Annex 1

Energy Saving Potential Study on Thailand's Road Sector:

Applying Thailand's Transport Model

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1. Purpose and Scope of the Study

In this study, a transport model for Thailand was developed to estimate oil demand of road transportation. This study captures only road transport, i.e. it excludes other modes of transport such as rail, water, and air. The model will calculate the demand for vehicle use on roads first, and then derive the amount of oil and other fuel required to run the vehicles.

Vehicles in Thailand are of several types, with the major types of vehicles in terms of energy consumption being private passenger cars (less than 7 passengers), light trucks (pick-up trucks), motorcycles, and heavy trucks. This model includes every type of vehicle on Thailand's roads, also taxis and buses, for example.

Different types of vehicles use different types of fuel. For example, fuel used in private passenger cars is probably gasoline, diesel, liquefied petroleum gas (LPG), compressed natural gas (CNG), hybrid, and others. Pick-up trucks also use several fuel types, i.e. gasoline, diesel, LPG, CNG, and others. Unlike private passenger cars and pick-up trucks, motorcycles mostly use gasoline.

2. Methodology

As mentioned above, this model is an end-user model. Fuel consumption is calculated as
the derived demand of vehicle use. The structure of the method shown below will give an idea how it works.

- CS = f(GDP per capita, vehicle price/CPI)

A change in vehicle stock (CS) depends on gross domestic product (GDP) per capita and the real price of the vehicle. The equation calculates the size of the vehicle fleet in the future. In other words, it estimates the numbers of each type of vehicle as a function of people's income and how affordable the vehicle is. Here price functions were applied only to private passenger cars, pick-up truck, and motorcycles.

- FC = Number of vehicles $_t$ * Mileage $_t$ / Fuel Economy $_t$ (n: vehicle, m: fuel)

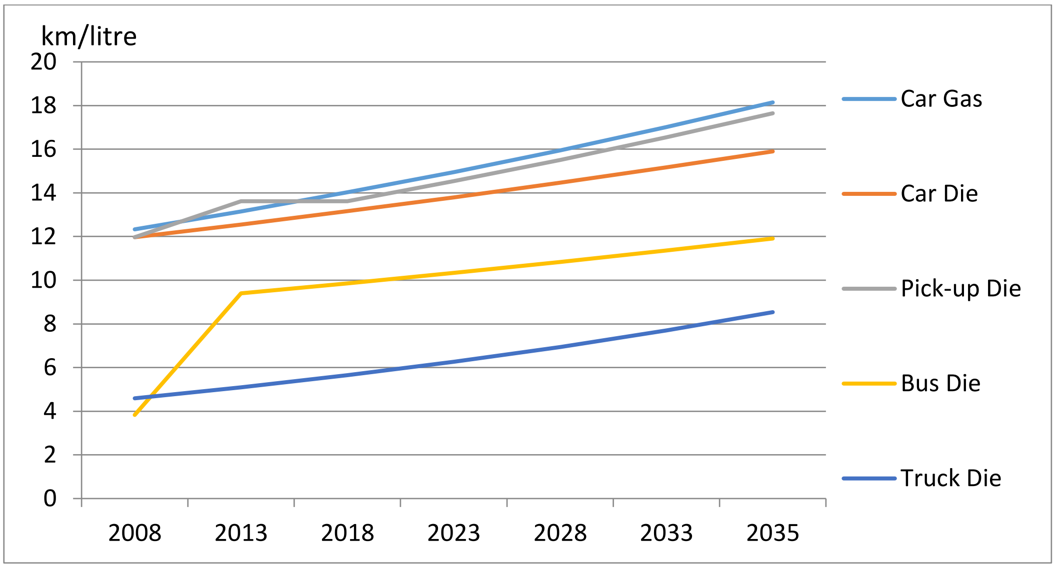
The above equation shows the fuel consumption (FC) of a vehicle. In year t, the total number of type n vehicles, which use fuel m, is multiplied by the average mileage of the vehicles. This is divided by average fuel economy (km/litre) of type n vehicles in year t. It estimates the consumption of fuel m by vehicle n. For example, the total consumption of gasoline by private passenger cars equals the number of private passenger cars times its average mileage per year divided by its average km per litre in the same year. This model relies heavily on survey information, especially regarding average mileage and fuel economy of each vehicle type and each fuel. The survey should be conducted as the priority sector.

