanasopon
29	Energy Regulatory Commission (ERC)	Krittiya	Channoy
30		Arisa	Anekwanna
31	Electricity Generating Authority of Thailand (EGAT)	Siva	Jaruwan
32		Weerapong	Mookjang
33		Tharinee	Peampongsan
34		Trithep	Pitasanurak
35	Metropolitan Electricity Authority (MEA)	Chutipon	Phongam
36		Lattanan	Kamolroongwarakul
37	Provincial Electricity Authority (PEA)	Parinya	Sonsaard
38	Office of Transport and Traffic Policy and Planning (OTP)	Nopporn	Jarungkiat
39		Suppanat	Chaleamsupanimit
40	Department of Land Transport (DLT)	Kiatnarong	Kruba
41		Chanitsa	Warachit

No	Organisations	First name	Last name
42	Office Of Natural Resources and Environmental Policy and Planning (ONEP)	Papada	Yensukho
43	Pollution Control Department (PCD)	Manwipa	Kuson
44	Office of Industrial Economics (OIE)	Yada	Ongwattanakul
45	Thailand Automotive Institute (TAI)	Thanawat	Koomsin
46		Thitipat	Dokmaithes
47		Chanudol	Churuangsakul
48	Thai Ethanol Manufacturing Association	Torsang	Chaipravat
49	Thai Biodiesel Producer Association	Sansanee	Wilaidaraka
50		Cattareeya	Suwannipa
51		Teerapat	Suthicharoen
52		Amolsiranat	Pulnual
53	Thai Automotive Industry Association (TAIA)	Soranan	Noppornprasith
54		Indra	Chandra Setiawan
55		Sasiwimon	Phattanaphattananon
56		Piyada	J
57		Preecha	Kriangseemuen
58		Chuthathip	Sinchow
59	National Metal and Materials Technology Center (MTEC)	Sumittra	Charojrochkul
60		Nuwong	Chollacoop
61		Peerawat	Saisirirat
62		Kampanart	Silva
63		Johannex	Fefeh
64		Kampanart	Thapmanee
65		Thawatchai	Ouchochasan

No	Organisations	First name	Last name
66		Phumanan	Niyomna
67		Papawee	Likitdecharoj
68	National Institute of Advanced Industrial Science and Technology (AIST), Japan	Makoto	Toba
69	Toyota Motor Corporation, Japan	Shoichi	Ichikawa
70	Economic Research Institute for ASEAN and East Asia (ERIA)	Venkatachalam	Anbumozhi

3. Presentation

The dialogue started with Dr Venkatachalam Anbumozhi giving the welcome address on behalf of ERIA, followed by an introduction of ERIA and the purpose of this energy project.

Dr Makoto Toba then gave an overview of this project on behalf of AIST as follows.

Purpose of the project:

- Proposal of best scenario of electrified vehicles (HV/PHV/BEV) introduction for reducing energy consumption (main theme)
  - ✓ Simulation of the greenhouse gas (GHG) emissions reduction effect will be carried out by the electric vehicle based on the electric power situation and the fuel efficiency improvement vehicles using biofuel.
  - ✓ The reduction effects of petroleum consumption and GHG emissions by the introduction of various electrified vehicles are specified.

- ✓ Best scenario of electrified vehicles (HV/PHV/BEV) introduction including biofuel utilisation for reducing energy consumption in transportation sector will be proposed.

- Estimation of the biofuel supply potential including the biofuel derived from non-conventional biomass resources (sub-theme)
  - ✓ Non-conventional biomass resources for next-generation biofuel production that enable the achievement of highly concentrated use of biofuel will be clarified.
  - ✓ For a typical case, a life cycle analysis will be done.

The policy dialogue focused on the main theme of the project, where best scenarios of electrified vehicles (HV/PHV/BEV) were presented to participants from the government, academic, and industrial sectors in order to crystalise policy recommendations for Thailand. Scenarios for India and Indonesia were also be presented for comparison.

