Annex 2

Best Energy Mix for Road Transportation in Indonesia

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June 2013

This chapter should be cited as
Widyaparaga, A., B. M. Sopha, J. Soemardjito, Deendarlianto, A. Budiman, I. Muthohar, K. Ota, A. Fuwa, I. C. Setiawan, H. Hayashi, A. Lindasista, S. Mukhtar, F.A. Nasution (2013), ‘Best Energy Mix for Road Transportation in Indonesia’ in Kimura, S. (ed.), *Analysis on Energy Saving Potential in East Asia*, ERIA Research Project Report 2012-19, pp.333-347.ERIA [online]. Available at: http:/www.eria.org/RPR_FY2012_No.19_ Annex_2.pdf

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A2-1: Introduction

Historically, indigenous oil, gas and coal reserves have played an important role in Indonesia's economy. Indonesia's vast reserves and resources of these three commodities have allowed extensive utilization as sources of energy, industrial raw material and national income. The extensive use of energy has contributed to the increase of economic growth which is represented by GDP. Between 2002 and 2030, it is projected that the Indonesian population will grow at 1 percent annually whereas GDP grows at 4.6 percent.[1]

The increase of population growth has in turn resulted in higher energy demand. The total energy consumption in Indonesia in the year 2000 was 778 million barrels

[1] Fuerte Jr. (ed.), (2006).

of oil equivalent (BOE). Within 11 years, this increased to 1,114 million BOE. The energy consumption by the transportation sector experienced the largest increase within this period. From the year 2000 to 2011, the energy consumption by the transportation sector grew at a rate of 6.5 percent annually from 139 million BOE to 277 million BOE. Meanwhile, oil production decreased 4 percent annually from 2000-2011 due to depletion of reserves and lack of investment for exploration and development.[2]

The transportation sector consumes over 60 percent of Indonesian oil, 70 percent of which attributed to road transportation. Summarizing, road transportation, the main contributor of energy consumption in transportation sector, will account for 87 percent of the total transport energy demand by 2030. The Asia Pacific Energy Research Centre predicts that the number of passenger vehicles will increase from 3.4 million units in 2002 to 13.9 million units by 2030 thus drastically increasing oil demand.[3]

An issue that arises is the continued financial burden to the Indonesian government due to the policy of subsidizing gasoline and diesel fuels for road transport. The increasing demand of these fuels will be accompanied by increasing subsidy, further made worse if domestic oil production continues to decline. It is thus necessary to explore alternative energy resources or fuel types for road transportation.

This study therefore aims to examine the effect of the implementation of alternative fuels, such as compressed natural gas (CNG) and biofuels, on fuel consumption, CO_2 emissions and fuel subsidies for the road transportation sector. In addition, new energy efficient technologies such as electric vehicles and hybrid vehicles are also examined. It is expected that the results of this study can provide insight to what fuel mix can best be applied to the Indonesian road transport sector in such a way that features a favourable balance of reduced gasoline/diesel consumption and subsidies, more efficient energy usage, and low CO_2 emissions.

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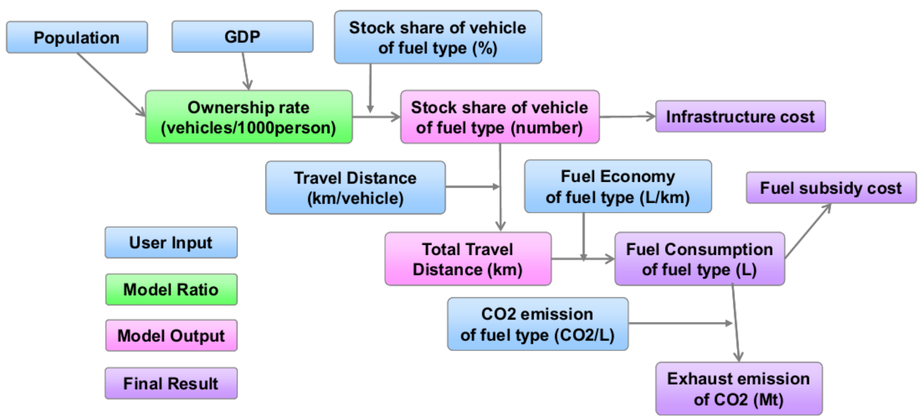
[2] Syahrial, *et al.* (2012).
[3] Fuerte Jr. (ed.), (2006).

