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Evaluation of CO_2 Emissions Reduction Through Mobility Electrification*

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Abstract: *The introduction of electrified vehicles (xEVs) is expanding to reduce energy consumption and greenhouse gas (GHG) emissions in the transport sector. This study examined scenarios for India, Indonesia and Thailand; and simulated energy consumption reduction and GHG emissions quantitatively to elucidate effective methods for introducing electric vehicles that contribute to reducing GHG emissions. In countries with high GHG emissions from power generation, such as India and Indonesia, the introduction of xEVs alone cannot reduce emissions levels. A combination of alternative fuel promotion and the introduction of xEVs is effective for reducing energy consumption and GHG emissions in the transport sector.*

Keywords: *Electrified vehicle, alternative fuel*
JEL Classification: L52; L62; Q42; Q47

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1. Introduction

The introduction of electrified vehicles (xEVs) is expanding to reduce energy consumption and greenhouse gas (GHG) emissions in the transport sector. Various types of xEVs have already been sold in the East Asia Summit region. However, infrastructure for charging such vehicles has not been developed in many countries, so the introduction of highly fuel-efficient vehicles such as hybrid electric vehicles (HEVs) which use liquid fuel have been introduced in advance.

To support xEV introduction, several countries have formulated motor vehicle electrification policies. India's Draft National Energy Policy includes promoting the introduction of hybrid and electric vehicles and developing charging stations as public facilities (National Institution for Transforming India, 2017). Its National Auto Policy adopts emissions standards that exceed Bharat Stage Emission Standard VI[1], and requires central and state government agencies and municipal enterprises to purchase green cars (Department of Heavy Industry, 2018a). India's National Electric Mobility Mission Plan 2020 aims to sell 6 million–7 million xEVs by 2020; and the Faster Adoption and Manufacturing of Electric Vehicles scheme will provide incentives to reduce the purchase price of vehicles in all segments, including four-wheeler vehicles and electric three-wheeler vehicles, and to maintain charging stations (Department of Heavy Industry, 2017). Some state governments have already introduced vehicle electrification policies, including incentives and infrastructure development.

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[1] Bharat stage Emission Standards (BSES) are emission standards instituted by the Government of India to regulate the output of air pollutants from internal combustion engines and Spark-ignition engines equipment, including motor vehicles. The standards and the timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment, Forest and Climate Change. http://egazette.nic.in/WriteReadData/2016/168300.pdf [in Thai] (accessed 16 August 2019)

Thailand has been promoting the introduction of xEVs since 2015. The National Research and Innovation System Policy Committee, chaired by the Prime Minister, approved Thailand's electric vehicle promotion roadmap on 7 August 2015 (Thailand's Energy Policy and Planning Office (EPPO), Ministry of Energy, Government of Thailand 2017). Grants for the production of xEV buses, retrofit xEVs, passenger car xEVs, and xEV components were established under the committee. According to the EV promotion roadmap (EPPO, 2017), the target is to introduce 1.2 million xEVs by 2036. EPPO announced an xEV action plan to promote xEVs in three phases: (i) demonstration of the xEV technology to the public, 2016–2017; (ii) initiation of domestic research and development of xEVs with the private sector, 2018–2020; and (iii) commercial use of xEVs, 2021–2036, as follow-up to the Energy Efficiency Plan, 2015–2036 (EPPO, 2015). The EPPO and the Board of Investment (BOI) have implemented policies to provide incentives to xEV products such as various xEVs and charging stations. xEVs, including hybrid pickups, have been promoted recently because the tax rate was reduced with the revision of the carbon dioxide (CO_2)-based excise tax (2016).

In Indonesia, the Ministry of Industry issued Regulation No. 33 of 2013 on the development of affordable, energy-efficient four-wheeler vehicles. However, this regulation is not yet compatible with xEVs. New regulations and roadmaps for electric vehicles are being finalised, which will set numerical targets for the introduction of xEVs from 2020 to 2035.

The Philippines is pilot testing the introduction of xEVs in the government and universities to inform policy formulation. The Department of Energy has endeavoured to replace national government service vehicles with hybrid vehicles to promote energy efficiency and clean air across the country. (Department of Energy (2017b))

The Electric Vehicle Association of the Philippines was established in 2009 to create a national xEV development program, which consists of four stages: (i) improvement of the technology required in the industry (2013); (ii) buildup of the local market and production capacity enhancement (2014-2015); (iii) local and export market expansion, along with horizontal and vertical integration with the local automotive industry (2016-2018); and (iv) full integration of regional and global developmental evolution in technological advancement and market size-up (2019-2023).

Universities, local governments, and automobile manufacturers are also making efforts to introduce EVs. Universities and local governments have introduced electric jeepneys (e-jeeps) on a trial basis as a means of transportation for students, seniors, workers, visitors, and residents on campus and in the community (Rappler, 2019a, 2019b). Japanese automobile manufacturers are working with the government and universities to raise public awareness of xEVs and promote their introduction (Mitsubishi Motors (2012), Toyota (2019)).

These countries have also introduced biofuels to reduce GHG emissions in the transport sector. Each country's energy plan has established targets for introducing bioethanol (alternative gasoline) and biodiesel (alternative diesel). Since these targets are formulated based on current vehicles, the required amount of fuel and demand for each type of oil are expected to change with the introduction of xEVs.

Well-to-tank (WtT)-based GHG emissions from plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) depend on the composition of power generation in each country. Since coal-fired power generation accounts for 75% of total electricity generation in India and 58% in Indonesia, GHG emissions from power generation are assumed to be high. On the other hand, natural gas is the largest source of power generation in Thailand, at 65%, while coal-fired power generation accounts for only 20%. Even if the same EV is used, the environmental impact reduction effect varies from country to country.

This study examined scenarios for three countries – India, Indonesia, and Thailand – where targets for the introduction of EVs have been established. It simulated energy consumption reduction and global warming in the transport sector quantitatively to elucidate effective methods for introducing EVs that contribute to reducing GHG emissions.

2. Methodology

Road transport energy consumption trends during 2015–2030 (or the target year of each country) were simulated using the energy mix model. The simulation model for each country was developed by Toyota Motor Corporation (in cooperation with Mizuho Information & Research Institute, Inc.) based on the International Energy Agency's Sustainable Mobility Project model (IEA, 2004). Road transport CO_2 emissions were also be estimated using WtT and tank-to-wheel (TtW) CO_2 emissions factors for each type of fuel. The Sustainable Mobility Project model handles all the transport energy globally, but we modified and established a model for road transport and a country-based energy mix model. Research organisations and project members provided each country's data, such as vehicle registration numbers, the actual fuel economy in each market, and the mileage travelled annually by vehicle and fuel type. Information of policies on energy and alternative fuels, including biofuels, xEVs, and power development, were also collected and examined by each project member.

The study evaluated the xEV mix scenarios in terms of the reduction in oil consumption and CO_2 emissions while using biofuels and natural gas.

3. Results and Discussion

(1) India

Scenarios

The following six scenarios were subjected to simulation.

Business as Usual (BAU)

The BAU scenario is characterised by the continuation of existing trends. Existing government policy measures have not been fully achieved, limiting their effectiveness in attaining India's Nationally Determined Contribution objectives for transport sector decarbonisation. Ambitions in the transport sector fall short of the targets set for 2030, including an increase in road transport shares, reduced reliance on public transport, and increased demand for petroleum-based fossil fuels.