Mr Sarat Prakobchart then gave the opening remarks on behalf of DEDE, where the topics of electrified vehicles and biofuel were included in the Energy Efficiency Plan (EEP) and the Alternative Energy Development Plan (AEDP), respectively. On behalf of DEDE, Mr Prakobchart sincerely thanked ERIA, AIST, and MTEC for presenting study results, which will help DEDE shape its appropriate policy recommendations.

Then, Dr Nuwong Chollacoop gave the Thailand presentation starting with Thailand's commitment to global CO_2 reduction at COP21, a part of Thailand's Climate Change Policy, where the Nationally Determined Contribution (NDC) Roadmap targeted 10 and 31million tons of CO_2 equivalent for transport biofuel and energy efficiency, respectively. Assumptions of energy demand models, including biofuel and EV introduction and/or expansion, were presented to define various scenarios. Analysis results on energy demand, fossil fuel demand, greenhouse gas emissions, and biofuel (ethanol and biodiesel) demand were also presented. Then, assumptions on fiscal analysis, such as excise tax, relative vehicle price, collected taxes, fuel and/or electricity prices, and battery cost trends, were illustrated for fiscal (owner) and economic (government) analysis on net present value, total cost of ownership, and the government's collected excise tax reduction, to arrive at the output on cost of CO_2 reduction, cost of energy reduction, and cost of fossil oil reduction. Hence, overall policy recommendations were proposed for further discussion amongst stakeholders.

Next, Mr Shoichi Ichikawa made two presentations on behalf of India and Indonesia, which were detailed in other sections of this report.

4. Discussion

Director of Energy Efficiency Sector, DEDE, Mr Sarat

Q: From the Thai government target on xEV (1.2 Million in 2037) and biofuel (ethanol and biodiesel), do you think these targets and/or plans are appropriate? What are the issues and key success?

A: The answer is separated into two topics:

- ✓ For biofuel, the stock management in regional countries should be the solution for supply–demand imbalance in each fuel market.
- ✓ In the case of xEVs, the targets of all xEVs (HEV and plug-in xEVs: BEV and PHEV) are challenging. Therefore, if considering the implementation cost, HEV may be a solution for the near term and the plug-in xEVs may be a longer-term solution.
- ✓ Additional measures could be considered, such as the area base measure (i.e. traffic-congestion charge and/or city-centre charge for mitigating poisonous emissions) or the season base measure (i.e. a specific measure in the high particulate matter (PM) atmospheric season)

Q: Sharing comment from the public hearing of the Thailand Integrated Energy Blueprint that planning may not be limited to domestic consumption, but should consider export as Thailand is becoming ASEAN hub.

A: Noted.

Q: The electric motorcycle (e-MC) should be considered and/or included in the model. There are supported measures for the e-MC in Thailand.

A: We could add another scenario for e-MC.

Director of Materials for Energy Research Group (MFRG), MTEC, Dr Sumitra Charojrochkul

Q: In this work, the considered measures and scenarios focused only on light duty vehicles (LDV) or passenger cars. Shall we also consider heavy duty vehicles (HDV)?

A: As the Thai road transport emissions are dominated by LDVs that have higher vehicle numbers, this work focuses on the implemented measures for this sector only. However, HDVs could also be included in the calculation model.

Q: In the case of BEV, does this model take into account the change of energy mix as in the Thailand Power Development Plan?

A: The emissions factors for xEVs GHG calculation in this model refer to Thailand's Power Development Plan 2018, which is varied by the energy share for the planned electricity production.

Representative from Thai Ethanol Manufacturing Association

Q: From the calculation results, why is the impact on GHG reduction lower than the NDC target (5 $MTonCO_2$ compared to 41 $MTonCO_2$ in Transport NDC)?

A: Because this work focuses only on some measures of the NDC plan. Total GHG emissions analysis should include other measures, e.g. travel demand management, mass transit promotion, eco-driving, etc.