A2-2: Predictive model

We have adopted a modified IEA/SMP Transport Spreadsheet Model to predict energy consumption, emissions and cost. The original IEA/SMP model calculates energy and CO_2/pollutant emissions based on fuel type using the IEA "ASIF" structure - Activity, Structure, Intensity and Fuel composition - and was designed to produce projections of vehicle stocks, travel, energy use and other indicators through 2050 for a reference case and for various policy cases and scenarios with incorporation of technological effects.[4] However, the model did not include cost structure and required modification to be able to examine the specific conditions of road transportation in Indonesia. We have therefore extensively modified the model for use with Indonesian provincial statistical data focusing only on road transport and have developed a cost prediction module incorporating subsidized fuel costs and infrastructure costs (Figure A2-1).

Due to the socio-economical and technological differences between the regions of Indonesia, this study grouped Indonesian provinces into six areas: Sumatra, Java & Bali, Kalimantan, Sulawesi, Nusa Tenggara, Papua and Maluku. This grouping also allows finer adjustment of scenarios such as the introduction of new technology or vehicles only within certain groups.

Figure A2-1: Model Algorithm



Calculation of vehicle ownership was based on vehicle sales obtained from the

[4] Center for Transportation and Logistics Studies of Gadjah Mada University, and South South North Project (2003).

Association of Indonesian Automotive Industries (GAIKINDO)[5] and the Indonesian Motorcycle Industries Association (AISI).[6] By correlating historical vehicle ownership to historical GDP per capita[7] for each study area, projections of ownership are predicted to 2030.

Annual travel distance was obtained from a study conducted by South South North and the Center for Transportation and Logistics Studies of Gadjah Mada University.[8] Average annual travel distance was calculated by estimating the number of the active days of the vehicle type within one year.

The majority of fuel economy data was adopted from an empirical research which investigated the fuel consumption of motorcycles, passenger cars (gasoline and diesel), buses and trucks in Indonesia, specifically the cities of Yogyakarta, Semarang and Surakarta.[9] The data was collected through field study which was then cross-validated with data from government institutions. Nevertheless, some data such as fuel-efficiency for CNG-vehicles (bus and truck) and electric-vehicles are not yet available in Indonesia so that those data are either obtained from manufacturers or assumed.[10]

Data on CO_2 emission collected through a literature survey on life-cycle assessment studies in Indonesia was utilized when available.[11] For cases where Indonesian data was not available, best estimates using other data was used.[12]

A2-3: Scenarios

We have developed five scenario types to examine the effect of the adoption of alternative fuels and fuel efficient technology on fuel and energy consumption, CO_2 emissions and fuel subsidies.

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[5] Association of Indonesian Automotive Industries (GAIKINDO), (2013a), GAIKINDO, (2013b); GAIKINDO (2012).
[6] Indonesian Motorcycle Industries Association (AISI), (2013).
[7] Badan Pusat Statistik (BPS), (2013).
[8] Center for Transportation and Logistics Studies of Gadjah Mada University, and South South North Project (2003)
[9] Sandra (2012).
[10] Sinaga, *et al.,* (2010).
[11] Restianti and Gheewala (2012a).
[12] Sevenster and Croezen (2006).

Scenario 0: Reference Scenario

In 2008, the Indonesian Ministry of Energy and Mineral Resources mandated that biofuel content within a biofuel blend reach 5 percent by 2015. Afterwards, biodiesel is expected to reach 20 percent content by 2025 while ethanol is expected to reach 5 percent. [13]

Due to limited stocks, production of a gasoline-ethanol blend was eventually suspended in 2009. However, biodiesel production met a good degree of success. In 2012, the biodiesel content was ahead of schedule and able to reach 5 percent with an increase to 7.5 percent beginning 2013. Therefore as a reference scenario, a constant biodiesel blend of 7.5 percent and ethanol blend of 0 percent was assumed until 2030.

