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Study of Renewable Energy Potential and Its Effective Usage in East Asia Summit Countries

Edited by

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List of Abbreviations and Acronyms

ADB	Asian Development Bank
AEDP	Alternative Energy Development Plan (Thailand)
BAU	business as usual
bpd	barrels of oil per day
BPPT	Badan Pengkajian dan Penerapan Teknologi (Agency for the Assessment and Aapplication of Technology, Indonesia)
CBM	coal bed methane
CES	basic cost of electricity supply
CNG	compressed natural gas
CO_2	carbon dioxide
CPO	crude palm oil
DEDE	Department of Alternative Energy Development and Efficiency (Thailand)
DPF	Diesel Particulate Filter
DSM	demand side management
EAS	East Asia Summit
EEBS	EAS–ERIA Biodiesel Fuel Standard
EEP	Energy Efficiency Plan (Thailand)
EEV	energy efficient vehicle
EPPO	Energy Policy and Planning Office (Thailand)
ERIA	Economic Research Institute for ASEAN and East Asia
EV	electric vehicle
FAME	fatty acid methyl esters
FE	fuel economy
FT-SPK	Fischer-Tropsch synthetic paraffinic kerosene
GDP	gross domestic product
GHG	greenhouse gas
HDO	hydrodeoxygenation
HEFA-SPK	hydroprocessed ester and fatty acid synthetic paraffinic kerosene
H-FAME	partially hydrogenated fatty acid methyl ester
HVO	hydrotreated vegetable oil
IAEC	Isuzu Advanced Engineering Center
IATA	International Air Transportation Association
IEA/SMP	International Energy Agency/Sustainable Mobility Project
INAF	Initiatives for Next Generation Aviation Fuels
KBOE	thousand barrels of oil equivalent
KEN	Kebijakan Energi Nasional (National Energy Policy, Indonesia)
kl	kilolitre
kt	kilotonne
KTOE	kilotonne of oil equivalent
LCS	low-carbon scenario

LNG	liquefied natural gas
LPG	liquefied petroleum gas
MCH	methylcyclohexane
MMB	million barrels
MMMT	million metric tonnes
MMSCF	million standard cubic feet
MMSCFD/mmscfd	million standard cubic feet per day
MoNRE	Ministry of Natural Resources and Environment (Viet Nam)
MTOE	million tonnes of oil equivalent
NGVPPT	Natural Gas Vehicle Program for Public Transport (Philippines)
PDP 7	National Power Development Plan VII (Viet Nam)
PEP	Philippines Energy Plan
Pertamina	Perusahaan Pertambangan Minyak dan Gas Bumi Negara (The Indonesian State Oil Company)
PLN	Perusahaan Listrik Negara (State Owned Power Company)
PTTPC	PTT Philippine Corp.
RE	renewable energy
RON	Research Octane Number
RPJMN	Rencana Pembangunan Jangka Menengah Nasional (Midterm National Development Plan, Indonesia)
RUEN	Rencana Umum Energi Nasional (General Planning for National Energy, Indonesia)
SKK Migas	Satuan Kerja Khusus Pelaksana Kegiatan Usaha Hulu Minyak (Government Executive Agency for Upstream Oil and Gas Business Activities, Indonesia)
SMPC	Semirara Mining and Power Corporation (Philippines)
SOP	standard offer programme
tcf	trillion cubic feet
TFEC	total final energy consumption
TPES	total primary energy supply
ULG	unleaded gasoline
VNEEP	National Energy Efficiency Program (Viet Nam)

Executive Summary

1. Background and Objectives

In line with the expanding energy demand in the transportation sector, import of crude oil and fuel products in East Asian countries will increase. From the viewpoint of energy security, energy resources should be changed from imported fossil fuels to renewable ones that can be produced domestically. East Asian countries are actively promoting the introduction of biofuels (especially first-generation biofuels such as bioethanol and biodiesel) according to their individual national energy plans. However, the amount of biofuel produced in each country cannot satisfy the amounts required to achieve the policy target. To reduce import of crude oil and energy consumption in the transportation sector, overall measures are required, such as production of next-generation biofuels from nonconventional resources, improvement of fuel efficiency of vehicles, and maintenance of road infrastructure.

Against this background, this report investigates the following three subjects: (1) study of the potential of a diversified transportation energy mix, (2) research on next-generation biofuels, and (3) biomethanol as an energy carrier during fiscal years 2015–2017.

The first subject deals with the outlook of transportation energy including biofuels based on the simulation of energy consumption from vehicle registration. The objectives are (1) to offer useful information for developing and adapting the Association of Southeast Asian Nations (ASEAN) renewable energy roadmap, (2) to predict the regional energy outlook in the transportation sector, and (3) to raise the level of data and analysis on ASEAN's energy policy and planning.

The latter two subjects investigate the production technologies of next-generation biofuels and their utilisation. We discuss their possible policy and introduction as transportation fuels and energy carriers. The objectives are (1) to enhance the research and development (R&D) network on renewable energy technology development and utilisation, and (2) to develop a nodal network with automotive and related industries on technological know-how and R&D activities for biofuel.

2. Methodology

The Working Group consists of invited energy experts, including policy makers and engineering scientists from each country. This study covers following topics.

(1) Potential Study of Diversified Transportation Energy Mix

We discuss the most suitable uses of the various types of transportation energy including biofuels from the viewpoint of international trade, energy consumption in the transportation sector, and domestic and international strategies for biofuel promotion. In the first fiscal year (FY 2015), we simulated energy consumption up to 2030 using the Energy Mix Model based on vehicle registration data, fuel economy (actual consumption) data, and mileage travelled annually by vehicle/fuel type supplied by members from three countries (Thailand, Indonesia, and the Philippines). We analysed the current and future energy issues of each country based on the simulation to propose possible measures for mitigating such energy issues (gap between energy supply and demand) and achieving the policy target. In the second fiscal year (FY 2016), we carried out a similar simulation and analysis based on data supplied by Vietnamese and Malaysian members. In the third fiscal year (FY 2017), the Working Group discussed multilateral cooperation to fulfil demand and supply of biofuel.

(2) Research of Next-Generation Biofuels

The Working Group investigates the production technologies of next-generation biofuels and discusses their policy and possibility of their introduction. In addition, the technical problems of next-generation biofuel production are clarified based on experiments. In the first fiscal year (FY 2015), we investigated the utilisation of cheap resources such as nonconventional resources and waste materials to produce alternative diesel and jet fuel, development and improvement of upgrading technology, and the fuel standard. This study clarified technical matters and merits of reducing fuel cost and greenhouse gas (GHG) emissions by using nonconventional resources. In the second fiscal year (FY 2016), resource availability and selection of the optimum production process were investigated. Various cheap raw materials are available for production next-generation biofuel. However, the production process of next-generation biofuel is yet to be established. Improving the manufacturing process may make it possible to reduce the biofuel production cost using nonconventional resources. In the third fiscal year (FY 2017), we investigated the effects of plant scale and other factors such as energy supply for reducing the cost of fuel production at operating factories. The production cost of next-generation biofuel strongly depends on economy of plant scale. An optimum plant scale with cost performance exists.

(3) Biomethanol as an Energy Carrier

The Working Group investigates biomethanol production and discusses its role as an energy carrier. In the first fiscal year (FY 2015), we investigated the current status of global methanol production, materials used as energy carriers, and utilisation of dimethyl ether (DME) as an automobile fuel. In the second fiscal year (FY 2016), the biomethanol production plants around the world were studied. In the third fiscal year (FY 2017), the merits of biomethanol utilisation were identified.

3. Results and Policy Recommendation

(1) Potential Study of Diversified Transportation Energy Mix

To study the potential of a diversified transportation energy mix and its effective use in the future (up to 2030), we simulated the energy consumption up to 2030 by using the Energy Mix Model based on vehicle registration data, fuel economy (actual consumption) data, and mileage travelled annually by vehicle/fuel type supplied by members from two countries (Malaysia and Viet Nam). Current and future energy issues of each country were analysed based on the simulation to propose possible measures for mitigating energy issues (gap between energy supply and demand) and achieving the policy target.