Leader of Transport Energy Efficiency Team, DEDE (Mr Watcharin)

Q: Because of the conflicting nature of EV and biofuel (EV promotion would reduce fuel consumption, and thus biofuel demand), does this study include this effect?

A: Yes, the model will take care of the net effect from these two factors.

Q: Should this study also include full life cycle analysis (LCA) on whole vehicle value chain?

A: Dr Anbu said this topic will also be included in the next phase of the ERIA project.

A: Dr Nuwong mentioned that the next phase of the ERIA project can be reported in the near future.

Vice President of Thailand Automotive Institute (Mr Thanawat Koomsin)

Q: Sharing personal viewpoints as automotive expert (not on behalf of Thailand Automotive Institute) as follows.

- ✓ This study focuses on the long-term policy of road transport vehicles, similar to the National Energy Development Plan, which has been changed often by political leaders, one after another. The direction of the national plan should be more solid and not change with political leaders, such as compressed natural gas (CNG) is no longer promoted as previously.
- ✓ Furthermore, mass transport measures should be prioritised to reduce CO_2 emissions, such as rail transport.
- ✓ Thailand wishes the best for all aspects like best safety, best emissions, best CO_2 reduction, etc. CNG promotion in the past needs to comply with the Euro IV standard.
- ✓ To address the PM2.5 crisis, additional measure policy packages, such as intensive vehicle maintenance or vehicle scrappage, may be necessary.
- ✓ If excise tax is removed from vehicles, it may help support the end-of-life policy to remove less energy-efficient vehicles with worse emissions.

A: Noted and will try to incorporate in the ERIA report for the Thailand case.

Representative from TAIA

Q: In the slide, there are the projection of ethanol/biodiesel fraction for the vehicle. Does the study take into account the recent oil fund law that cannot be used for fuel subsidies for 3 years (could be extended by cabinet approval for 2 years)?

A: The model assumption does not take into account the no-subsidy biofuel policy yet. The calculation refers to the base fuel for gasohol E20 and biodiesel B10.

Q: Why is battery price replacement cheaper over time and why are two BEV models listed?

A: The battery assumption is from already available information with some BEV models as representatives.

Q: Does this calculation include the impact of the vehicle age on fuel economy?

A: Yes, this model includes this issue. On the other hand, the relationship between vehicle age and annual mileage will be studied in the future.

Policy Dialogue in Indonesia, 3 March 2020, Yogyakarta, Indonesia

1. Agenda

Organised by the Directorate General of New, Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources

Venue: Meeting Hall, Centre for Geological Disaster Technology Development, Ministry of Energy and Mineral Resources, Yogyakarta

Proceedings of the policy dialogue on Energy Conservation for Road Transport organised by EBTKE, Ministry of Energy and Mineral Resources on 3 March 2020, at the Meeting Hall, Centre for Geological Disaster Technology Development, Yogyakarta. The meeting was held in the Indonesian language as the WG members from abroad were unable to attend due to the COVID-19 epidemic.

08:30–09:00	Registration	
09:00–09:15	Welcome and Opening	Director of Energy Conservation (EBTKE-ESDM)
09:15–10:15	Data Presentation and Energy Conservation Policy in the Transport Sector	Directorate of Energy Conservation
10:15–10:30	Coffee Break	
10:30–11:30	Expose the Benefits of the Transportation System Management to Energy Conservation	Center for Transportation and Logistics Studies, UGM
11:30–12:00	Discussion	
12:00–13:00	Lunch	
13:00–14:00	Exposure of Energy Sector Energy Conservation Policy Options	Center for Energy Studies, UGM
14:00–15:00	Exposure to the Description of Conditions of Energy Use in the Long-Term Transport Sector	Center for Energy Studies, UGM
15:00–15:30	Discussion	
15:30–16:00	Closing	