In general, the average vehicle mileage of a country should decline when the vehicle stock increases. For example, in the case of Japan from 1970 to 2013, we found that the average mileage declined at a rate of between -0.68 percent to -0.80 percent a year approximately. However, in the case of Thailand, the surveys have been conducted periodically every 3 or 5 years. A clear trend of mileage change has not yet been detected. If such a clear trend is observed in future surveys, it will benefit the model assumptions and the quality of results. Mileage information, according to surveys carried out in 2008, is presented in Table 1.

Table 1. Average Mileage by Vehicle Type in 2008

Type	Km per Year (Country Average)
Passenger Cars	19,787
Light Truck (Pick-up)	25,669
Motorcycles	7,114

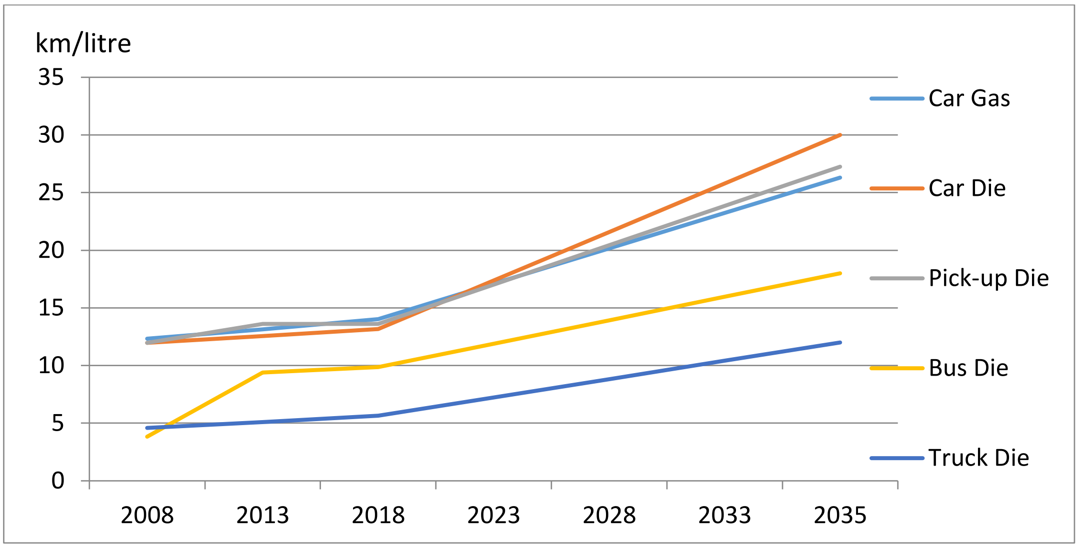
Figure 1. Fuel Economy (km per litre) 2035 BAU



BAU = Business-as-Usual scenario; km = kilometre; die = diesel.

Fuel economy improvement is easier to deduce from the 2008 and 2013 surveys. The improvement varies by vehicle type. The improvement rate between surveys becomes an assumption for the Business-as-Usual scenario (BAU) (See Figure 1). In case of the Alternative Policy Scenario (APS), the government will put in a strong effort to achieve the Energy Efficiency (EE) plan (See Figure 2). Fuel economy consumption improvement will be focused on and will be assumed to apply state-of-the-art technology, which will be assumed to have a positive impact into the next 2 decades, at the end of which it will be country average assumption finally.