To achieve the oil reduction target, an integrated approach of oil reduction measures (infrastructure development, traffic flow management, etc.) is required in the five study countries. In 2030, the expected CO_2 reduction through implementation of policy to conserve energy (i.e. oil reduction and alternative energy introduction) in the transportation sector is estimated to be 37.1 kilotonnes of CO_2 per year (kt-CO_2/year) in Thailand, 93.8 kt-CO_2/year in Indonesia, 35.4 kt-CO_2/year in the Philippines, 39.9 kt-CO_2/year in Malaysia, and 21.7 kt-CO_2/year in Viet Nam. Because of the gap between the energy supply and demand, diesel fuel consumption should be reduced by discouraging the excessive use of pick-ups in Thailand. Gasoline consumption should be reduced by promoting the use of electric vehicles in Indonesia. A reduction of gasoline consumption will be required in Malaysia, with the introduction of ethanol for the gasoline blend playing an important role for that purpose. In Viet Nam, the use of domestic gas and biofuels (moderate blending ratio is acceptable) is recommended, but there are concerns about being able to secure feedstock, especially for biodiesel, within the country. A new funding system to enhance biofuel utilisation is required in every country.

Policy recommendations to achieve the national policies are as follows:

THAILAND

Alternative Energy Development Plan (AEDP): Excess introduction of ethanol deteriorates the gasoline/diesel ratio; much effort is required for biodiesel.

Energy Efficiency Plan (EEP): Efficiency improvement measures through traffic management are required to achieve the policy target.

INDONESIA

National Energy Policy (KEN)/General Planning for National Energy (RUEN): To realise the use of gas in the transportation sector, the key issue is the introduction of ethanol for the gasoline blend. Efficiency improvement measures through traffic management are required to achieve the policy target.

PHILIPPINES

Philippine Energy Plan (PEP): A mismatch exists in the low-carbon scenario projection of the transportation sector between the amount of energy to be reduced and to be achieved by the proposed measures; this needs to be reviewed.

MALAYSIA

Alternative fuels

- Consider ethanol (including cellulosic ethanol) besides biodiesel, and recommend hydrotreated vegetable oil beyond B10. Expand the use of domestic gas.

Energy conservation

- Promote energy-efficient vehicles by setting a clear oil reduction target; also, efficiency improvement measures through traffic management are required.

VIET NAM

Alternative fuels

- Fiscal support for biofuel utilisation (moderate blending ratio is acceptable) is required. Consider biofuel trading (import) as feedstock is lacking. Also, consider the effective use of gas for public transportation.

Energy conservation

- A clear oil reduction target and an incentive scheme along with energy efficiency labelling are needed.

(2) Research of Next-Generation Biofuels

With increased biofuel consumption, it will be necessary to use new resources. Currently, information is limited regarding non-edible feedstocks such as the availability and technical problems surrounding production and utilisation of biofuels.

To introduce first-generation biofuels from non-edible feedstock, important points to consider are as follows:

1) We should consider not only its fruit/seed yield and oil content, but also composition and physical properties in case of raw material selection.

2) A pretreatment process is sometimes needed to improve quality when low-grade feedstocks are used as raw materials.

3) Fuel properties can be improved by reforming and refining.

Hydrocarbon-type next-generation biofuels produced by refinery systems are welcomed by automobile manufacturers because of their qualities. The next-generation biofuels contribute to diversification of resources, such as the use of nonconventional solid resources and expensive waste materials. Using nonconventional resources may also contribute to improving sustainability as well as reducing GHG emissions.

The biomass potential in each country should be considered for production of next-generation biofuels based on not only amount but also availability (materials remaining for utilisation). A supply chain of the nonconventional raw materials should be established.

On the other hand, the cost performance of the next-generation biofuels is ambiguous because fuel manufacturing processes have not yet been established. At present, some commercial plants are operational. However, the price of supplied next-generation biofuel is relatively high. Therefore, cost reduction is very important for accelerating the introduction of next-generation biofuels. Based on investigation of articles, the following factors are important to improve the cost performance of next-generation biofuels:

1) Securing cheap resources

2) Improving raw material productivity

3) Reducing transportation

4) Locating the manufacturing plant

5) Selecting the fuel manufacturing process and its scale

6) Applying measures of energy supply

In the future, it will be possible to supply the next-generation biofuel more economically by optimising the combination of such factors as well as developing higher-performance manufacturing technology.

The demand for aviation fuel will increase in developing countries, including in ASEAN. The introduction of biofuel is effective for reducing GHGs. ASEAN Member States should consider introducing alternative aviation fuels produced from their own resources. To promote the introduction of alternative aviation fuels, a national policy decision is required. Fischer–Trøpsch synthetic paraffinic kerosene (FT-SPK) and hydroprocessed esters and fatty acids (HEFA-SPK) are main alternative aviation fuels. Catalyst technology makes it possible to produce both alternative aviation fuel and alternative diesel fuel for automobiles, selectively. The quality of petroleum-alternative mixed jet fuel and each blendstock should be controlled by standards specification.

(3) Biomethanol as an Energy Carrier

Methanol is currently mainly produced from fossil resources. If methanol can be produced from biomass (biomethanol), it would become a bio-based renewable intermediate for producing transportation fuel. Methanol is a key compound in producing not only fuel, but also new energy carriers such as hydrogen and DME. To promote the conversion of resources from fossil resources into biomass, data are needed regarding the availability of biomass resources. These data are also required to produce next-generation biofuels. In addition, there should be discussion about the optimal manufacturing process and factory located in the ASEAN region based on resource availability. From the viewpoint of energy carriers, methanol has some advantages (liquid fuel, ease of storage and transportation). One of the applications of methanol is DME production. DME can be used as an alternative diesel fuel and fuel for households. The use of DME for vehicles has already been demonstrated.

This report investigates the biomethanol production plants around the world and conducts a cost estimation. From the viewpoint of CO_2 reduction, many countries focus on methanol as the energy carrier to store energy.

Biomass can be easily converted into methanol through synthetic gas by gasification. The technologies used in the production of methanol from biomass are relatively well-known, since they are similar to coal gasification technology, which has been applied for a long time. However, the scale of current production plants is relatively small and production costs are high because it is difficult to collect large amounts of biomass resources. To solve these problems, a methanol manufacturing factory (gasification and methanol synthesis) should be constructed in the vicinity of biomass districts. If a biodiesel manufacturing factory is built attached to a methanol plant, the transportation cost of methanol to the biodiesel fuel factory can be reduced.

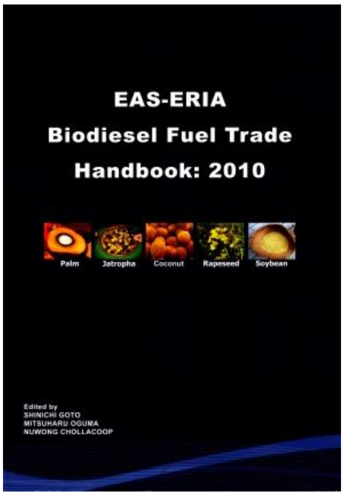
We hope the outcome of our studies will contribute to the key energy strategies indicated in the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025 and the ASEAN Economic Community (AEC) Blueprint 2025. In particular, the "Potential study of diversified transportation energy mix" will provide useful information from the simulation of energy consumption based on vehicle registration for developing and adapting the ASEAN renewable energy roadmap (APAEC 3.5 Programme Area No.5: Renewable Energy, AEC II. C.4. Energy v), predicting the regional energy outlook in the transportation sector, and raising the level of data and analysis on ASEAN's energy policy and planning (3.6 Programme Area No. 6: Regional Energy Policy and Planning, AEC II. C.4. Energy vi). "Research of next generation bio-fuels" and "Bio-methanol as an energy carrier" will contribute to enhancing the R&D network on renewable energy technology development and utilisation (APAEC 3.5 Programme Area No. 5: Renewable Energy, AEC II. C.4. Energy v) and developing a nodal network with automotive and related industries on technological know-how and R&D activities for biofuel (3.6 Programme Area No. 6: Regional Energy Policy and Planning, AEC II. C.4. Energy vi).