2. Affiliation of participants

1	Devi Laksmi	Ministry of Energy
2	Muhammad Hasan Imaddudin	PSE UGM
3	Adhika Widyaparaga	PSE UGM
4	Prof Tri Widodo	PSE UGM
5	Andi Luxbinatur	Ministry of Energy
6	Putri Cresti Ekacitta	Ministry of Energy
7	Indra Setiadi	Ministry of Energy - Centre of Data
8	Sunar	Ministry of Energy - Centre of Data
9	Rima Agustin	Ministry of Energy
10	Bambang Dwi	Ministry of Transportation
11	Arif B.P.	Ministry of Transportation
12	Sari Murdiyati	Ministry of Energy
13	Awaliah	Ministry of Energy
14	Anggraeni	Ministry of Energy
15	Joko Purwanto	ERIA
16	Andi Komara	Ministry of Industry
17	Rio Jan Piter	ASEAN Centre for Energy
18	Agus Taufik Mulyono	PUSTRAL UGM
19	Joewono S.	PUSTRAL UGM
20	Deni Prasetio	PUSTRAL UGM
21	Evi Wahyuningsih	IEA
22	Lestari	Ministry of Energy
23	Irwan Wahyu K	Ministry of Energy
24	Nanang	Ministry of Energy

3. Presentation

Dr Adhika introduced the energy situation and policies of Indonesia's transport sector, and reported the simulation results of energy consumption, CO_2 emissions, and costs of electrified vehicle introduction based on the scenario.

4. Discussion

Andi Luxbinatur, Ministry of Energy

- The results show that xEVs have very a small effect on oil consumption and emissions. Could you explain?

Answer: The xEVs comprise only a small part of the vehicle population. As there is no vehicle retirement policy, the existing internal combustion engine fleet, which also comprises older vehicles, continues to consume large amounts of fuel and produce emissions.

- Do the emissions include the lifecycle emissions from the xEV batteries? This is important as emissions reductions obtained from the use of xEVs might be offset by the life cycle emissions.

Answer: At the moment our model does not include any life cycle emissions. But that is an interesting prospect for the development of the model. We will note that.

Alloysius Joko Purwanto, ERIA

- I would like to highlight the importance of (Indonesia) having a comprehensive database for transportation information. For example, at the moment it is difficult to obtain the actual number of vehicles operating on the road. Having more data would contribute towards an effective predictive model.

Evi Wahyuningsih, IEA

- In the model how do you account for the energy content of biofuels? The energy content is known to be smaller than fossil fuels.

Answer: We have accounted for this using a multiplier for energy content of biofuels. The model thus presents the energy consumption in the form of standardised units (litter gasoline equivalent or MTOE) and also in volume of the fuel.

- Why was 0.5% per year used as an assumption for the fuel economy improvement? It might be too low.

Answer: We have made 2%/year scenarios that show an improvement in oil reduction. For this presentation we wanted to highlight the effect of xEVs and alternative fuels without the effect of increased fuel economy improvement. As such we did not include it in the presentation. We chose 0.5% as a worst case fuel economy annual improvement.

Andi Komara, Ministry of Industry

- The reason why the bioethanol mandate is not working is not because of a lack of supply or feedstock. The main issue in regards to ethanol supply for transport is the price the Ministry of Energy sets at a fixed value periodically (every month). The value is currently set at around IDR10,000 per litre. Bioethanol producers are reluctant to sell as there is an economic gap and they prefer to export or sell for other purposes.

Reply from Arif B.P, Ministry of Transportation. But even if the price is right, our production capability is insufficient to provide for the entire vehicle population.

Reply from Andi Komara, Ministry of Industry. If there is sufficient demand and an acceptable price, producers can upscale production.

Andi Komara, Ministry of Industry

- The model shows that a large portion of the costs are due to the cost of xEVs. xEVs are expensive mainly due to the battery cost. But this cost will reduce with time.

  After 2022, the cost of batteries is projected to reduce to below US$100 per kilowatt hour. This will bring the cost of xEVs down. As such, the cost of xEV purchase should also be modified to change annually.

Answer: Noted. We will update the model for variable vehicle costs.