Scenario 1: Biofuel Scenario

Two biofuel scenarios were added to simulate the effect of increased biofuel content towards energy consumption, carbon emissions and cost:

Scenario 1A: The current bioethanol blend of zero or E0 is increased gradually to an ethanol content of 10 percent or E10 by 2020. Likewise the biodiesel content is increased from the current 7.5 percent or B7.5 to 10 percent or B10 by 2020.

Scenario 1B: Similar to Scenario 1A up to 2020. Afterwards, from 2010, the bioethanol blend content is increased gradually to 20 percent or E20 by 2030.

Scenario 2: Natural Gas Scenario

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 transportation sector from 10 percent to 25 percent by 2025[14]. Two gas scenarios were created to simulate the effect of CNG adoption:

Scenario 2A: CNG cars, buses and trucks are sold and old gasoline and diesel cars, buses and trucks are converted in islands which are adjacent or contain gas producing areas, namely Sumatera, Kalimantan, Sulawesi, Papua and Maluku. New CNG cars are produced and sold in the Indonesian market beginning 2016 beginning

[13] Indonesian Ministry of Energy and Mineral Resources (2008).
[14] Indonesian Ministry of Energy and Mineral Resources (2010).

at 10 percent of vehicles sold and reaching 100 percent by 2030. CNG conversion of older gasoline and diesel cars begins in 2015 at 0.2 percent of vehicles present and reaching 100 percent by 2030. Both are assumed to follow an exponential curve. This resulted in a final population of CNG passenger cars comprising 31 percent of the total car population.

Scenario 2B: Similar to Scenario 2A but with the addition of new cars, buses and trucks sold and old cars, buses and trucks converted to CNG operation in Java and Bali. In Java and Bali, it is assumed that CNG conversion begins in 2015 at 0.5 percent of old gasoline and diesel vehicles and CNG vehicle sales begins in 2016 at 10 percent of all vehicle sales. Both vehicles sales and conversion are assumed to reach 100 percent at 2030. The population of CNG passengers was found to reach 99.6 percent of the total car population by 2030.

Scenario 3: Electric vehicles

Scenario 3 introduces the sales of electrical passenger cars. Scenario 3 assumes sales of electric vehicles into the Indonesian market begin in 2016 with 0.5 percent of cars sold. In 2030, the ratio of sales of EVs to total passenger cars sales is 100 percent. A fuel economy of 45 km per litre gasoline equivalent was assumed in 2016. The final population of EV passenger cars by 2030 was 16 percent of the total passenger car population.

Scenario 4: Hybrid cars

Scenario 4 introduces the sales of hybrid cars. Similar to Scenario 3, sales of hybrid vehicles into the Indonesian market begin in 2016 with 0.5 percent of cars sold and reach 100 percent in 2030. Hybrid vehicles were modelled to be able to adopt to bioethanol and were assumed to have a fuel economy of 14 km per litre gasoline equivalent in 2016. Similar to Scenario 3, the final population of hybrid passenger cars by 2030 was 16 percent of the total passenger car population.