Chapter 1

Introduction

Energy consumption in the transportation sector in East Asia Summit (EAS) countries is expanding. To reduce the amount of imported crude oil, each country has established a target for reducing energy consumption. To achieve this target, biomass is being used from the viewpoint of introducing renewable energy and using domestic resources in various countries in the Association of Southeast Asian Nations (ASEAN). In particular, the introduction of first-generation biofuels such as bioethanol and biodiesel has been promoted in the transportation sector. Biofuel is often produced using a domestic resource at a relatively small-scale factory. Therefore, the fuel quality is not uniform and the low-grade fuel often causes engine trouble. To respond to this situation, our working group discussed between 2007 and 2012 creating a benchmark fuel standard to maintain the quality of biodiesel in the EAS region. We proposed the EAS–ERIA biodiesel fuel standard (EEBS2008) and published the EAS–ERIA Biodiesel Fuel Trade Handbook 2010 (Figure 1-1). It describes the importance of fuel quality assurance, the current status of the fuel specification of each country, and upgrading the technology of the first-generation biofuels. From 2013 to 2014, we revised the EAS–ERIA biodiesel fuel standard (EEBS2013) based on the revised European standard. This standard was introduced to the national standard in some ASEAN countries.

Figure 1-1. EAS–ERIA Biodiesel Fuel Trade Handbook: 2010



EAS-ERIA
Biodiesel Fuel Trade
Handbook: 2010

Edited by
SHINICHI GOTO
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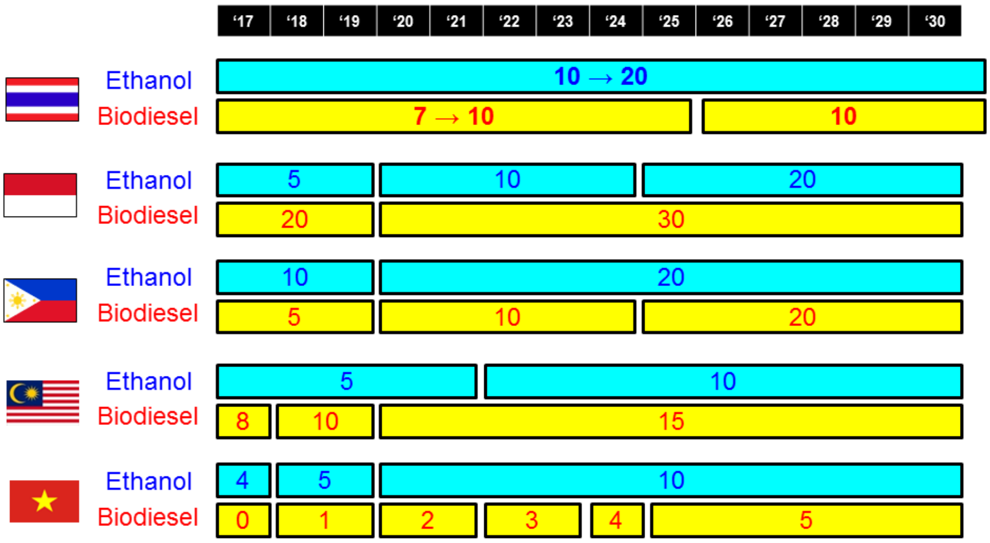
NUWONG CHOLLACOOP

Source: ERIA, 2010, available at:
http://www.eria.org/EASERIA_Biodiesel%20Fuel%20Trade_Handbook_2010.pdf

Following this, energy-related ministries established medium- and long-term plans to promote the further introduction of biofuel in each ASEAN country (Figure 1-2). An ambitious target is set up as a biofuel introduction in the new plan.

To achieve the target, it is necessary to conquer various problems such as supply of raw materials, expansion of fuel production facilities, and quality assurance for high-concentration biofuel use. However, no optimum way has been identified yet.

Figure 1-2 Biofuel Road Map in Five ASEAN Countries



ASEAN = Association of Southeast Asian Nations.
Source: ASEAN.

However, when we look closely at the relationship between car registration numbers classified by the kind of fuel used and the biofuel introduction policy in various ASEAN countries, we recognise that there are discrepancies. That is, there is a gap between the current situation in the transportation sector and the fuel policy. It is important to establish a biofuel introduction policy that corresponds to the demand in the market to supply the necessary fuel. To achieve the reduction target for petroleum consumption, the transportation sector needs to consider using various resources, improving fuel efficiency of vehicles and road infrastructure, as well as promoting biofuel.

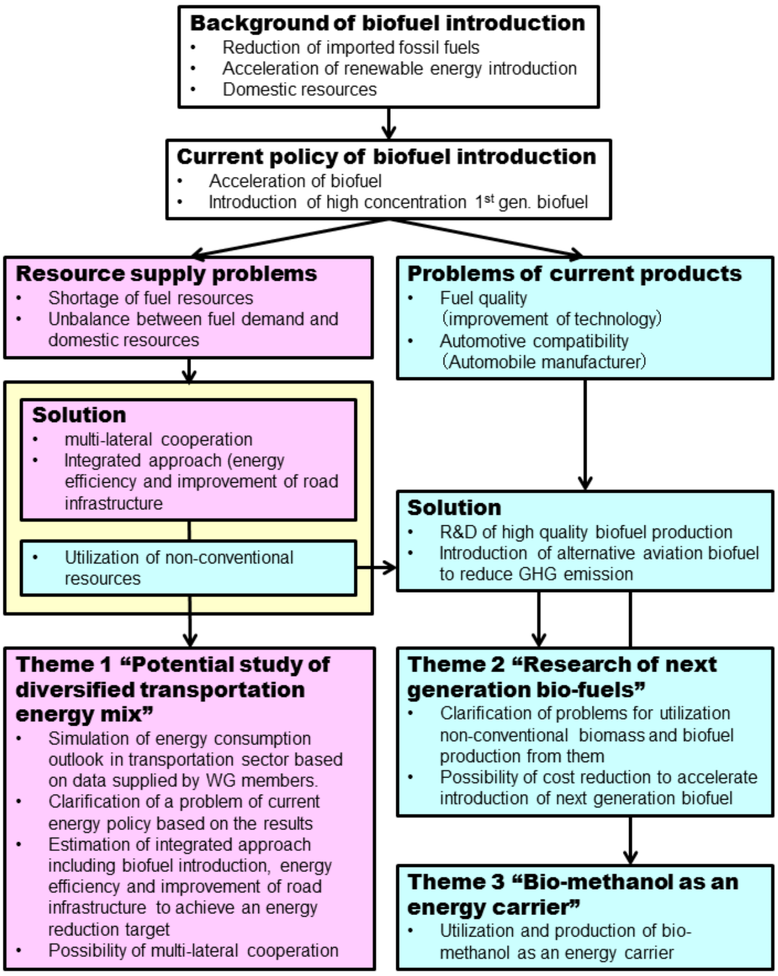
To find solutions to the problems mentioned above, the working group set three themes from the viewpoints of raw material supply and fuel quality (Figure 1-3).

For a solution based on raw material supply, the fuel supply and demand outlook in the transportation sector has been simulated up to 2030 based on the present policy and biofuel supply in theme 1 'Potential study of diversified transportation energy mix'. We chose five major ASEAN countries (Thailand, Indonesia, the Philippines, Malaysia, and Viet Nam), according to the number of cars registered in the country. The purpose of this theme is to propose measures for mitigating energy issues in the transportation sector (Chapter 2).

Theme 2 ‘Research of next-generation biofuels’ mainly deals with the next-generation biofuels that are more compatible with cars even with high concentrations of biofuel in the mix., We look at the current status from the aspect of biofuel technology. For future introduction, we clarify the factors related to technical development in production and cost reduction. The last aim is to find economical means to contribute to a high-quality fuel supply (Chapter 3).