Figure 2. Fuel Economy (km per litre) 2035 APS



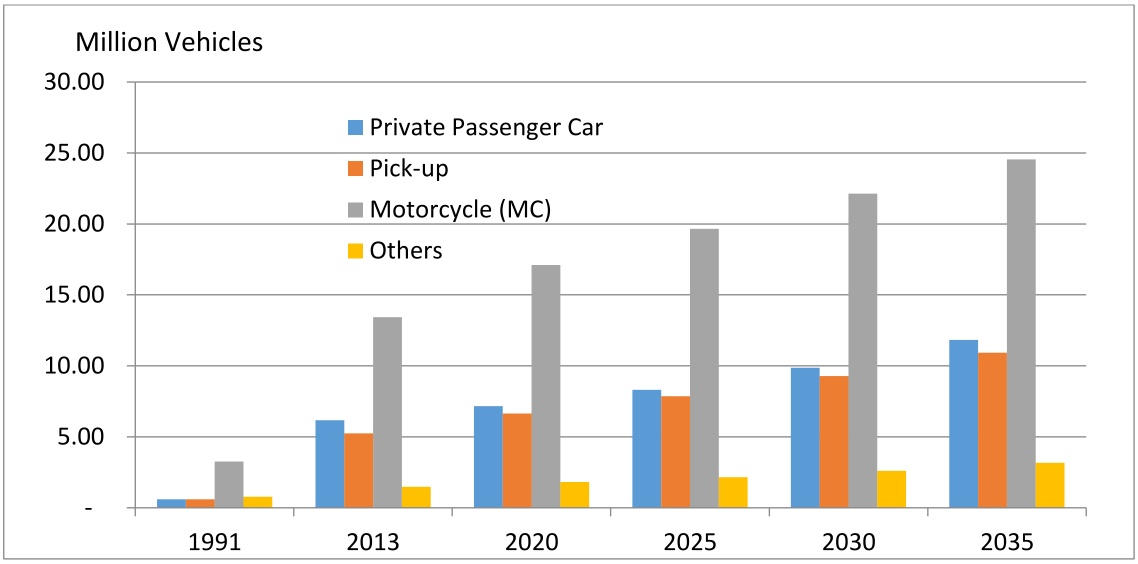
APS = Alternative Policy Scenario; km = kilometre; die = diesel.

3. Outlook Results

3.1. Vehicle Fleet Stocks in Thailand

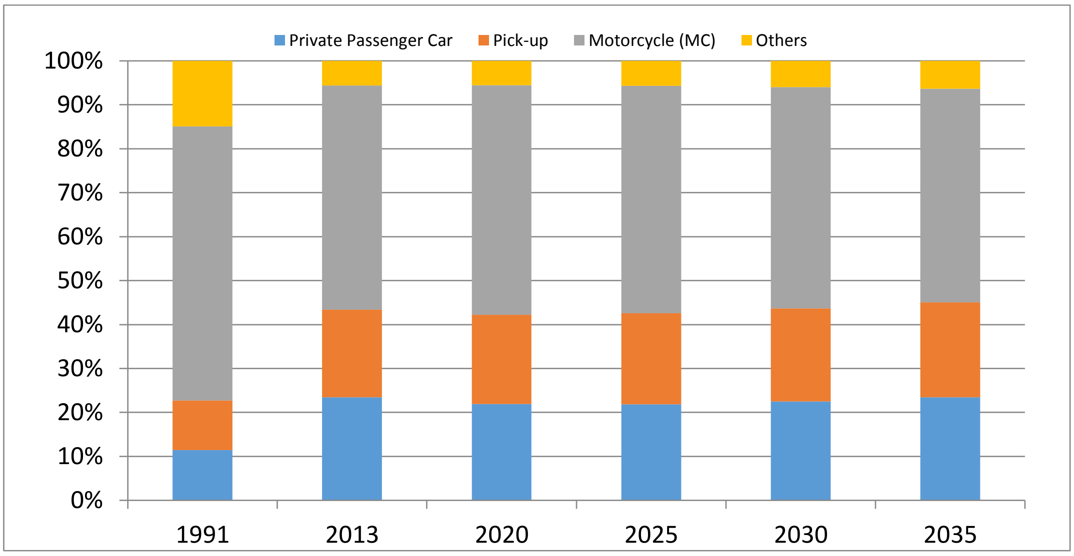
In 2013, private passenger cars, pick-up trucks, and motorcycles were the three largest fleets in Thailand, together making up more than 94 percent of the total vehicle population in 2013, and this will remain the case until 2035. Of all types of vehicles, the motorcycle population is the largest, with 13.4 million vehicles in 2013, followed by private passenger cars (6.2 million), pick-up trucks (5.3 million), and the others (1.5 million). From 1991 to 2013, vehicles in Thailand showed robust growth, especially private passenger cars and pick-up trucks, which had the highest growth of 11.2 percent and 10.4 percent, respectively. In 2035, total vehicles are forecast to grow at around 3.0 percent on average, a compound growth of private passenger cars, pick-up trucks, and motorcycles (of 3.0 percent, 3.4 percent, and 2.8 percent, respectively) and reach 11.8 million, 10.9 million, and 24.6 million vehicles, respectively (Figures 3 and 4).

Figure 3. Vehicle Stock by Type



Source: National Statistical Office (NSO), 2016.