Scenario 5: Hybrid, CNG and biofuel Energy mix

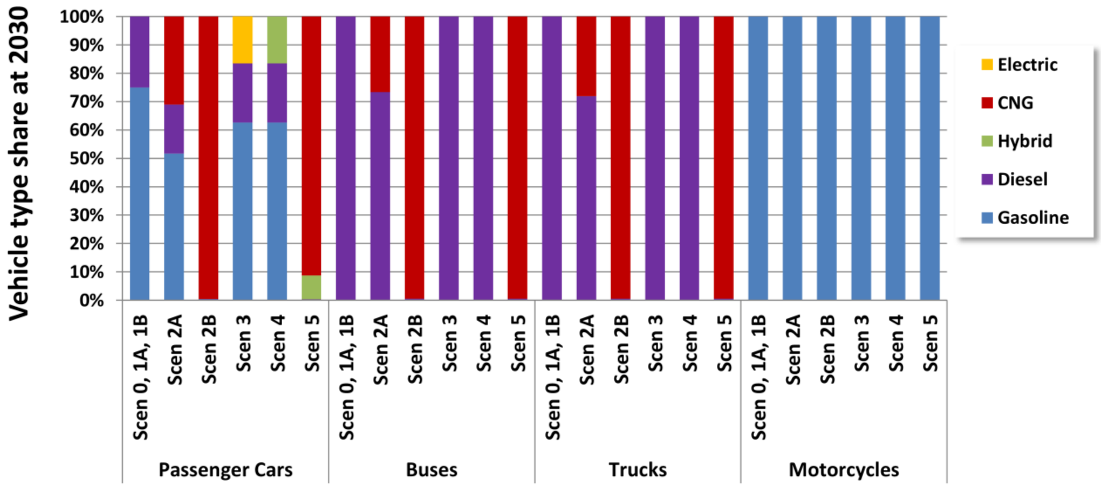
A fuel mix was proposed in Scenario 5. This scenario combines the use of hybrid vehicles and CNG vehicles. New hybrid passenger cars begin sale nationwide at 0.5 percent in 2016 and reaches 45 percent of total passenger cars sales by 2030. As in Scenario 2B, CNG cars are only sold and converted in Sumatra, Java, Bali, Kalimantan, Sulawesi, Papua and Maluku due to the presence or close proximity of natural gas production facilities and distribution infrastructure. New CNG cars begin sale at 10 percent in 2016 and reach 55 percent by 2030. Conversion of older cars to CNG operation begins at 0.5 percent of gasoline and diesel vehicle population for Java and Bali in 2015 and at 0.2 percent for other areas. Conversion reaches 100 percent of non-hybrid vehicle population in 2030. The final result of fuel type composition for passenger cars was 8 percent hybrid passenger cars and 91.3 percent CNG cars by 2030.

A2-4. Results and discussion

Vehicle Fuel type composition

As a result of new vehicles of different fuel types being sold and conversion of old vehicles to another fuel type (i.e. conversion of old cars to CNG), the vehicle populations of different fuel types (vehicle fuel type composition) will change. Figure A2-2 shows the final composition of vehicle fuel types by 2030. As can be seen, introduction of EV and hybrid technology (Scenario 3 and 4) that only relies on gradually increasing sales of new vehicles will result in a limited share (i.e. 16 percent) by 2030. To have a larger share, more aggressive adoption of these vehicles must be adopted or the older vehicles should be retired or converted to the new fuel type. For CNG (Scenario 2A and 2B), a larger share was obtained because older vehicles were converted to CNG.

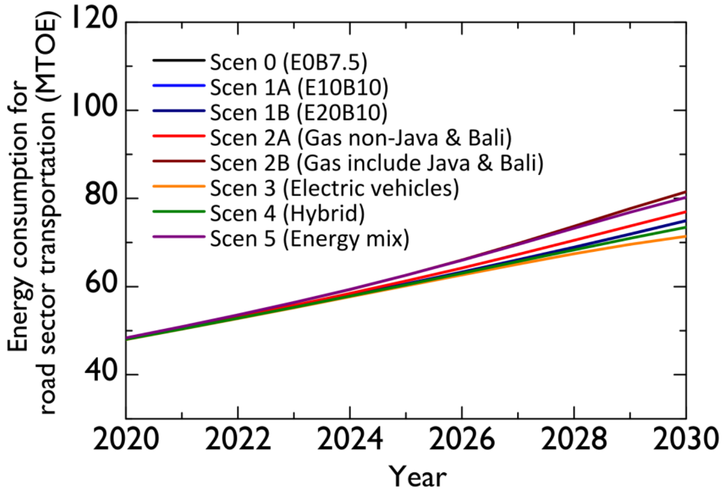
Figure A2-2: Vehicle Composition by Fuel Type in 2030