Theme 3 ‘Biomethanol as an energy carrier’ deals with methanol produced from biomass. Currently, methanol is mainly produced from fossil resources. To promote methanol production from biomass resources, we investigate the current status of the manufacturing plants and consider the availability of methanol as a biofuel intermediate (Chapter 4).

Figure 1-3. Composition of Each Research Theme



Source: Authors.

Finally, we integrate these results and indicate measures for the reduction of energy consumption in the transportation sector as well as the promotion of next-generation biofuel introduction.

Chapter 2

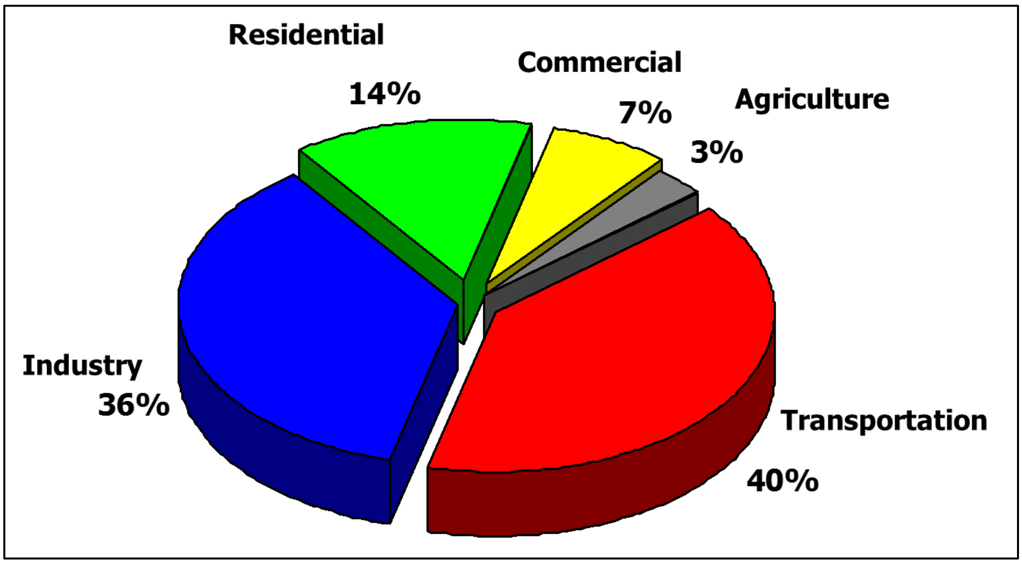
Potential Study of Diversified Transportation Energy Mix

1. Current Status of Transportation Energy Supply Demand and National Policy in ASEAN Member States

1.1. Thailand

In 2017, Thailand's gross domestic product (GDP) grew approximately 3.9% from investment and export to a recovering world economy. Total primary energy consumption in 2017 was 2.754 million barrels of oil equivalent per day (BOE/day), an increase of 2.4% from the previous year. A detailed look reveals that gasoline, diesel, and jet fuel increased by 3.8%, 2.6%, and 4.4%, respectively, whereas fuel oil, liquefied petroleum gas (LPG), and compressed natural gas (CNG) decreased by 7.2%, 1.8%, and 0.1%, respectively. Electricity consumption increased by 1.4% (EPPO, 2017a). This final energy consumption is mainly for transportation (40%) and industry (36%), as shown in Figure 2.1.1-1 (EPPO, 2017b).

Figure 2.1.1-1 Share of Final Energy Consumption in Thailand by Sector, 2017



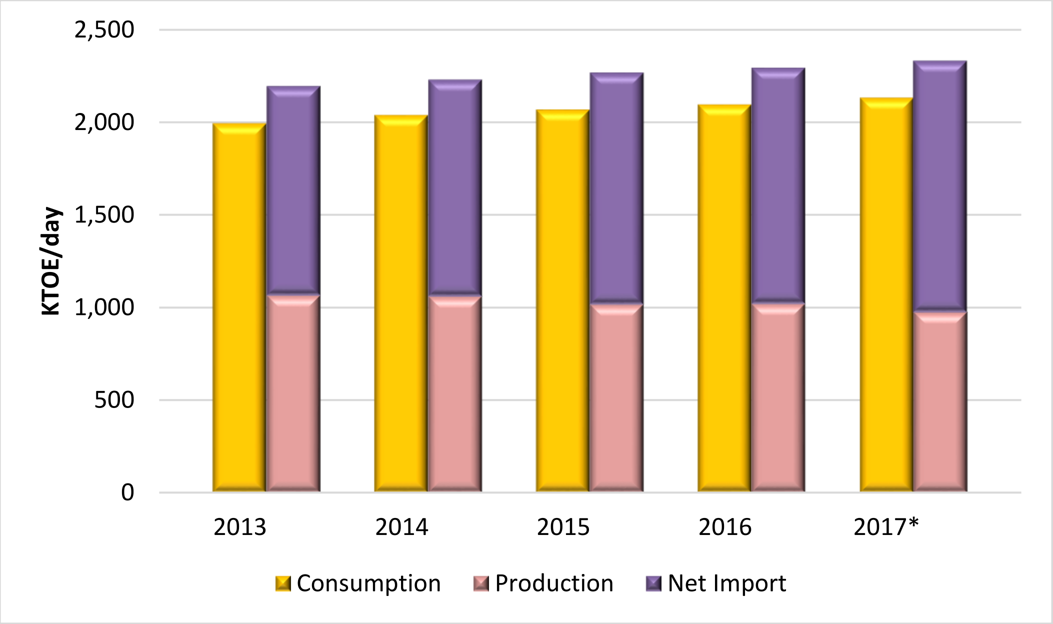
Source: EPPO (2017b).

1.1.1. Current Status of Energy Supply

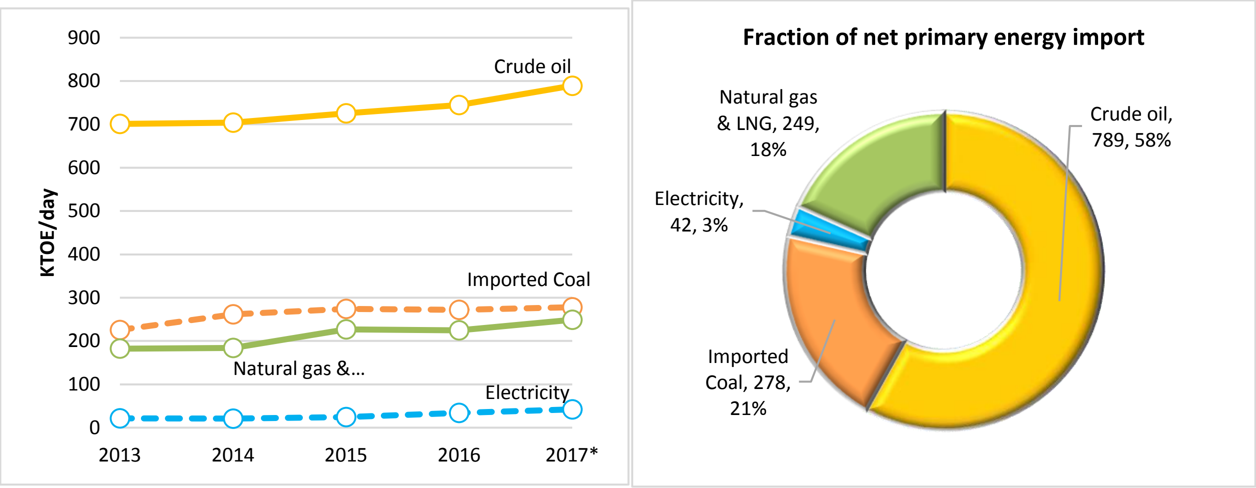
Thailand's energy supply has relied on energy import more than domestic production (Figure 2.1.1-2(a)), to cover energy demand by approximately 110% (EPPO, 2017b). The share of energy import in energy consumption steadily increased from 57% in 2013 to 64% in 2017, implying that Thailand has becoming more dependent on energy import. As shown in Fig. 2.1.1-2(b), Thailand's greatest energy import (over 50%) is crude oil for the transportation and industry sectors, followed by coal, natural gas and/or LNG, and some electricity with an increasing trend over the past 5 years. On the other hand, Thailand's domestic energy production (Fig. 2.1.1-2(c)) has been mainly based on natural gas (over 60% of total primary energy production), but this has recently started to decline due to depleting natural gas wells, leading to import of LNG.