Figure 4. Share of Vehicle by Type

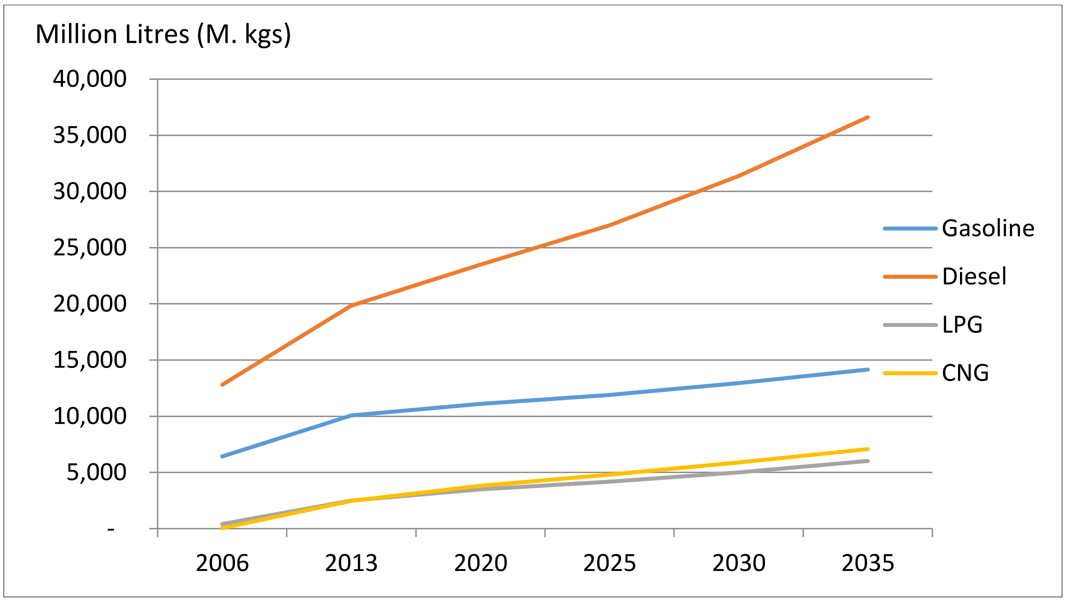


Source: National Statistical Office (NSO), 2016.

3.2. Business-as-Usual Scenario (BAU) – Oil Consumption

Road transport in Thailand consumed a lot of oil, natural gas, diesel, gasoline, and LPG from oil. Diesel was the largest fuel in this sector in 2013, reaching 19.8 billion litres, and is forecast at 36.6 billion litres in 2035 with an average growth rate of around 2.8 percent. For gasoline, LPG, and CNG, the average growth rate up until 2035 will be 1.6 percent, 4.1 percent, and 4.9 percent, respectively. Consumption is expected to increase from 10.1 billion litres, 2.5 billion litres, and 2.5 billion kg in 2013 to 14.2 billion litres, 6.0 billion litres, and 7.1 billion kg, respectively, in 2035. (See Figure 5.)

Figure 5. Oil and Natural Gas Consumption by Road Transport, BAU



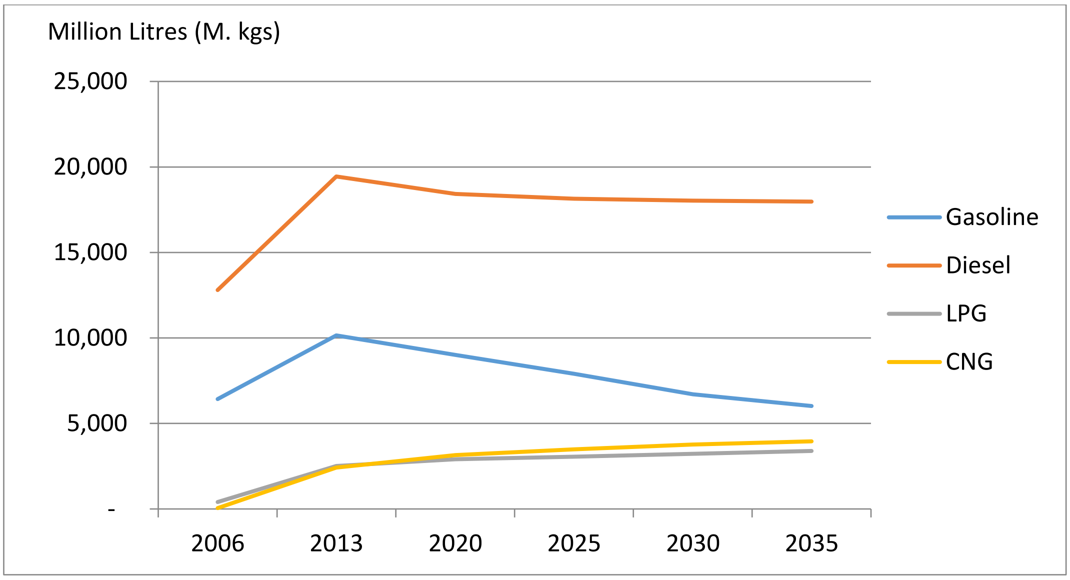
BAU = Business-as-Usual scenario; M. kgs = million kilogrammes; LPG = liquefied petroleum gas; CNG = Compressed Natural Gas.
Source: National Statistical Office (NSO), 2016.