Energy consumption

The predicted energy consumption for each scenario is shown in Figure A2-3. As can be seen, low energy consumption occurs when high efficiency vehicles are introduced. The lowest energy consumption is for the electric vehicle scenario due to the highest efficiency of these vehicles. This is followed by the hybrid vehicle scenario. As it is assumed that CNG vehicles are not optimized and dedicated CNG vehicles but bi-fuel capable vehicles, these vehicles therefore have a lower efficiency than gasoline and diesel vehicles. Thus, the largest energy consumption occurs in Scenario 2B. Scenario 5 shows a slightly less energy consumption due to the mix of hybrid vehicles with CNG vehicles.

Figure A2-3: Energy Consumption



Reduction of gasoline and diesel usage

A main issue with transportation fuel in Indonesia is the heavy burden of gasoline and diesel subsidies that the Indonesian government allocates from its annual budget. Reduction of gasoline and diesel fuel usage will directly alleviate this burden. This will be an important consideration in deciding an action plan in regards to road sector energy planning.

Figure A2-4: Percentage reduction of gasoline (left) and diesel fuel consumption (right) compared to reference scenario consumption

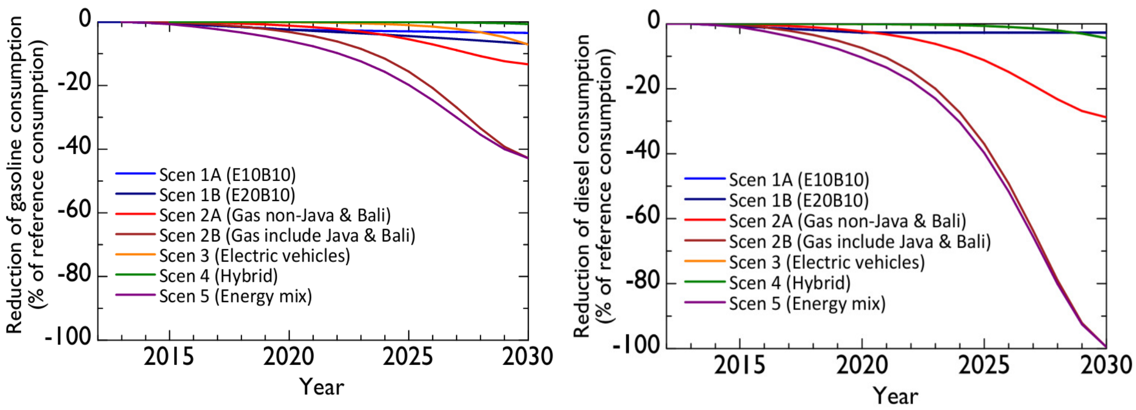
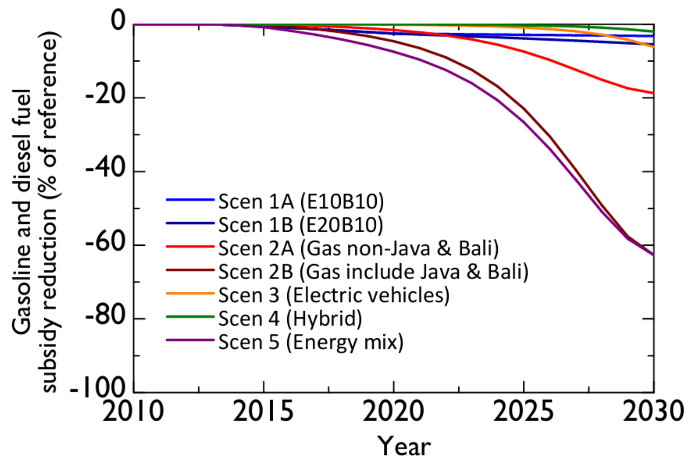


Figure A2-4 display the reduction of gasoline and diesel fuel usage respectively in regards to application of different energy mix scenarios. As can be seen, the largest reduction of gasoline and diesel fuels is obtained by Scenarios 2B and Scenario 5 which model a nationwide conversion of older gasoline and diesel vehicles and sales of new CNG vehicles. Introduction of new energy efficient technology such as hybrid vehicles and electric vehicles reduce the gasoline and diesel consumption at a milder rate since these technologies involve only newer vehicles sold without conversion of older vehicles. It is thus apparent that to significantly reduce gasoline and diesel consumption, an action plan must consider the presence and involve the existing population of gasoline and diesel vehicles. This is especially important considering the scarce retirement of old vehicles.