Figure 2.1.1-2 Energy Balance of Thailand, 2013–2017

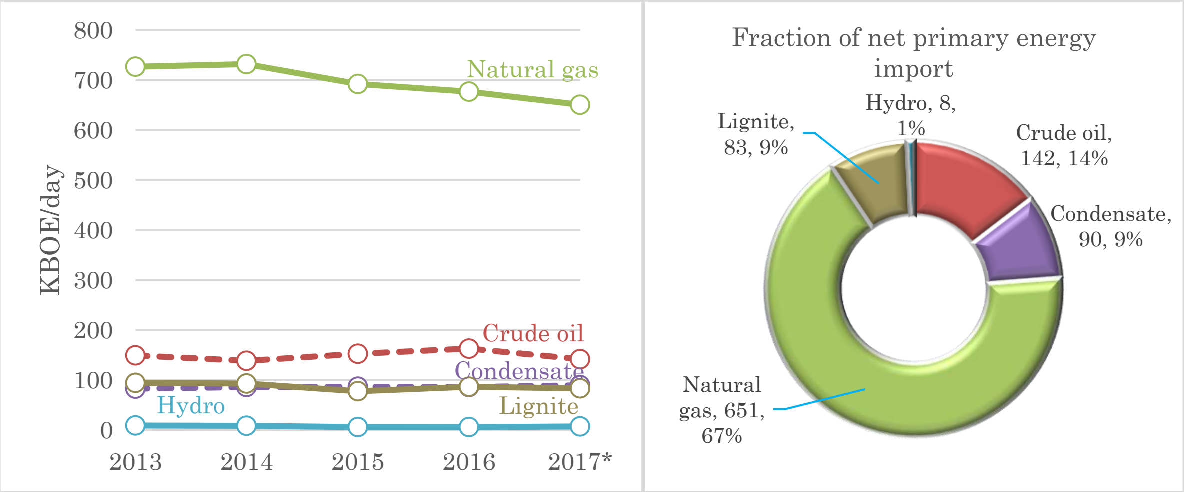
(a) Consumption, Production, and Import



(b) Energy Import



(c) Energy Production

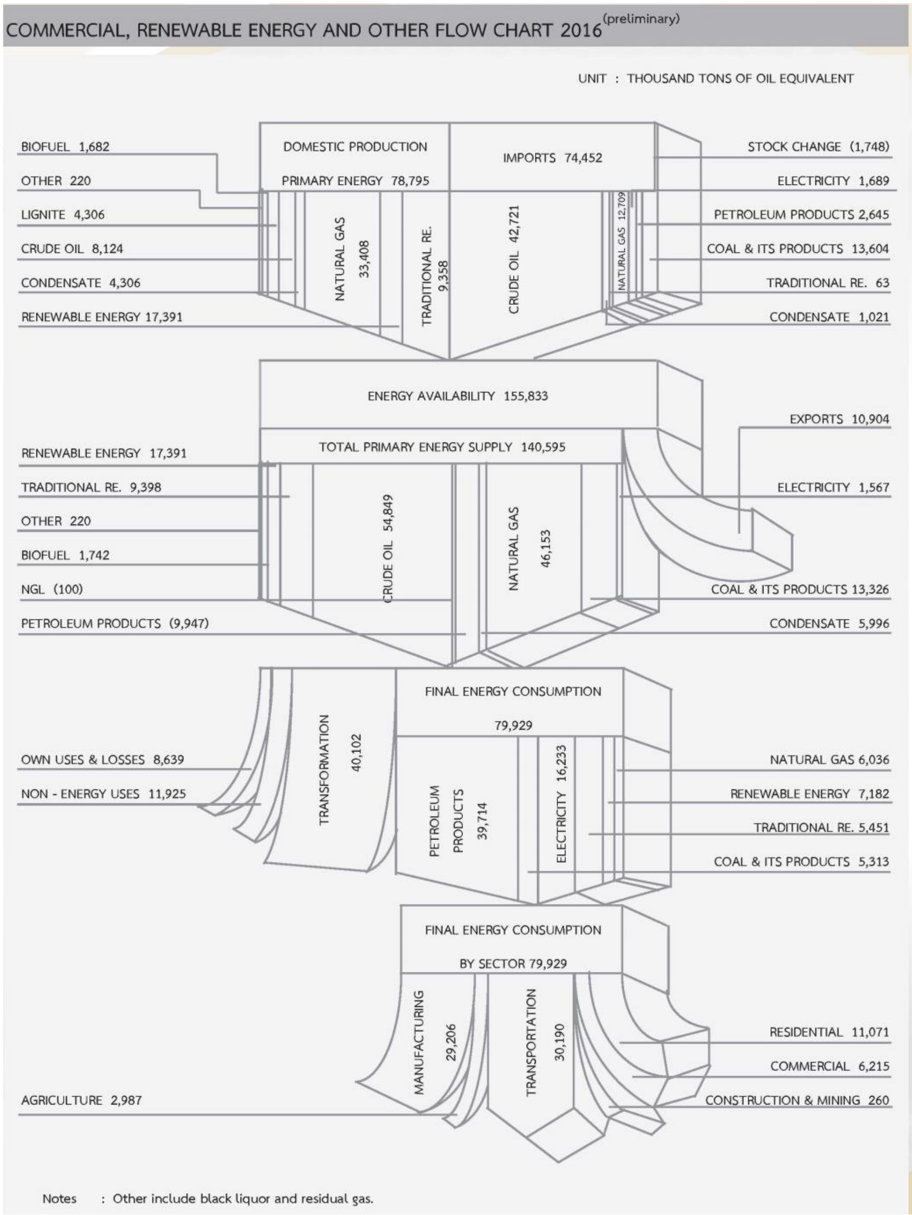


KBOE = thousand barrels of oil equivalent, LNG = liquefied natural gas.
Source: EPPO (2017b).

As the final details of Thailand's energy balance have not yet been released, a summary of the energy balance for 2016 is shown in Fig. 2.1.1.-3, where domestic production of energy is slightly higher than energy import due to inclusion of renewable energy, unlike in Figure 2.1.1-2(a). As in Figures 2.1.1-2(b) and (c), energy import is dominated by crude oil, whereas energy domestic production is mainly natural gas.

In terms of energy availability, crude oil and natural gas accounted for 65%. However, most natural gas has undergone transformation as electricity, leaving petroleum products accounting for 50% of final energy consumption, which is used mainly in transportation (about 38%) and manufacturing and/or industry (about 37%).

Figure 2.1.1-3 Energy Balance of Thailand, 2016



Notes : Other include black liquor and residual gas.

Source: DEDE (2016).