- In Perpres 55/2019, there is a provision to set tariffs to 0% for BEVs and PHEVs as both can operate fully on electric power. For class B vehicles which cost around IDR200 million, if there are xEVs of that class, the cost still seems affordable. But vehicle manufacturers seem to prefer making xEVs for class C vehicles which are more expensive.

Question: Has there been any initiative from the Ministry of Industry to approach vehicle manufacturers to produce xEVs domestically? Certainly that can reduce cost further?

We have approached multiple vehicle manufacturers, but it seems that they are reluctant to produce locally. We think that this is likely due to the investment risk as the demand is still uncertain.

Alloysius Joko Purwanto, ERIA

I agree with a system of carbon taxing to help promote greener initiatives. But applying a carbon tax scheme must consider revenue and growth.

Tri Widodo, PSE UGM

We have conducted a study on carbon tax for vehicles previously. The carbon abatement tax we found was US$42.7 per ton CO_2 equivalent and was still applicable with positive economic growth. This can be a solution for cross subsidising.

Policy Dialogue in India, 13 March 2020, New Delhi, India

1. Agenda

Organised by TERI School of Advanced Studies (TERI SAS) and The Energy and Resources Institute (TERI)

Venue: Conference Hall, The Energy and Resources Institute (TERI), India Habitat Centre, New Delhi

Proceedings of the roundtable policy dialogue organised by TERI SAS and The Energy TERI on 13 March 2020, at the Conference Hall, The Energy and Resources Institute (TERI), India Habitat Centre, New Delhi.

Time (Hours)		Details
11:00–11:05	Welcome and Setting the Context	Mr Shri Prakash, TERI School of Advanced Studies
11:05–11:10	About the study by ERIA	Dr V. Anbumozhi, Economic Research Institute for ASEAN and East Asia (ERIA)
11:10–11:05	About the study	Dr M. Toba National Institute of Advanced Industrial Science and Technology, Japan (through video conference)
11:15–11:50	Findings from Thailand and Indonesia Country Study	Mr Shoichi Ichikawa, Toyota Motor Corporation, Japan (through video conference)
11:50–12:20	Findings from India Country Study	Prof. Atul Kumar, TERI School of Advanced Studies
12:20–12:50	Moderated Round Table Discussion	
12:50–13:00	Conclusion	Dr V. Anbumozhi, ERIA

2. List of participants

S.No.	Name	Organisation
1	Venkatachalam Anbumozhi	ERIA
2	Shri Prakash	TERI SAS/TERI
3	Atul Kumar	TERI School of Advanced Studies
4	I.V. Rao	TERI

5	S. Ichikawa*	Toyota Motor Corporation, Japan
6	Makoto Toba*	AIST, Japan
7	Soranan Noppornprasith*	Toyota Daihatsu Engineering & Manufacturing, Thailand
8	Sasiwimon Phattanaphattananon*	Toyota Daihatsu Engineering & Manufacturing, Thailand
9	Sourabh Rohilla	SIAM
10	Dipanjan Banerjee	Tata Motors
11	Abhishek Sharma	Praj Industries
12	Paresh Kumar Goel	MoRTH
13	Yash Saigal	Tata Motors
14	Piyali Das	TERI
15	Sanjukta Subudhi	TERI
16	Arindam Datta	TERI
17	Saswata Chaudhary	TERI
18	Shariff Qamar	TERI
19	Palak Thakur	TERI
20	Aravind Harikimar	TERI
21	Promit Mookherjee	TERI
22	Michael Dioha	TERI School of Advanced Studies
23	N Balaji	TERI School of Advanced Studies
24	Suchit Hoti	TERI School of Advanced Studies
25	Shinu Kari	TERI School of Advanced Studies
26	Swapnil Nikam	TERI School of Advanced Studies
27	Chetan Gusain	TERI School of Advanced Studies
28	Shadman Haque	TERI School of Advanced Studies
29	Suraiya Rahman	TERI School of Advanced Studies
30	Madhumitha C L	TERI School of Advanced Studies
31	Zubin Anand	TERI School of Advanced Studies
32	Md. Anas Imam	TERI School of Advanced Studies
33	Saurabh Nepal	TERI School of Advanced Studies

*: Through video conference.