Reduction of gasoline and diesel fuel consumption will directly affect the amount of fuel subsidy. Figure A2-5 shows the reduction of annual fuel subsidy for each scenario. To better compare cost reduction between scenarios, a constant oil price and constant subsidy per litre gasoline and diesel was assumed. As expected, the largest amount of fuel subsidy reduction was achieved by scenarios with the largest gasoline and diesel fuel consumption reduction, Scenario 2B and Scenario 5 of which by 2030 achieved similar reduction of annual subsidies of 131.2 trillion IDR, a reduction of 62.7 percent. In addition, energy mix Scenario 5 which introduces sales of hybrid vehicles and includes distribution of E20 and E10 biofuels achieved a larger reduction earlier compared to Scenario 2B which only considers CNG usage.

The simulation results have shown that scenarios which have involved the conversion of old vehicles to CNG use have resulted in the most drastic reduction of consumption and managed to reduce gasoline and diesel fuel usage by 15.6 percent and 37.0 percent in 2025 respectively. This reduction reaches 42.8 percent for gasoline and 99.5 percent for diesel fuel consumption by 2030 and resulted in a subsidy reduction of 62.7 percent in 2030.

Figure A2-5: Percentage reduction of gasoline and diesel fuel subsidy reduction compared to reference scenario subsidies



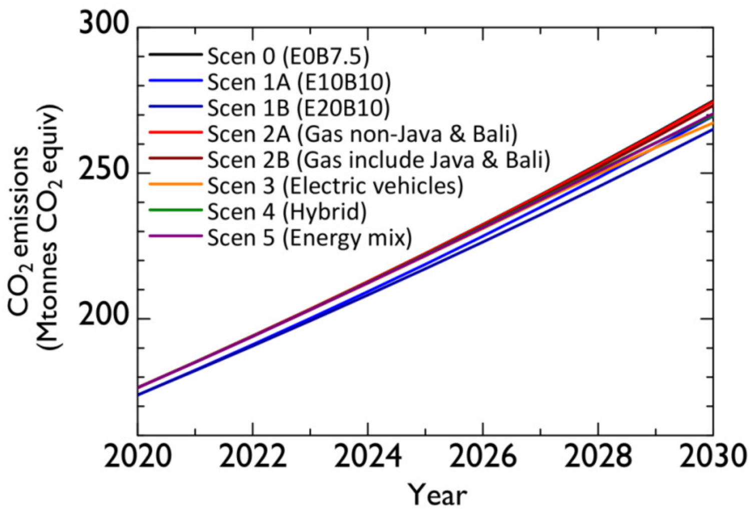
Results of Scenario 5 show that biofuel can well supplement other measures such as the introduction of hybrid vehicles and CNG conversion resulting in a larger reduction of gasoline and diesel fuel usage in short and mid-terms. Measures to increase the biofuel content further and implement biofuel usage to motorcycles will result in an even greater reduction of gasoline and diesel consumption.