Alternative Fuels Scenario

The AFS assumes that biofuel blending will achieve 10% ethanol blending with gasoline and 5% biodiesel blending with diesel by 2030. It is characterised by policy promotion to increase the share of vehicles using CNG as fuel. The policy focuses on accelerating the development of city gas distribution infrastructure. As a result, barriers to the spread of CNG fuel vehicles will be removed, and new sales of CNG fuel vehicles will increase across all vehicle types.

Moderate Electrification Scenario

In the MES, in contrast to the limited deployment of EVs in the two-wheelers category in the BAU scenario, electrification will be across all categories of road transport vehicles, including taxis, passenger cars, three-wheelers, and buses. The same conditions as the AFS are assumed for promoting the introduction of CNG fuel vehicles and alternative fuels.

Moderate Electrification cum Hybrid Promotion Scenario

In this scenario, the percentage share of new sales of HEVs is enhanced compared with the MES. The same conditions as the AFS are assumed for promoting the introduction of CNG fuel vehicles and alternative fuels.

Aggressive Electrification Scenario

In this scenario, government electrification targets are much higher than BAU levels and encompass the aggressive penetration/adoption of BEVs and HEVs. Further, the electrification levels will be higher across all categories of road transport vehicles, including taxis, passenger cars, three-wheelers, and buses. The same conditions as the AFS are assumed for promoting the introduction of CNG fuel vehicles and alternative fuels.

Only Electrification Scenario

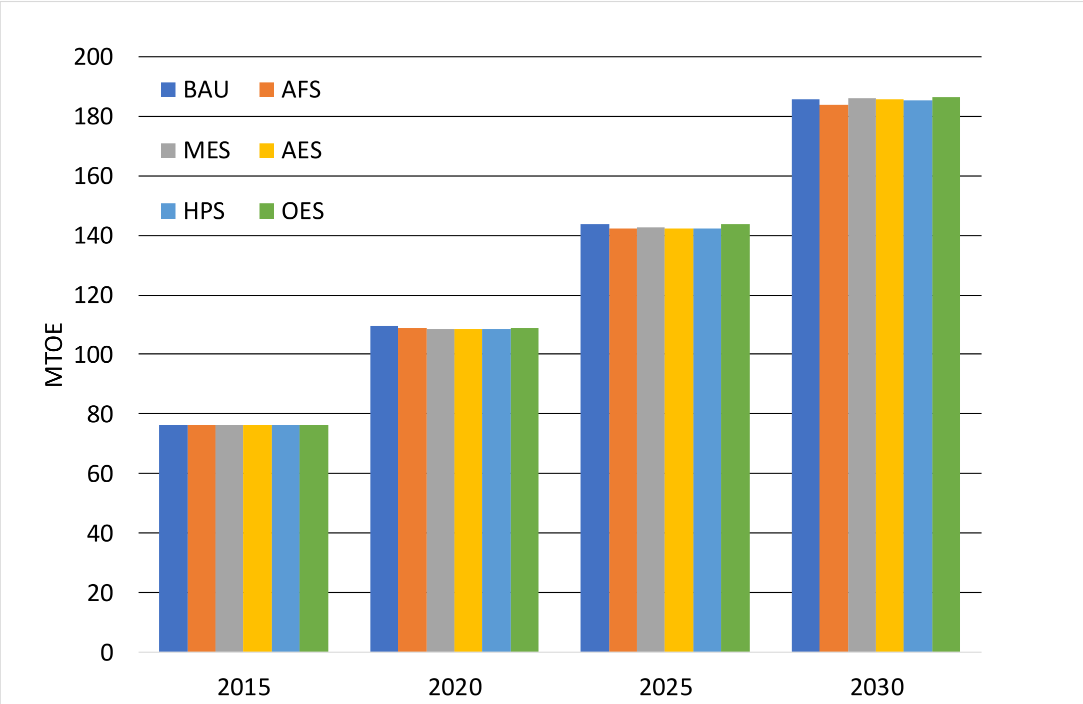
This scenario assumes that the AFS car electrification scenario will be implemented when there is no active introduction of biofuels and CNG vehicles. In other words, this scenario clarifies the effect of automobile electrification only.

Study Results

Figure 1 shows the total final energy demand in the transport sector across scenarios. There is no significant difference between the scenario. The model results indicate that the increased deployment of CNG-fuelled vehicles across various vehicle categories and enhanced use of alternative fuels results in a marginal decline in the total final energy demand in the AFS to 142.7 million tons of oil equivalent (MTOE) (1.2% reduction from BAU) by 2025 and 184.5 MTOE (0.72% reduction from BAU) by 2030.

In the electrification-centric scenarios, the HPS has the maximum reduction of 0.8% by 2025 and 0.3% by 2030 when compared to their respective BAU levels. This reduction is a result of the aggressive electrification coupled with the increased share of HEVs.

Figure 1: Total Final Energy Demand in Transport Sector Across Scenarios

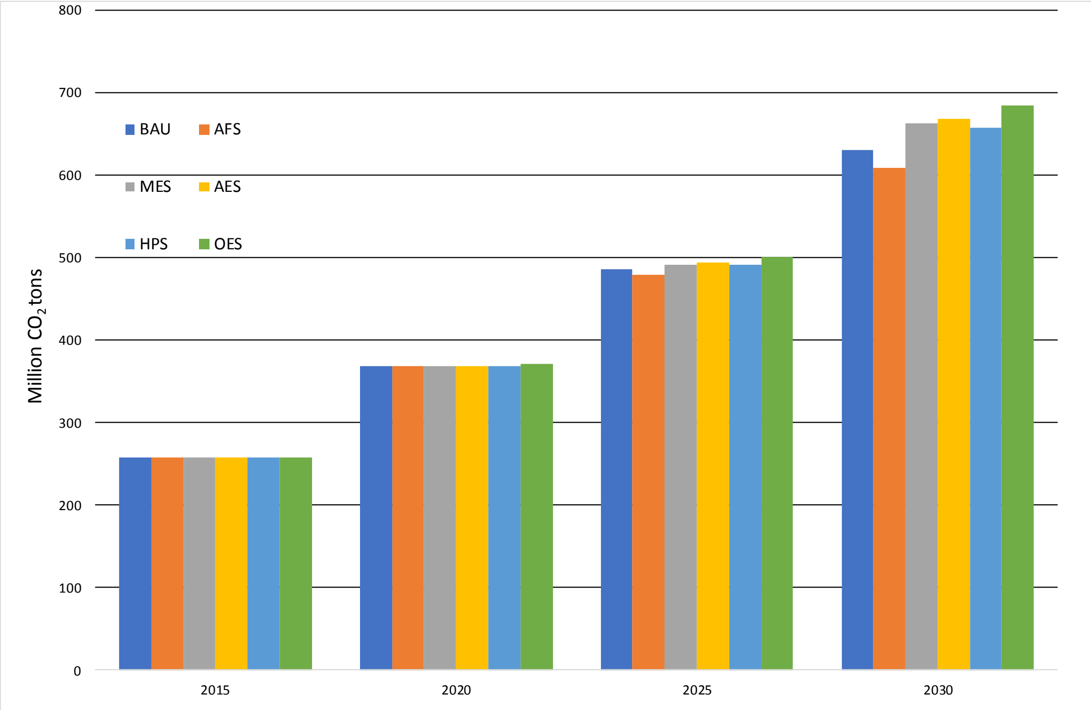


AES = aggressive electrification scenario, AFS = alternative fuels scenario, BAU = business as usual, MES = moderate electrification scenario, MTOE = million tons of oil equivalent.