3. Presentation

Dr Venkatachalam Anbumozhi, ERIA, Indonesia

The objective of this study is to find out the policy directions for the growth of electric vehicles and biofuels. Electric mobility has been a debated topic across the globe. In India, electric mobility has been advocated to address concern on raising level of air pollution. Electric mobility can bring a sizeable reduction in air pollution from the transport sector. However, as electricity generation in India is dominated by coal, consequently electric mobility will increase CO_2 emissions from the power sector.

In this study, we have conducted well-to-wheel and tank-to-wheel type of analysis. The electric vehicle introduction is coming at the same time with biofuel. Hence in this study, we are creating awareness and providing a scenario analysis based on the assumptions. This will give some idea on how East Asian economies can achieve energy security with the Paris agreement goals.

The study has two broad divisions:

1. Evaluation of emissions reduction in the transport sector by mobility electrification and biofuels.
2. Best scenarios for emissions reduction.

Three countries of India, Thailand, and Indonesia were analysed in this study. These countries have their basic policy frameworks for electrification of the transport sector. We analysed the policies and identified what could be future opportunities in the transport sector. Therefore, we conducted this round table to get feedback on policy direction from the industry stakeholders and the policymakers.

Dr Makoto Toba, AIST, Japan

The purpose of the study was to find the best-case scenario of electrified vehicles (HV/PHV/BEV) introduction for reducing energy consumption in the transport sector. The motivation of this project is to obtain the optimal answers to the questions raised on electrification of vehicles through simulation.

The following scenarios were assumed for the simulation study:

India scenarios:

1. Business as Usual (BAU) scenario (Base/Reference)
2. Alternative Fuels Scenario (AFS)
3. Moderate Electrification Scenario (MES)
4. Aggressive Electrification Scenario (AES)
5. Moderate Electrification cum Hybrid Promotion Scenario (HPS)
6. Only Electrification Scenario (OES)

Indonesia scenarios:

1. Business as Usual (BAU) Scenario (Base/Reference)
2. Increased Biodiesel Use Scenario
3. Increased Bioethanol Use Scenario
4. CNG Implementation Scenario
5. Vehicle Electrification (xEV) Scenarios

Thailand scenarios:

1. Business as Usual (BAU) Scenario (Base/Reference)
2. Alternative Fuels Scenario
3. Plug-in xEVs Expansion (1.2 million xEVs) Scenario
4. Hybrid Expansion Scenario (Minimum HEV)
5. Hybrid Expansion Scenario (Maximum HEV)
6. Combination Scenario (Alternative fuel + Minimum HEV)

Analysis of the simulation results showed that the combination of xEVs and the use of alternative fuels such as biofuels is the most effective way for carbon emission reduction. The use of CNGs for heavy duty vehicles and electrification of light duty vehicles are reasonable solutions to reduce oil consumption, in turn, reducing the carbon emissions. Scenarios are compared for cost of BEV introduction due to the construction of infrastructure and the cost-effectiveness of reducing oil consumption and/or CO_2 emissions due to BEV introduction, the combined cost of xEV mix and alternative fuel use.

Mr Shoichi Ichikawa, Toyota Motor Corporation, Japan

The results of 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternate Fuels Introduction', for Thailand and Indonesia case were presented as reference information.

Scenario analysis for Thailand

The following scenarios were taken for the study.

Alternative Energy Scenarios: Ethanol E20 will be successfully implemented in the market until 2037 causing total demand of 7.5 million L/day. Biodiesel B10 will be successfully implemented in the market till 2037 causing total demand of 8 million L/day.

1.2 million xEVs Scenario: Electrification of vehicles, that is 1.2 million units, sold up to 2036.

HEV BOI and HEV Extreme Scenarios: Total HEV sale achieves 320,000 units within 2023 (full production capacity of BOI investment plan committed in 2018) and HEV dominates 50% sales of passenger cars (gasoline originated) by 2036.