3.3. Energy Saving Potential, Alternative Policy Scenario (APS)

The APS targets to reduce diesel and gasoline consumption in road transport. If, under the APS, diesel and gasoline are to meet the targets of 18.9 and 6.8 billion litres, respectively, in 2035, these must be achieved through efficiency improvements and use of alternative fuels. The transport model would recommend that today the best efficiency vehicles could be applied to reach the 2035 average fuel economy. Meeting these targets cannot be achieved by efficiency improvements alone; it would also require use of alternative fuel vehicles such as electric vehicles (EV) and fuel cell vehicles (FCV) to replace gasoline-fuelled private passenger cars. It will substantially reduce gasoline consumption in private passenger cars as they are the top gasoline consumers in road transport, along with motorcycles.

As a result, consumption of diesel and gasoline are projected to decline to 18.0 and 6.0 billion litres in 2035, compared with their targets of 18.9 and 6.8 billion litres, respectively. However, consumption of LPG and CNG will be 3.4 billion litres and 4.0 billion kg with average growth of 1.4 percent and 2.2 percent, respectively, due to the impact of efficiency improvements of all vehicles.

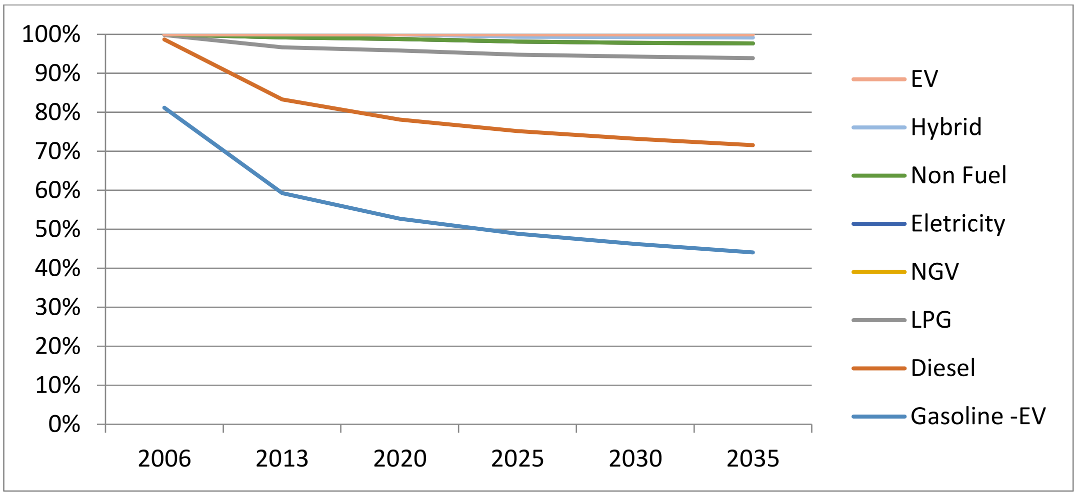
Figure 6. Oil and Natural Gas Consumption by Road Transport, APS



APS = Alternative Policy Scenario; M. kgs = million kilogrammes; LPG = liquefied petroleum gas; CNG = Compressed Natural Gas.
Source: National Statistical Office (NSO), 2016.