Source: Authors.

Well-to-wheel (WtW) CO_2 emissions are shown in Figure 2. Total WtW CO_2 emissions will more than double, increasing from 256 million tons-CO_2 in 2015 to 626 million tons -CO_2 by 2030 in the BAU scenario, registering a 6.1% compound annual growth rate (CAGR). In the AFS, the increased share of CNG-fuelled vehicles in road transport fleets and enhanced usage of alternative fuels results in reducing WtW CO_2 emissions to 608 million tons-CO_2 by 2030, translating to about 3% reduction from the BAU level in 2030. However, in the electrification-related scenarios, WtW CO_2 emissions exhibit an increase of 5% in the MES, 7% in the AES, 4.7% in the HPS, and 9% in the OES, relative to the BAU level. The HPS witnesses the smallest percentage increase in WtW CO_2 emissions relative to the BAU level. This implies that the gains from the reduction in aggressive electrification are more than offset by slow improvements in fuel efficiency and less uptake of CNG-fuelled vehicles and alternative fuels. It also 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 vehicle technology, in the BAU scenario, heavy commercial vehicles are seen to contribute about 36% of CO_2 emissions by 2030, which can be attributed to the large percentage of fossil fuels they consume, followed by buses with 18.2%, and cars and jeeps with 15.4%; three-wheelers are observed to account for the lowest amount of CO_2 emissions by 2030, with a share of only 4%.

Figure 2: Well-to-Wheel CO_2 Emissions from Road Transport Sector

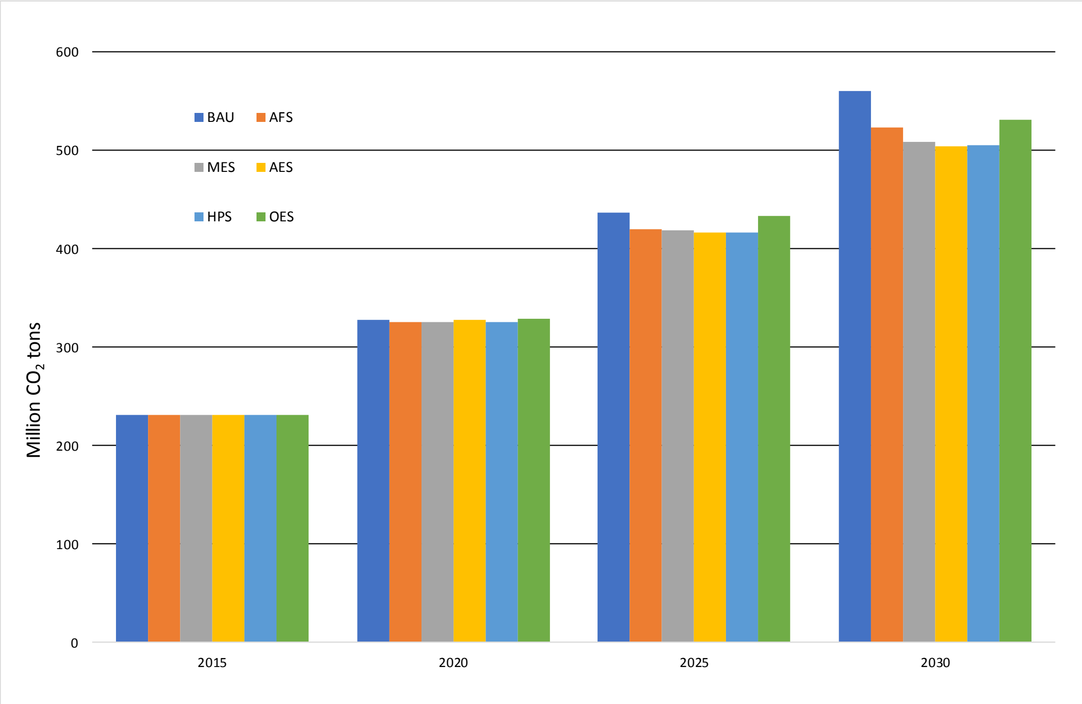


AES = aggressive electrification scenario, AFS = alternative fuels scenario, BAU = business as usual, CO_2 = carbon dioxide, HPS = hybrid promotion scenario, MES = moderate electrification scenario, OES = only electrification scenario.
Source: Authors

TtW CO_2 emissions are shown in Figure 3. Total TtW CO_2 emissions will more than double, increasing from 230 million tons-CO_2 in 2015 to 561 million tons -CO_2 by 2030 in the BAU scenario, registering a 6.1% CAGR. In the AFS, the increased share of CNG-fuelled vehicles in road transport fleets and enhanced usage of alternative fuels results in TtW CO_2 emissions reduction to 525 million tons -CO_2 by 2030, translating to a 6.3% reduction from the BAU level in 2030. However, in sharp contrast to the results of the WtW CO_2 emissions in the electrification-related scenarios, Reduction of TtW CO_2 emissions exhibit a reduction of 9.4% in the MES, 10.8% in the AES, 9.8% in the HPS, and 4.89% in the OES relative to the BAU level. The AES witnesses the maximum reduction in TtW CO_2 emissions relative to the BAU level, followed very closely by the HPS.

These results suggest that the increase in CO2 emission of WtW resulting from the introduction of xEVs is caused by power generation.

Figure 3: Tank-to-Wheel CO_2 Emissions from Road Transport Sector

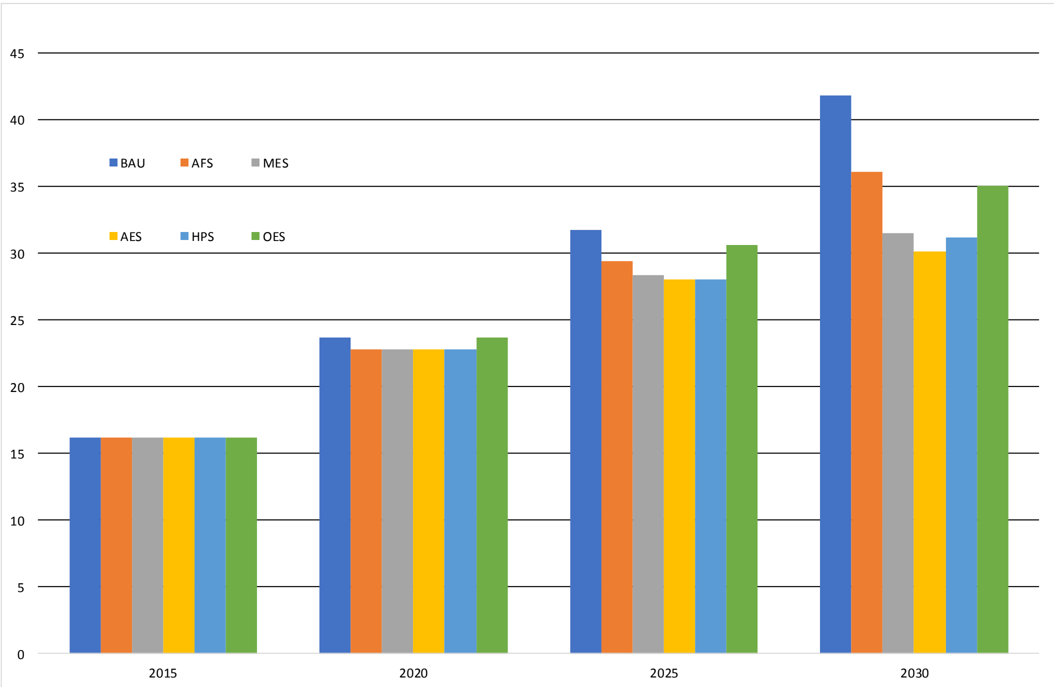


AES = aggressive electrification scenario, AFS = alternative fuels scenario, BAU = business as usual, CO_2 = carbon dioxide, HPS = hybrid promotion scenario, MES = moderate electrification scenario, OES = only electrification scenario.
Source: Authors.