The introduction of new fuel efficient vehicles have been shown to reduce gasoline consumption by 0.7 percent and diesel consumption by 4.4 percent for hybrid vehicles, resulting in a subsidy reduction of 2.0 percent in 2030. The reduction by electric vehicles was 7 percent and 4.4 percent gasoline and diesel fuel consumption respectively, resulting in a subsidy reduction of 6.2 percent. The relatively limited reduction of gasoline and diesel fuel consumption is due to the fact that at 2030 the population of these new vehicles will only account for 16 percent of the total passenger car population by 2030, assuming a 100 percent sales market share at that time. Competition with other fuel types, such as the with the sales of CNG cars as shown in Scenario 5, will result in a lower population count of the new technology cars. In Scenario 5, assuming 45 percent sales market share of hybrid vehicles in 2030, the final proportion of hybrid cars to total cars was 8 percent. Again, this highlights the importance of dealing with older gasoline and diesel vehicles already present in the vehicle population. Nevertheless, the eventual natural retirement of older vehicles will gradually increase the impact of these newer technology hybrid and electric vehicles in the long term and thus should not be ignored.

Carbon emissions

Carbon emissions were calculated based on fuel consumption and specific carbon emissions. Figure A2-6 shows that the road sector CO_2 emissions were not so different between the scenarios modelled. By 2030, reference Scenario 0 featured the largest annual CO_2 emissions, a value of 274 million tonnes CO_2 equivalent. CNG Scenario 2B was second largest, despite the low specific emissions of CNG, due to the lower fuel economy of bi-fuel CNG vehicles. Meanwhile the lowest CO_2 emissions of 267 million tonnes CO_2 equivalent were obtained by the EV scenario. Even though EVs had a good fuel economy of 45 kms per litre gasoline equivalent, the specific CO_2 emissions were quite high for Indonesian electric power as shown due to the dominance of coal fired power plants[15] thus reducing the impact of EVs in regards to CO_2 emissions.

Figure A2-6: CO_2 Emissions



[15] Widiyanto, *et al.* (2003).

A2-5: Conclusion

The results have shown that to significantly reduce gasoline and diesel fuel usage and ultimately reduce fuel subsidies, the population of old gasoline and diesel vehicles must be put into consideration. The scarce retirement of older vehicles in Indonesia results in these vehicles still consuming a sizable amount of gasoline and diesel fuel despite introduction of newer, more efficient and alternative fuel capable vehicles. This resulted in a somewhat limited impact of introduction of high fuel economy vehicle like hybrid vehicles and electric vehicles due to the low population of these vehicles by 2030. If the portion of these high fuel economy vehicles is increased, either by the reduction of old vehicles or by accelerating the adoption of high fuel economy vehicles, the impact will be more pronounced.

The largest CO_2 emissions was obtained by the reference scenario at 274.8 million tonnes CO_2 by 2030, while the least was obtained by Scenario 3 (electric vehicles) with a value of 267.3 million tonnes CO_2 a difference of less than 3 percent due to the lower population size or due to increase of CO_2 by power generation for the electric vehicles. As such, CO_2 emissions were relatively similar between each scenario.

This conclusion is a result of the calculation under specific conditions. Based on the results, implementation of a fuel mix policy intended on reducing reliance on gasoline and diesel fuel consumption should consider the following:

- A plan to reduce the population of old gasoline and diesel vehicles must be considered, either by adopting a vehicle retirement scheme or by converting these vehicles to non-gasoline/diesel fuels.
- A recommended course of action is the implementation of a CNG conversion plan for older gasoline and diesel vehicles. While bi-fuel CNG vehicles are slightly less efficient, the end result is still only less than 6 percent rise in energy consumption, with the potential benefit of 60 percent reduction in fuel subsidies.
- Further development, production and adoption of biofuel blends with increasing biofuel content should be conducted in conjunction with other initiatives such as CNG conversion. In addition to being compatible with

a good portion of older vehicles, biofuel adoption will help reduce fuel subsidies earlier in the short term compared to adoption of CNG, EVs or hybrid technologies. A policy to mandate biofuel compatibility of motorcycles will further increase the impact of biofuel adoption.

- For the introduction of new fuel efficient technologies such as hybrid vehicles and electric vehicles to make a significant impact, the increase of the population portion of such vehicles must be accelerated, either by a more aggressive adoption plan or by retirement of older less efficient vehicles. A more aggressive adoption of new technologies may be promoted by the government by introducing policies such as subsidies or reduced taxes for high fuel efficiency vehicles.

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