1.1.2. Current Status of Transportation Fuel Supply

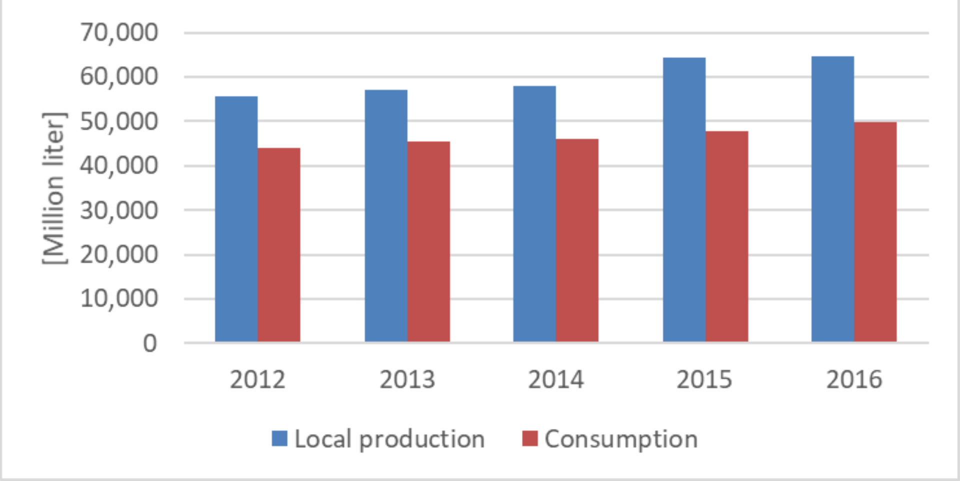
As shown in Table 2.1.1-1 and Figure 2.1.1-4, Thailand has six large refineries with a capacity of over 100,000 barrels/day for a total production capacity in 2016 of approximately 1.2 million barrels per day (BBL/day), where about 75% of the production amount is consumed.

Table 2.1.1-1 Official Refinery Capacity in Thailand with Actual Production and Consumption

Refinery plant (BBL/day)	2012	2013	2014	2015	2016
PTTGC	280,000	280,000	280,000	280,000	280,000
Thai oil	275,000	275,000	275,000	275,000	275,000
IRPC	215,000	215,000	215,000	215,000	215,000
Esso	170,000	177,000	177,000	177,000	177,000
Star Petroleum	150,000	150,000	165,000	165,000	165,000
Bangchak	120,000	120,000	120,000	120,000	120,000
Fang	2,500	2,500	2,500	2,500	2,500
RPCG	17,000	17,000	17,000	0	0
Total	**1,229,500**	**1,236,500**	**1,251,500**	**1,234,500**	**1,234,500**

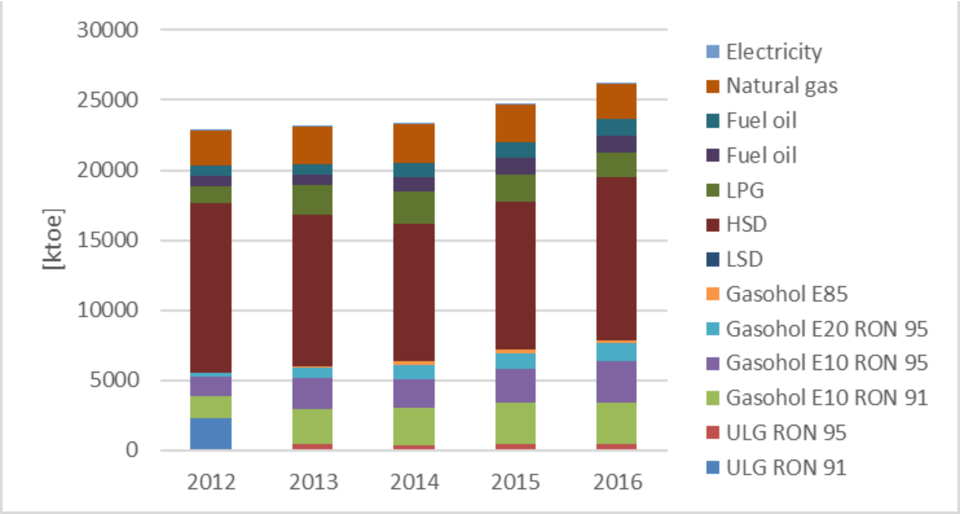
BBL = barrel, PTTGC = PTT Global Chemical Public Company Limited.
Source: DEDE (2016).

Figure 2.1.1-4 Comparison of Yearly Local Production and Consumption of Petroleum Products in Thailand, 2012–2016



Source: DEDE (2016).

Figure 2.1.1-5 Energy Consumption of Various Fuels in the Transportation Sector in Thailand, 2012–2016



HSD = high speed diesel, ktoe = kilotonne of oil equivalent, LPG = liquefied petroleum gas, LSD = low sulphur diesel, ULG = unleaded gasoline.
Source: DEDE (2016).

Amongst the transportation fuel types in Thailand, diesel fuel has accounted for approximately 42%, more than double the amount of gasoline, as shown in Fig. 2.1.1.-5. Consistent with government policy, biofuel has been commercially used in transportation fuel. Bioethanol has been blended with gasoline at 10%, 20%, and 85%, known as gasohol E10, gasohol E20, and gasohol E85, respectively. On the other hand, biodiesel has been mandated to be blended up to 7% in all diesel.

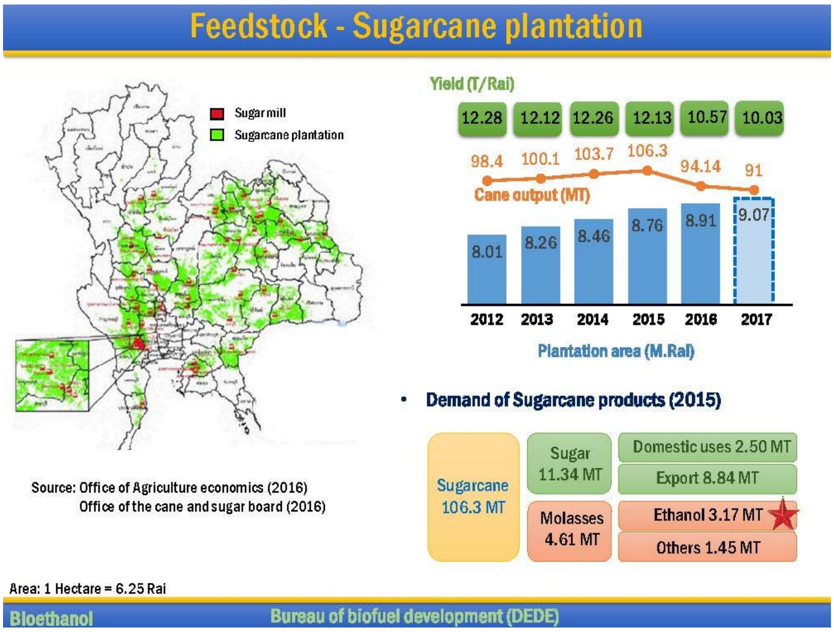
1.1.3. Current Status of Biofuel Supply in the Transportation Sector

Focusing on the biofuel supply in the transportation sector, bioethanol (blended in gasoline) is made from molasses, by-products of sugar, and cassava, whereas biodiesel is made from palm oil. Thailand's policy on feedstock clearly states that its use is always as food first, before the surplus is used for biofuel. As shown in Figure 2.1.1-6(a), sugarcane plantations are mostly located in the central and north-eastern parts of Thailand with bioethanol production from molasses and sugarcane by-product. On the other hand, Figure 2.1.1-6(b) shows a larger area for cassava plantations, where cassava product is mainly for export (Thammanomai, 2017). As ethanol demand increases from bioethanol blending in gasoline, those cassava exports can be used domestically to produce ethanol since sugarcane plantation is more limited.

As a result of the Thailand gasohol programme, ethanol production has been increasing over time (twofold from 2011 to 2014), as shown in Fig. 2.1.1-7(a). Even though molasses still dominate bioethanol feedstock, the share of cassava has increased with newer ethanol production plants using cassava as feedstock. It is worth noting that the large increase of ethanol demand from 2012 (656 megalitres, or ML) to 2013 (1,014 ML) was due to the ban of ULG91 (unleaded gasoline with octane 91 without ethanol blending), but continued use of ULG95 with an added high tax for luxury cars, as shown in Fig. 2.1.1-7(b). Since 2013, the fraction of gasohol E10 (octane 91 and 95) has dominated the market share, with increased sale of E20.