In the BAU scenario, gasoline consumption is observed to increase at a 6.5% CAGR from 16 MTOE in 2015 to about 42 MTOE in 2030, which is about 2.6 times greater than the base year (Figure 4). Increased ethanol blending with gasoline in the AFS causes 5.6% CAGR (37 MTOE in 2030) lower growth in gasoline consumption compared with the corresponding BAU level. 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 4.6% (32 MTOE), 4.3% (30

MTOE), 4.4% (31 MTOE), and 5.3% (35 MTOE). In the HPS, for obvious reasons, although the growth in gasoline consumption is lower than BAU levels, it is higher than in the MES, AES, and OES because of the increased share of HEVs in new sales of passenger cars and taxis. In the BAU scenario, gasoline is the second most consumed fuel after diesel across all years from 2015 until 2030, accounting for 23% of total fuel consumption in 2030. It holds its position as the second most consumed fuel in all years across all the other scenarios, with a percentage share reducing to 20% in the AFS, 17% in the MES, 16% in the AES, 17% in the HPS, and 19% in the OES in 2030 compared with the corresponding BAU level.

Figure 4: Comparison of Gasoline Consumption across the Scenarios (MTOE)

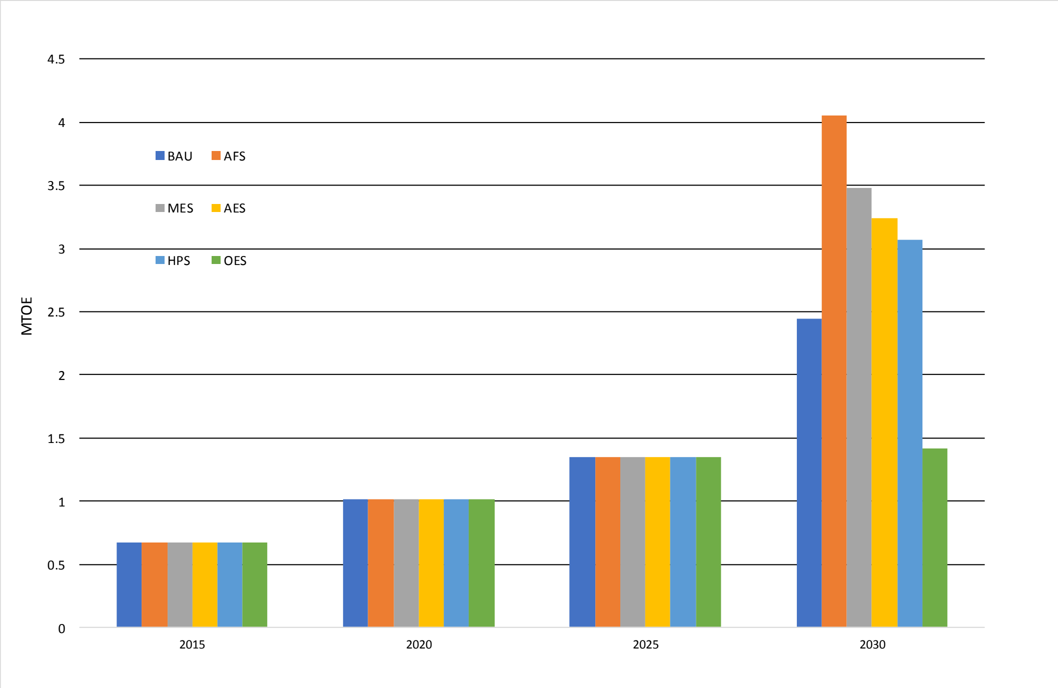


Source: authors

In the BAU scenario, ethanol consumption almost tripled from 0.6 MTOE in 2015 to 1.7 MTOE in 2030, increasing at a CAGR of about 7%. Assuming that India will achieve its 10% mandated target of blending ethanol with gasoline by 2030, driven primarily by the increased domestic availability, in the AFS, MES, AES, and HPS, ethanol consumption in the Indian transport sector exhibited double-digit growth with respective CAGRs of 13% (4.1 MTOE in 2030), 12% (3.5 MTOE in 2030), 11% (3.2 MTOE in 2030), and 11% (3.1 MTOE in 2030), respectively. In the OES, the magnitude and growth rate of ethanol consumption is the same as the BAU scenario since the ethanol-to-gasoline blending ratio is assumed to be the same. This contributes to lower growth in ethanol, at a 5.5% CAGR during 2015–2030, compared with the MES, AES, and HPS, wherein the ethanol-to-gasoline blending ratio is assumed at the AFS level.

In the case of combining the electrification of vehicles and the promotion of biofuels, it is necessary to adjust the supply amount of biofuel in accordance with the spread of xEVs.

Figure 5: Comparison of Ethanol Consumption Across the Scenarios



AES = aggressive electrification scenario, AFS = alternative fuels scenario, BAU = business as usual, HPS = hybrid promotion scenario, MES = moderate electrification scenario, OES = only electrification scenario.

Source: Authors.

(2) Thailand

Scenarios

The following five scenarios were subjected to simulation.

<u>BAU Scenario (Baseline)</u>

In addition to the current trends in road traffic systems, this scenario is based on the realisation of the following Thai biofuel policy:

- Gasohol E20 and biodiesel B10 are achieved – the ethanol share shifting to gasohol E15 and biodiesel B10 for commercial-grade diesel[2]; and

- 1,800 hybrid buses are purchased (Bangkok Mass Transit Authority (BMTA), 2018).

Alternative Fuels Scenario

This scenario assumes the promotion of biofuel introduction:

- Gasohol E20 will succeed (90%) with some E85 share (10%) in the automotive market (assuming the ethanol share in gasohol demand is E26.5) in 2036; and
- biodiesel demand for the transport sector will achieve half of the Alternative Energy Development Plan (AEDP) target or 7 million litres/day in 2036 (assuming that the blending ratio of commercial grade diesel fuel achieves B12).

Plug-in xEV Expansion (1.2 million xEVs) Scenario

This scenario assumes that the on-road plug-in xEVs are introduced:

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

Hybrid Expansion Scenario

This scenario assumes the case where the introduction of hybrid vehicles are promoted. The following two cases are assumed:

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[2] Gasohol E20 and biodiesel B10 are fuel names. There is a range of standard values, and the mixing ratio of biofuels actually distributed is not always the same.