The study results when analysed in terms of total energy reduction, fossil fuel reduction, and CO_2 emissions reduction showed that the use of biofuels combined with an HEV/BOI scheme is an effective solution. Thailand' s power generation mix is dominated by natural gas and coal, and thus electricity from environmentally-friendly sources for BEV should be ensured in the Power Development plan in terms of well-to-tank CO_2 emissions. A combination of xEVs (HEV/PHEV/BEV) introduction together with biofuel utilisation is the most effective in reducing oil consumption/CO_2 emissions. xEV mix (especially HEV expansion) consideration has a positive effect on promoting the use of biofuel thereby supporting the agricultural sector. While xEV promotion will contribute mainly to the reduction of gasoline consumption, imbalance between gasoline and diesel fuel consumption is still an issue since diesel fuel consumption is much larger than gasoline consumption. Hence, reducing diesel fuel consumption should be prioritised by the appropriate blend of biodiesel.

Scenario analysis for Indonesia

The following scenarios were taken for the study.

Reference scenarios: Created as BAU based on the current biofuel condition in 2018 with B20 for biodiesel and no implementation status for ethanol. Governments' biofuel mandate, CNG roadmap, and LCEV roadmap are considered.

Biofuel scenarios: Developed and compared to reference (BAU) to examine the effect of the following scenarios on oil use and carbon emissions. In this scenario, three cases were assumed. Bio1 is according to biofuel plan (Biodiesel B30 and Bioethanol E20). Bio2 where biodiesel taken as B30 and Bioethanol as E0. Bio3 where biodiesel taken as B0 and Bioethanol as E20. Bio4 where biodiesel taken as B50.

xEVs Scenarios: Developed and compared to reference (BAU) to examine the effect of the following scenarios on oil use and carbon emissions. In this scenario, three cases were assumed. xEVs-1, is according to the Ministry of Industry, LCEV roadmap. xEVs-2 is according to roadmap for BEV trucks, buses, and motorcycles but all passenger cars as BEVs. xEVs-3 is according to the roadmap for BEV trucks, buses, and motorcycles but all passenger cars as HEVs. xEVs-4 is according to the roadmap for BEV trucks, buses, and motorcycles but all passenger cars as PHEVs.

The results showed oil consumption and CO_2 emissions of road transportation will decrease by 20% and 12% respectively, making it the largest reduction. This is due to the combined effect of the EV plan and biofuel, and also the use of CNG. The effect of xEVs for reducing oil consumption and CO_2 emissions is limited as contribution is only to new vehicle population, no difference of CO2 emissions between the xEVs without electricity from renewable energy.

The most cost-effective single action for reducing oil consumption and CO_2 emissions is biofuel implementation due to the widespread effect for all existing vehicles using gasoline and diesel fuel blends, with a larger reduction of oil consumption by ethanol blend. Therefore, the combined use of biofuels and CNG with xEV mix (including HEV) is the most effective and needs to be encouraged.

Toba and Ichikawa participated in a video conference from Japan due to immigration restrictions associated with the epidemic of COVID-19.

Prof Atul Kumar, TERI SAS

The results of 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternate Fuels Introduction', Findings from India Country Study was presented as the main message of the policy dialogue.

Scenario analysis for India

The following scenarios were taken for the study.

Business-as-Usual Scenario: Characterised by continuation of existing trends.

Alternative Fuels Scenario (AFS): Accelerated pace of deployment of CNG-fuelled vehicles and biofuels such as ethanol/biodiesel.

Moderate Electrification Scenario (MES): Moderately higher road-transport electrification across all vehicle categories compared to BAU.

Aggressive Electrification Scenario (AES): Aggressively higher road-transport electrification across all vehicle categories compared to BAU.

Moderate Electrification cum Hybrid Promotion Scenario (HPS): Variant of MES with higher share of HEVs compared to MES scenario.