Figure 2.1.1-6 Bioethanol Feedstock in Thailand

(a) From Molasses



Feedstock - Sugarcane plantation

Source: Office of Agriculture economics (2016)
Office of the cane and sugar board (2016)

- Demand of Sugarcane products (2015)

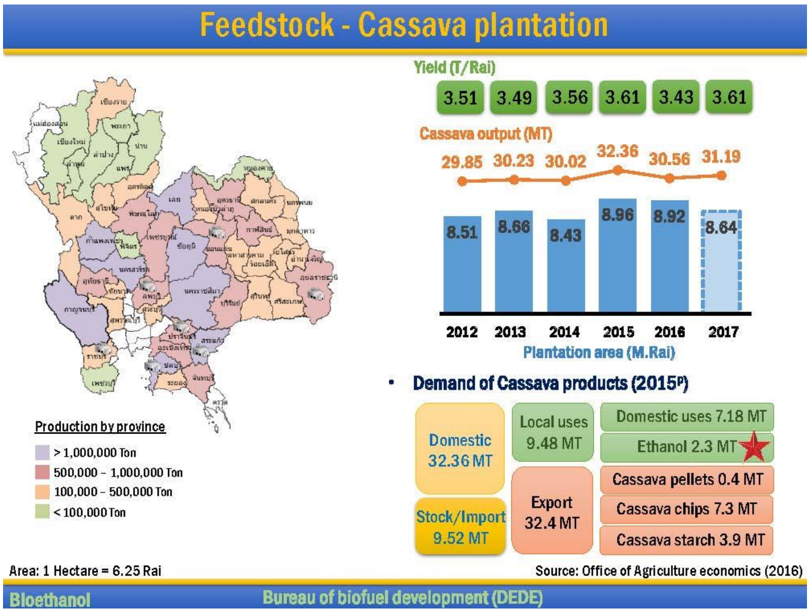
Sugarcane 106.3 MT
Sugar 11.34 MT
Domestic uses 2.50 MT
Export 8.84 MT
Molasses 4.61 MT
Ethanol 3.17 MT
Others 1.45 MT

Area: 1 Hectare = 6.25 Rai

Bioethanol

Bureau of biofuel development (DEDE)

(b) From Cassava



Feedstock - Cassava plantation

Production by province
> 1,000,000 Ton
500,000 – 1,000,000 Ton
100,000 – 500,000 Ton
< 100,000 Ton

- Demand of Cassava products (2015^{P})

Domestic 32.36 MT
Stock/Import 9.52 MT
Local uses 9.48 MT
Domestic uses 7.18 MT
Ethanol 2.3 MT
Export 32.4 MT
Cassava pellets 0.4 MT
Cassava chips 7.3 MT
Cassava starch 3.9 MT

Area: 1 Hectare = 6.25 Rai

Source: Office of Agriculture economics (2016)

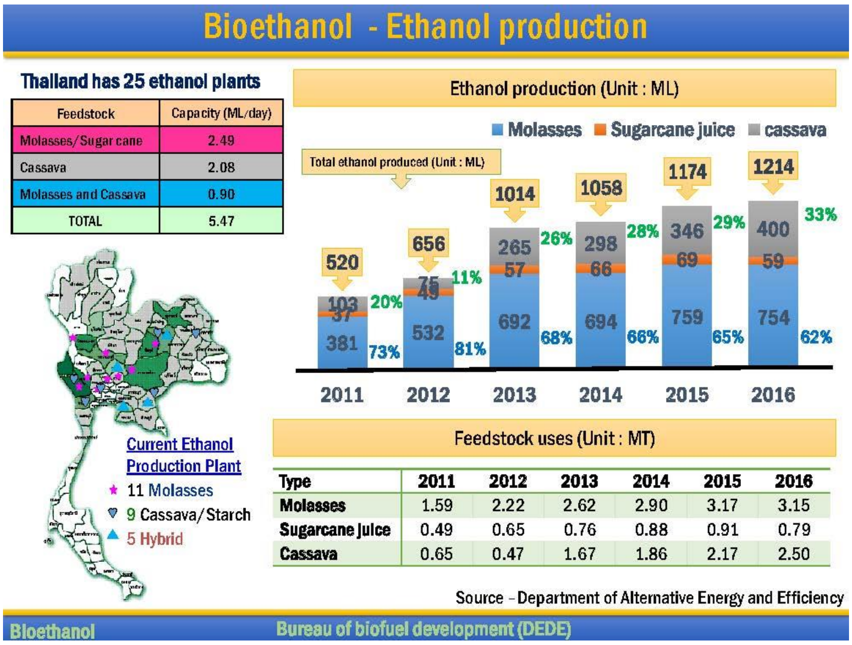
Bioethanol

Bureau of biofuel development (DEDE)

Source: Thammanomai (2017).

Figure 2.1.1-7 Bioethanol Production with Blending in Thailand

(a) Bioethanol Production



Bioethanol - Ethanol production

Thailand has 25 ethanol plants

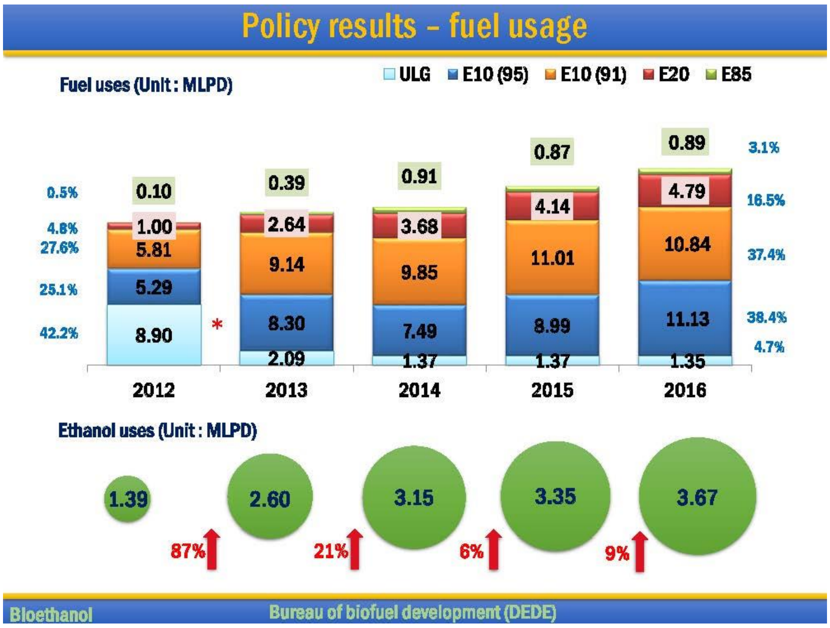
Feedstock	Capacity (ML/day)
Molasses/Sugar cane	2.49
Cassava	2.08
Molasses and Cassava	0.90
TOTAL	5.47

Feedstock uses (Unit : MT)

Type	2011	2012	2013	2014	2015	2016
Molasses	1.59	2.22	2.62	2.90	3.17	3.15
Sugarcane juice	0.49	0.65	0.76	0.88	0.91	0.79
Cassava	0.65	0.47	1.67	1.86	2.17	2.50

Source – Department of Alternative Energy and Efficiency

(b) Blending in Gasoline at Various Fraction



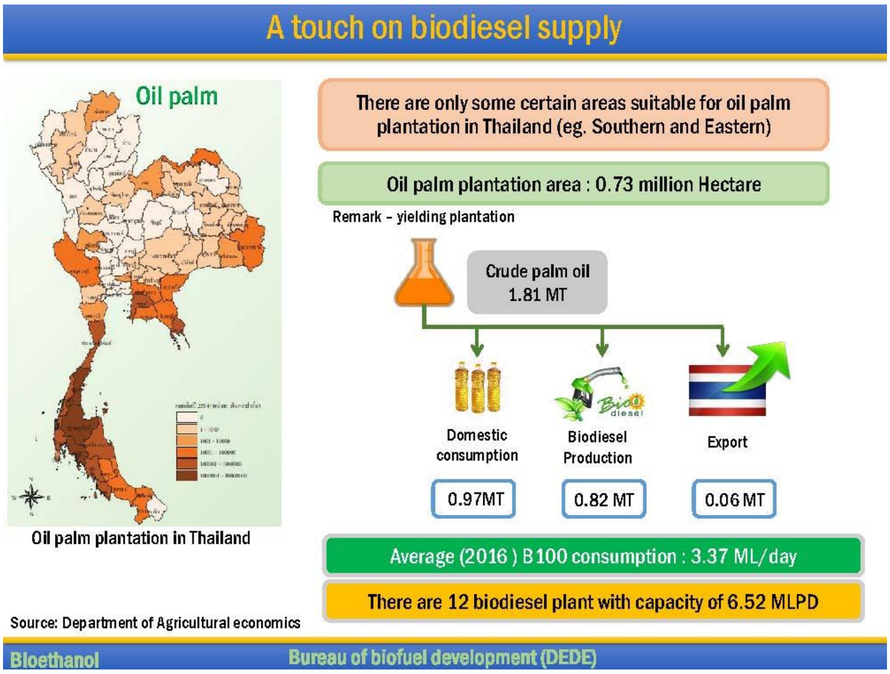
Source: Thammanomai (2017).