- Minimum HEVs: total HEV sales achieve 320,000 units by 2023, 5 years after the investment plan commitment to the BOI in 2018 (Prachachart, 2018), and 4.7 million units in 2036
- Maximum HEVs: HEVs dominate 50% of passenger car sales (gasoline-originated) by 2036 and 7.1 million in 2036

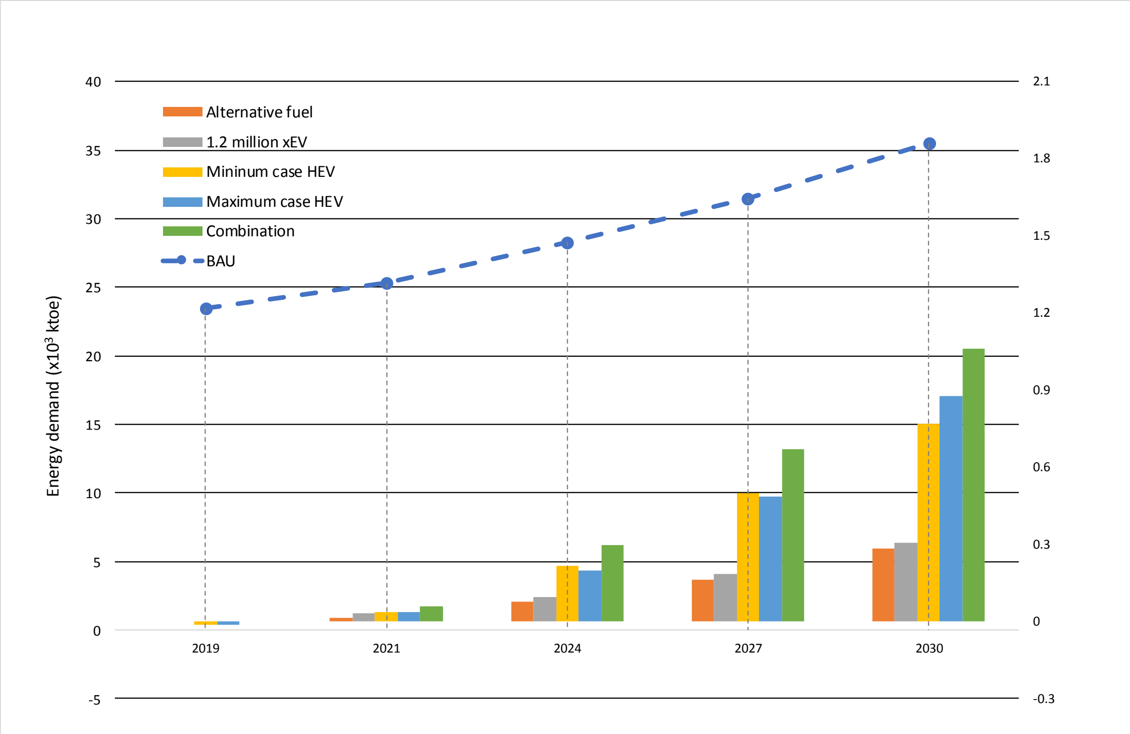
Combination Scenario

This combines the alternative fuel promotion scenario and the minimum HEV scenario.

Study Results

Figure 6 shows energy demand in the transport sector for BAU and five scenarios. xEV technology (plug-in xEVs or hybrid expansion scenarios) can help reduce total energy demand. Two HEV scenarios are more effective for the reduction of energy demand. The most effective scenario to reduce energy demand is the combination (minimum HEV + alternative fuel) scenario.

Figure 6: Energy Demand in the Transport Sector for Scenarios

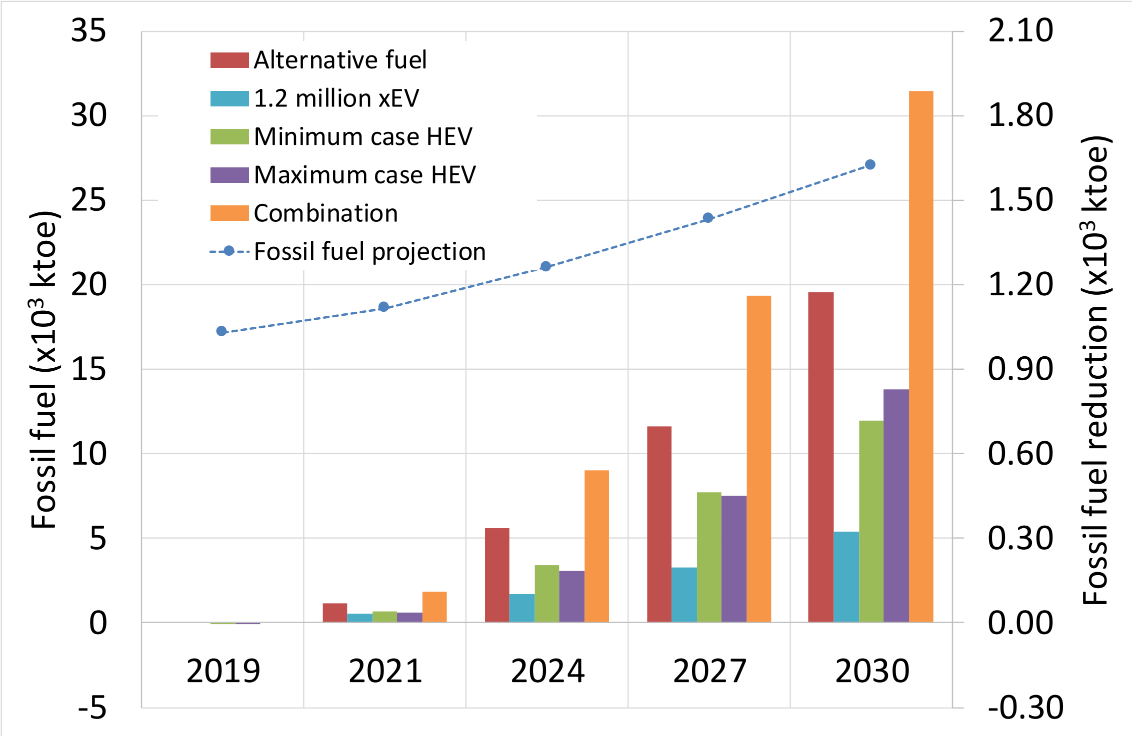


HEV = hybrid electric vehicle, ktoe = kilo ton oil equivalent, xEV = electrified vehicle.

Source: Authors.

From the viewpoint of fossil fuel consumption from imports, the alternative fuel scenario is better than the introduction of xEVs, including HEVs (Figure 7). In this case, the most effective scenario to reduce fossil fuel consumption is the combination (minimum HEV + alternative fuel) scenario.