Only Electrification scenario (OES): Hybrid of BAU cum AES scenario.

Policy Recommendations: BEVs could be a better alternative to fuel-based automobiles to mitigate air pollution, but to switch to electric mobility in the short term is hard to achieve, and the effect of BEV introduction in reducing oil consumption/CO_2 emissions is limited as contribution is only to the new vehicle population. Key factors such as consumer acceptability and desirability need to be addressed before making BEVs a reality in India. The major challenges in the transition to electric mobility today remains the relatively high cost of BEVs (due to battery cost) and lack of a ubiquitous charging infrastructure network. Due to coal dominance of electricity generation in India, electrification alone do not have much effect in reducing CO_2 emissions. Use of alternate fuels such as biofuels and CNG will play a crucial role. Use of CNG should be promoted for HCVs and long-haul buses, while efforts on electrification of LCVs maintained, as these vehicle categories are dominated by diesel fuel, which is the majority of petroleum fuel consumption in India.

4. Discussion

Mr Banerjee, TATA Motors

- Growth of powertrain and biofuel both are recommended.
- Mix of powertrain and biofuel will depend on use case scenario. While there might be pure electrification in two-wheelers and three-wheelers, there might be mix in four-wheelers and heavy-duty vehicles going forward.
- In India, two-wheelers growth is significant and the pollution count is higher. Hence, targets should be specified for electrification of two-wheelers.
- Fuel cell applications should also be considered in near future.

Mr Saurabh Rohilla, Society of Indian Automobile Manufacturers (SIAM)

- It is evident from the study results that the emissions reduction in the transport sector can be carried out using a mix of technologies.
- We should have multi-faceted objectives in the policies.
- Pollution should be the major factor in the policy objective. Technology improvement should thus be based on that objective.
- From industry point of view, the technology improvement should be followed with respect to consumer requirements.

Mr Abhishek Sharma, PRAJ Industries

- It is evident that in the near future there will be a good demand for biodiesel and bioethanol. Studies on the availability of agricultural produce available for biofuel generation should be done.

Dr Piyali Das, Sustainable Biofuel Division, TERI

- Countries with high diesel and coal demand should be targeted.
- According to 2017–18 data, crude oil import to India was 220 million metric tons having a carbon value of 190 million metric tons; import of coal was 200 million metric tons having a carbon value of 150 million metric tons, and natural gas is 15 million metric tons having a carbon value of 11.6 million metric tons.
- If we transfer the import to resources like agri-residues, forest residues, landfill biogas, municipal solid waste, and used cooking oil. These resources are not readily available.

- Technology development to elevate the use of these resources is needed.
- Refinery integration of existing refineries for vegetable oil and pyrolysis oil will be one of the best solutions.

Dr Sanjukta Subudhi, Sustainable Biofuel Division, TERI

- Use of second-generation biofuels should be recommended.
- Hydrogen and fuel cells should also be connected with the source. Technology advancements also should be done for such alternative fuels.

Mr Shoichi Ichikawa, Toyota Motor Corporation

- In India, the use of CNG and LNG for heavy duty vehicles should be recommended.
- Bio-ethanol targets should be improved in future.

Prof Atul Kumar, TERI SAS

Q: What is the industry view on CNG and LNG use for heavy duty vehicles?
A: The technology is commercially mature. As soon as the infrastructure for LNG distribution is built, there will be rollout of LNG-based vehicles.

Mr Michael Dioha, TERI SAS

- Electrification of vehicles should be built on consumer acceptance.
- Cost to the consumer is the current limitation for the electrification of vehicles.
- Robust policies to incentivise xEVs is needed.

Concluding remarks by Dr V. Anbumozhi, ERIA

- Market readiness is a major difficulty for transformation.
- In India, PHEV should be encouraged in the short and medium term.
- Consumer markets should be built for transformation from internal combustion engine vehicles to biofuel to electric and then to hydrogen vehicles.
- Superimpose the mode of transport, that is using public modes of transport for regular commuting.