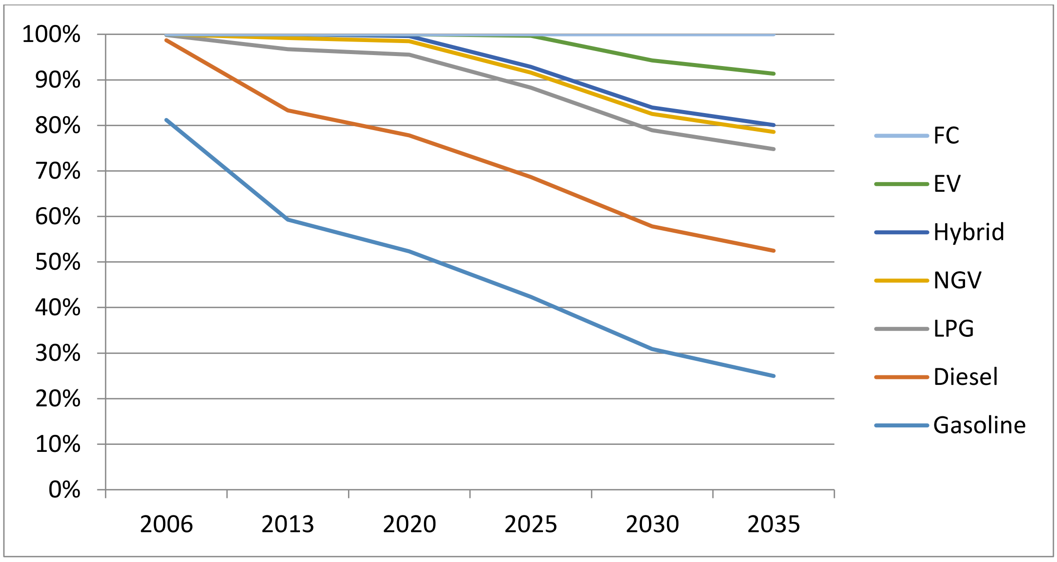
There will be a change in the number of gasoline vehicles when an efficiency policy to reduce the consumption of gasoline by substituting gasoline vehicles with EV and FCV is implemented under the APS. Due to greater diversification in vehicle powertrain technologies, the APS implies that oil can be replaced to a greater extent by other fuels – Electric Vehicles (EV), Fuel Cell Vehicles (FCV), Natural Gas Vehicles (NGV), and Liquefied Petroleum Gas (LPG, only from natural gas). (See Figures 7 and 8.)

Figure 7. Private Passenger Cars by Fuel Type, BAU



BAU = Business-as-Usual scenario; EV = electric vehicles; NGV = natural gas vehicles; LPG = liquefied petroleum gas; CNG = Compressed Natural Gas.
Source: National Statistical Office (NSO), 2016.

Figure 8. Private Passenger Cars by Fuel Type, APS



APS = Alternative Policy Scenario; FC = fuel consumption; EV = electric vehicles; NGV = natural gas vehicles; LPG = liquefied petroleum gas; CNG = Compressed Natural Gas**.**
Source: National Statistical Office (NSO), 2016.

4. Findings and Recommendations

The transport model we developed for Thailand shows that efficiency improvements alone are unlikely to achieve the goals of the APS. However, the goals could possibly be achieved when policy is combined with efficiency improvements and alternative fuel technologies such as EV and FCV. Furthermore, electric powertrain technologies can be applied to motorcycles as well, which would further reduce gasoline consumption significantly.

When comparing fuel economy improvements in gasoline and diesel in passenger cars, diesel has a higher figure, at nearly 30 km/litre, than gasoline, somewhere around 26 km/litre. Policy should place greater emphasis on promoting fuel efficiency in diesel vehicles than in gasoline vehicles.

Finally, for Thailand to achieve its ultimate goal of reducing total oil consumption, it should set ambitious policy targets for energy efficiency in transportation. Firstly, to improve vehicle efficiency to at least today's state-of-the-art technology, so as to reduce fuel consumption per kilometre, is one of the most effective ways to reduce oil consumption for the country as a whole. Secondly, to promote diesel vehicle use in private passenger cars, the efficiency improvement of diesel is expected to occur sooner than that of gasoline. Lastly, to diversify vehicle types, compared between the BAU and the APS, without promoting EV, FCV, Hybrid, and CNG, the oil consumption reduction goal for 2035 cannot be achieved through efficiency improvements alone.