Figure 7: Fossil Fuel Reduction in the Transport Sector for Scenarios

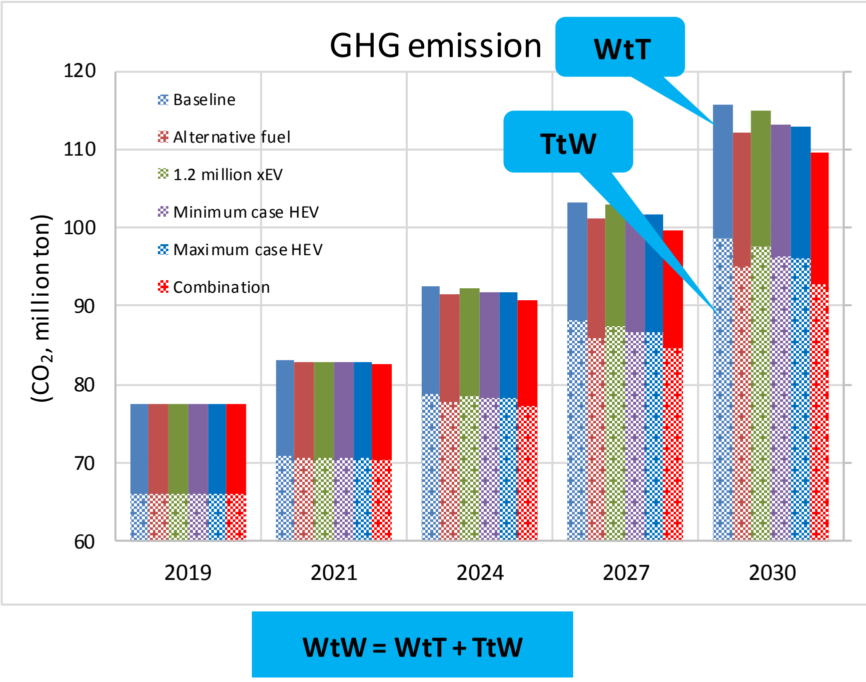


HEV = hybrid electric vehicle, ktoe = kilo ton oil equivalent, xEV = electrified vehicle.

Source: Authors.

Figure 8 shows greenhouse gas emissions in the transport sector for BAU and five scenarios. From the environmental aspect, the alternative fuels scenario shows less TtW emissions than the 1.2 million xEVs scenario. For WtT emissions, which rely on net energy consumption and the WtT CO_2 emissions factor, WtT emissions of hybrid expansion scenarios are better than the alternative fuels scenario, which implies that the impacts of HEV energy efficiency are higher than the difference in the WtT emissions between fossil fuel and biofuels. The combination scenario can help remove 6.12 million tons of WtW CO_2 emissions (5.79 million tons from TtW), an amount equivalent to about 5.3% of the baseline.

Figure 8: Greenhouse Gas Emissions Reduction in the Transport Sector for Scenarios

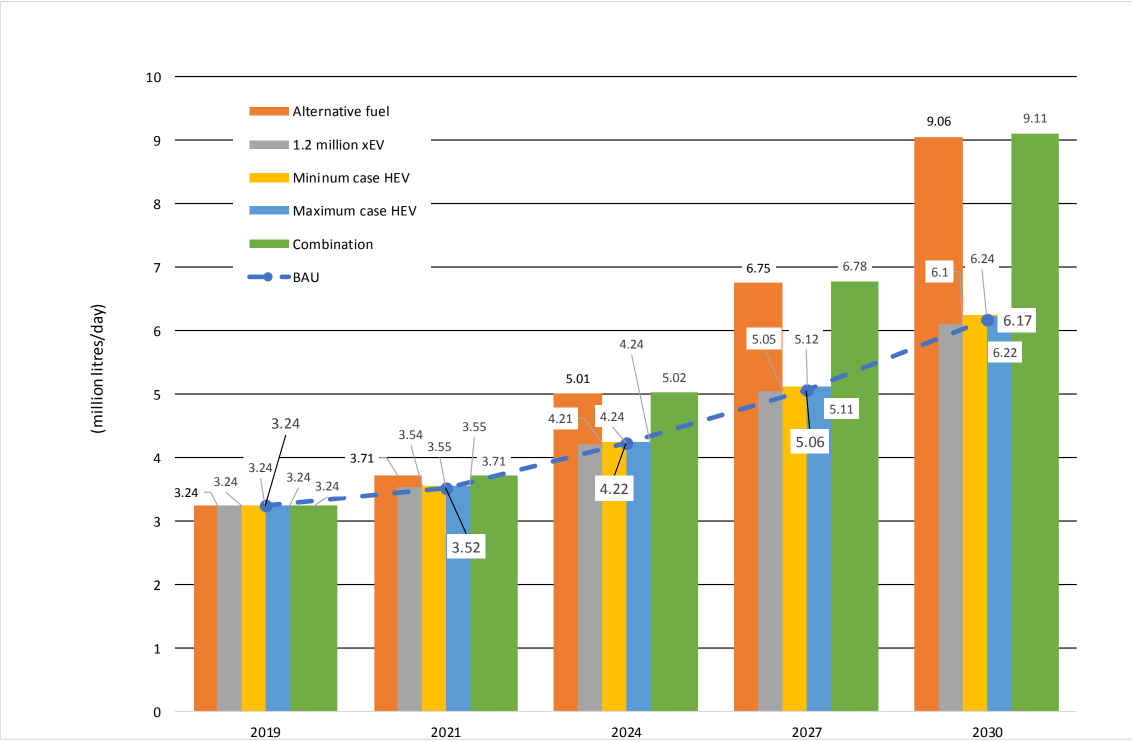


CO_2 = carbon dioxide, GHG = greenhouse gas, HEV = hybrid electric vehicle, TTW = tank-to-wheel, WTT = well-to-tank, WTW = well-to-wheel, xEV = electrified vehicle.
Source: Authors.

Aside from the difference in scenarios, the effects of introducing alternative fuels and xEVs on energy consumption and global warming gas emissions differ substantially between India and Thailand. This is presumed to be due to the difference in the fuels used for power generation and the registration status of vehicles by fuel. India's power generation relies heavily on coal-fired power generation, while natural gas is the main source of power generation in Thailand.

From the biofuel demand aspects shown in Figures 9 (bioethanol) and 10 (biodiesel), the alternative fuels scenario can produce an increase of 2.85 million L/day of ethanol and 1.26 million L/day of biodiesel in 2030. According to the scenario definition, the share of diesel cars will be reduced with xEVs' increasing share. Therefore, biodiesel demand will be reduced in the 1.2 million xEVs scenario and both the minimum and maximum HEV scenarios. On the other hand, ethanol demand will be increased slightly in those two HEV scenarios but reduced in the 1.2 million xEVs scenario. In summary, the combination scenario can help increase ethanol demand by 2.90 million L/day (46.7% of baseline) and biodiesel by 1.04 million L/day (23.3% of baseline).

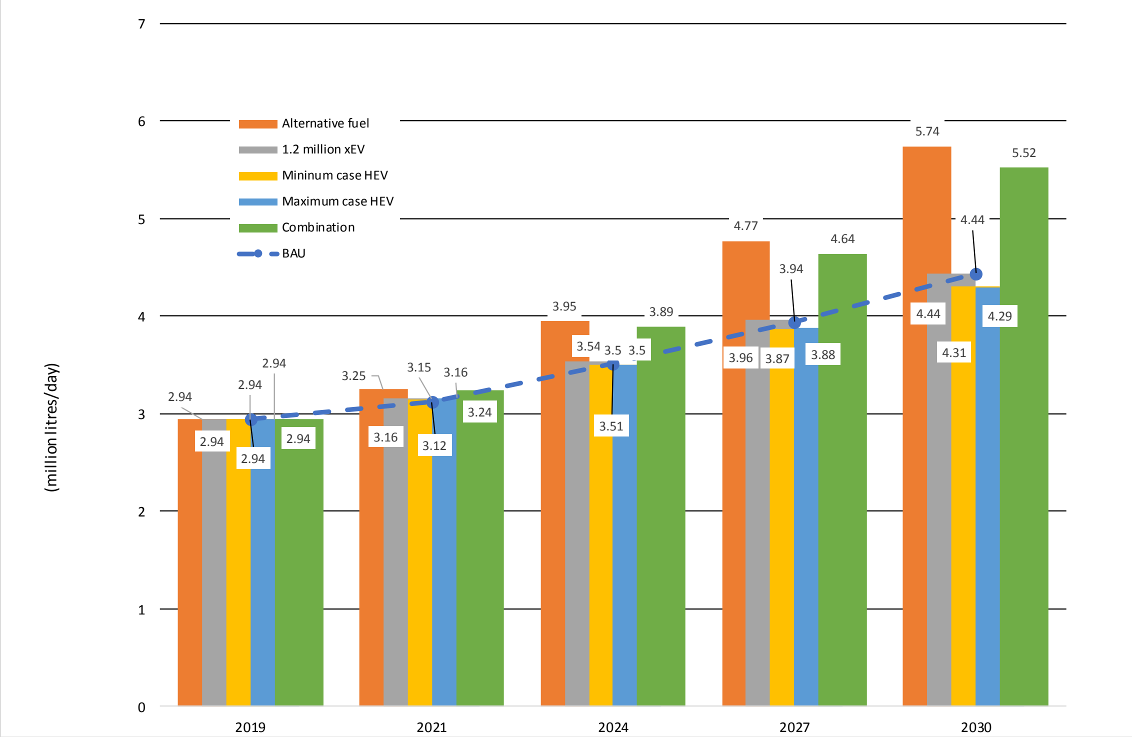
Figure 9: Increased Bioethanol Demand in the Transport Sector for Scenarios



HEV = hybrid electric vehicle, xEV = electrified vehicle.

Source: Authors.

Figure 10: Increased Biodiesel Demand in the Transport Sector for Scenarios



HEV = hybrid electric vehicle, xEV = electrified vehicle.

Source: Authors.

(3) Indonesia

Scenarios

Reference/Business as Usual Scenario

The BAU scenario assumes that biofuel usage is maintained at 2018 conditions:

- 0.5% per year of fuel economy improvement for all new vehicles for a given production year;
- no introduction of CNG vehicles; and
- following the 2015 biodiesel mandate up to B20, but no utilisation of ethanol.

Increased Biodiesel Usage Scenario

The increased biodiesel usage scenario simulates full implementation of the biodiesel mandate to B30 without implementation of bioethanol:

- 0.5% per year of fuel efficiency improvement for all vehicles;
- no introduction of CNG vehicles;
- implementation of the 2015 biodiesel mandate up to B30; and
- no ethanol implementation.

Increased Bioethanol Usage Scenario

The increased bioethanol usage scenario simulates the mandatory content of the Ministry of Energy and Mineral Resources Regulation No. 12 of 2015. In this study, it is assumed that motorcycles are bioethanol-compatible, and this scenario simulates the increase with the following parameters:

- 0.5% per year fuel efficiency improvement for all vehicles;
- no introduction of CNG vehicles;
- implementation of 2015 biodiesel mandate up to B20; and
- implementation of 2015 bioethanol mandate up to E20.

CNG Implementation Scenario

The CNG implementation scenario simulates the introduction of new CNG vehicles for public transport with the adoption of biofuels, in accordance with the 2015 mandatory biodiesel content schedule. Based on 2013 taxi sales, this means that 1.5% of passenger car sales are attributed to CNG taxis. Regarding CNG buses, it is assumed that 40% of truck chassis sold were converted into buses based on the Indonesia Central Agency on Statistics (BPS)[3]. The ratio of registered buses to registered trucks

[3] See https://www.bps.go.id/

increases. New CNG public transport and trucks are assumed to be introduced in 2020. As CNG implementation is unlikely to involve the construction of infrastructure covering most of Indonesia before 2035, not all new public transport and trucks will use CNG. Thus, this scenario assumes that infrastructure is constructed in Palembang, Jakarta, Surabaya, Bandung, and Medan, allowing 48% of all new public transport and trucks to be CNG-capable. This scenario simulates CNG usage with the following parameters:

- 0.5% per year of fuel efficiency improvement for all vehicles;
- the introduction of CNG for public transport and trucks in Palembang, Bandung, Medan, Jakarta, and Surabaya, resulting in 48% of all new taxis, buses, and trucks being CNG-capable; and
- following the 2015 biofuel mandate up to B20, but no utilisation of ethanol.

Vehicle Electrification (xEV) Scenarios

This scenario investigates the plan to introduce xEVs, and assumes the conditions of the BAU scenario – with the added condition of the introduction of xEVs according to the government’s schedule, which includes the implementation of BEVs for trucks, buses, and motorcycles, all of which require additional charging stations.

Separate xEV plan variations will be also studied. In HEV, PHEV, and BEV scenarios, simulations are performed assuming that all passenger cars are each type of xEV.

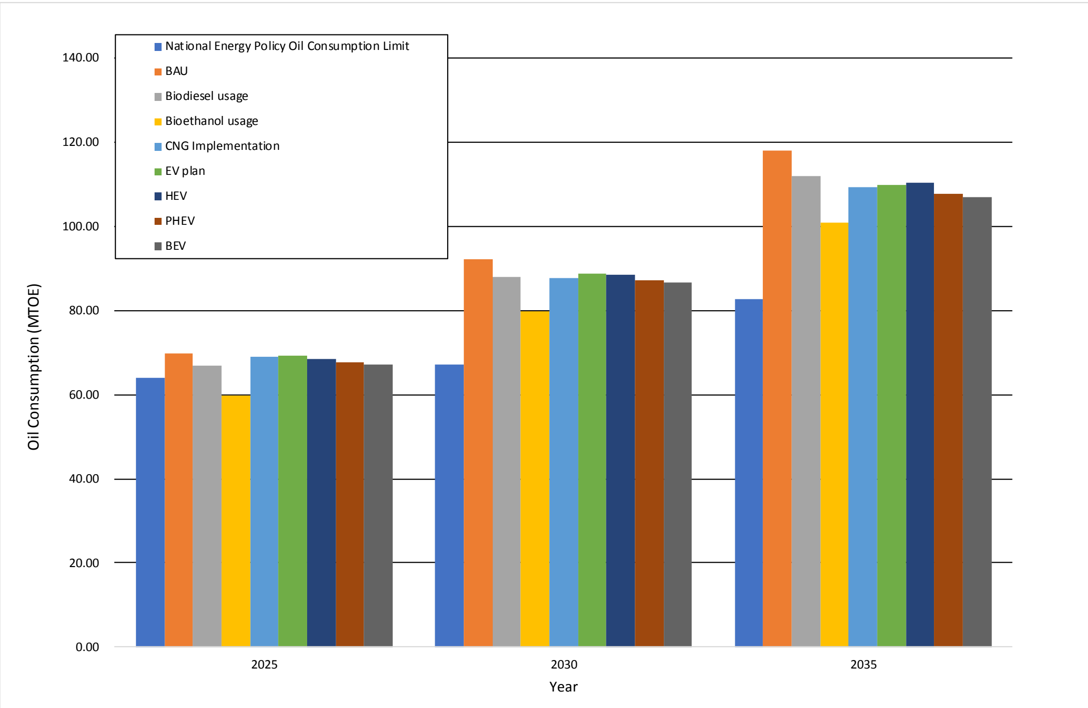
Study Results

Figure 11 shows oil consumption reduction in the transport sector for BAU and seven scenarios. The introduction of more aggressive usage of biofuels, in accordance with the 2014 mandatory content regulations (Ministry of Energy and Mineral Resources (MEMR), Indonesia (2014)), will reduce oil usage. For the increased biodiesel usage scenario, the biodiesel blend is increased to B30. In 2030, oil consumption will be 4.9 MTOE lower for B30 implementation. The scenario still exceeds the NEP (Government of Indonesia (2014)) oil limit, showing that an isolated biodiesel increase measure is far from sufficient. Compared with the BAU case, the increased bioethanol usage scenario results in a sizable reduction in oil consumption. Most vehicles in Indonesia, including motorcycles, are gasoline-based. Therefore, the substitution of gasoline with bioethanol would affect the oil consumption of much of Indonesia's vehicle population. In 2030, oil consumption is reduced by 12.4 MTOE because of the introduction of E20 and by 15.8 MTOE in 2035. While this still does not meet the oil target, the reduction achieved through E20 was slightly less than 50% of the required reduction, indicating the importance of bioethanol adoption that also involves motorcycles.

Many Indonesians are reluctant to use CNG vehicles because of a perceived lack of safety. Therefore, public vehicles, which can be mandated by policy, are the most likely candidates for CNG usage. Trucks are easier to regulate than other public vehicles since they fulfil commercial and/or industrial functions, and can be added to CNG-capable vehicles. The CNG implementation scenario assumes the availability of infrastructure for Jakarta, Bandung, Medan, Palembang, and Surabaya. As the vehicle population in these cities is estimated to comprise 48% of the national total, this study simulates that 48% of all taxi, bus, and truck sales will be CNG-capable vehicles beginning in 2020. The oil reduction from the implementation of CNG taxis, buses, and trucks by 2030 is 5.3 MTOE and 8.5 MTOE by 2035.

The introduction of EVs is expected to reduce both oil consumption and carbon emissions. The government will introduce xEVs and electric motorcycles. In 2035, oil consumption will be 7.9 MTOE lower because of the implementation of xEVs. The scenario still exceeds the National Energy Policy oil limit. The government has specified the composition of BEVs, HEVs, and PHEVs in the xEV population. However, it is important to examine alternative compositions to evaluate the degree to which alternatives can achieve cost-effective reductions in oil consumption and carbon emissions. Three alternative scenarios (modified EV plan with all passenger car xEVs being HEVs, PHEVs, and BEVs, respectively) were modelled. The oil consumption of these three scenarios in comparison to BAU is shown in Figure 11. As can be seen, the difference in oil consumption between each xEV scenario is relatively small.

Figure 11: Oil Reduction in the Transport Sector for Scenarios

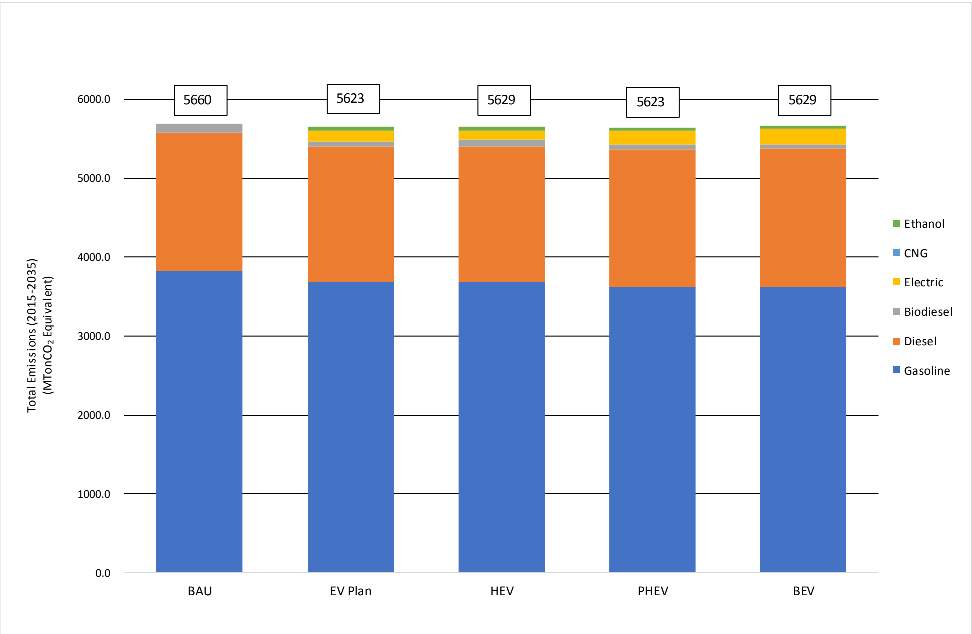


BAU = business as usual, BEV = battery electric vehicle, CNG = compressed natural gas, EV = electric vehicle, HEV = hybrid electric vehicle, MTOE = million tons of oil equivalent, PHEV = plug-in hybrid electric vehicle.

Source: authors.

Total carbon emissions from 2015 to 2035 are shown in Figure 12 for the combined EV plan and biofuel plan. The results are compared with the modified xEV plan and BAU. Regarding CO_2 emissions, increasing PHEV and BEV numbers increases emissions about 0.1% compared with the government EV plan, while increasing HEV numbers will result in similar emissions. Despite the higher efficiency of EVs, a significant decrease in emissions was not observed. This is likely because of the higher specific emissions of electricity compared with the gasoline and bioethanol blend.

Figure 12: Comparison of Carbon Emissions of BAU, EV Plan, and Modified EV Plan with BEVs, HEVs, or PHEVs for the Entire Population of xEV Passenger Cars



BAU = business as usual, BEV = battery electric vehicle, CNG = compressed natural gas, CO_2 = carbon dioxide, EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.

Source: authors.

4. Conclusion as Policy Recommendation

In countries with high GHG emissions from power generation, such as India and Indonesia, the introduction of xEVs alone cannot reduce emissions levels. First, it is necessary to promote power generation by using renewable energy, and in parallel with this, promote the introduction of xEVs.

The introduction of xEVs with only passenger cars has little effect on reducing energy consumption and GHG emissions in some countries. For example, in India, heavy commercial vehicle, light commercial vehicle, and buses account for about 70% of the energy consumption of the transport sector. Therefore, electrification for these major vehicle types should be considered to solve energy and environmental issues in the transportation sector.

In the electrification of automobiles, infrastructure development such as charging stations is also important. In urban areas with high transportation density and highways for long-distance transportation, it is desirable to set up a Charging stations that are easily accessible for cars.

On the other hand, the introduction of biofuels is effective in reducing fossil fuel consumption and GHG emissions. Combined with the improvement in fuel efficiency through the introduction of xEVs, it is more effective to reduce energy consumption and GHG emissions. Policies to introduce biofuel should be promoted in the future. Since current xEVs are mainly gasoline vehicles, the introduction of xEVs may cause a shift from diesel vehicles to gasoline vehicles. Therefore, it is necessary to adjust the production amounts of bioethanol and biodiesel flexibly in accordance with the spread of xEVs. When introducing xEVs, it will be necessary to formulate a renewable energy introduction plan that takes into consideration both power generation and biofuel supply.

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