As for diesel, only palm oil is commercially used as feedstock for biodiesel with plantations mostly in the southern part of Thailand, as shown in Figure 2.1.1-8(a). Again, Thailand’s policy on biodiesel is to use surplus palm oil from edible cooking oil. In fact, the country’s biodiesel programme has been a tool to absorb surplus palm oil in the market, as clearly shown in Figure

2.1.1-8(b), where the share of biodiesel greatly increased from 17% in 2008 to 40% in 2015. It is worth noting that the big increase of biodiesel demand from 2011 (1.71 ML/day) to 2012 (2.42 ML/day) was due to the mandate to blend 5% biodiesel in diesel, or B5. From 2013 to 2014, biodiesel demand should have gone up again due to a mandate of B7, but a palm oil shortage made it difficult to blend economically so the percentage blend of biodiesel was adjusted with consideration of the palm oil price.

Figure 2.1.1-8 Biodiesel Feedstock in Thailand

(a) A touch on Biodiesel Supply



A touch on biodiesel supply

Oil palm

Oil palm plantation in Thailand

Source: Department of Agricultural economics

There are only some certain areas suitable for oil palm plantation in Thailand (eg. Southern and Eastern)

Oil palm plantation area : 0.73 million Hectare

Remark – yielding plantation

Crude palm oil
1.81 MT

Domestic consumption	Biodiesel Production	Export
0.97MT	0.82 MT	0.06 MT

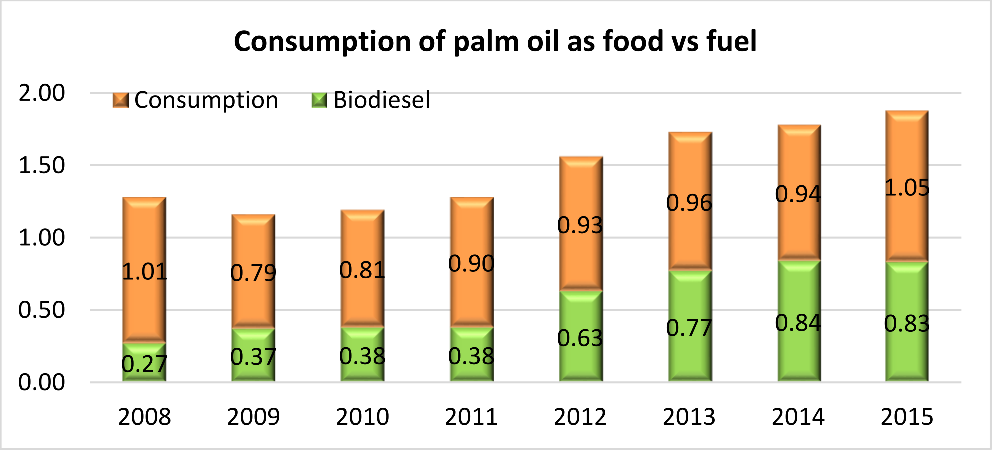
Average (2016) B100 consumption : 3.37 ML/day

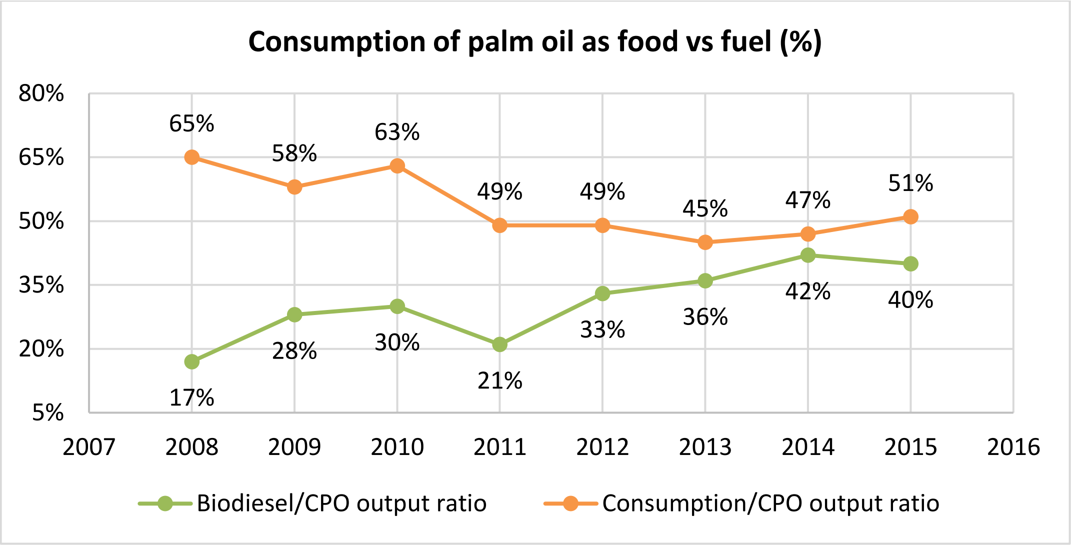
There are 12 biodiesel plant with capacity of 6.52 MLPD

Bioethanol

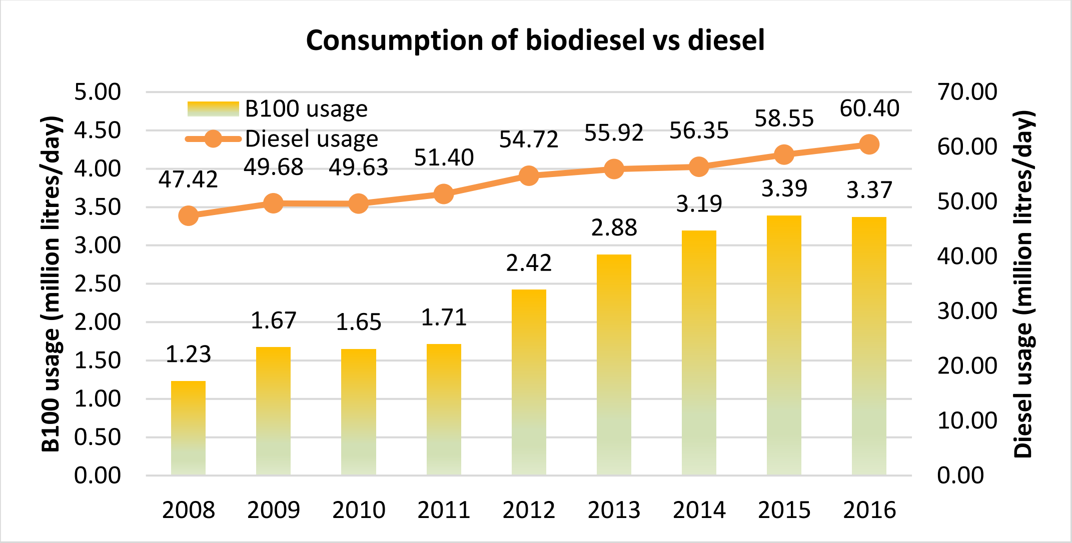
Bureau of biofuel development (DEDE)

(b) As a Tool to Manage Palm Surplus





(c) With Increasing Use of Biodiesel Blended in Diesel

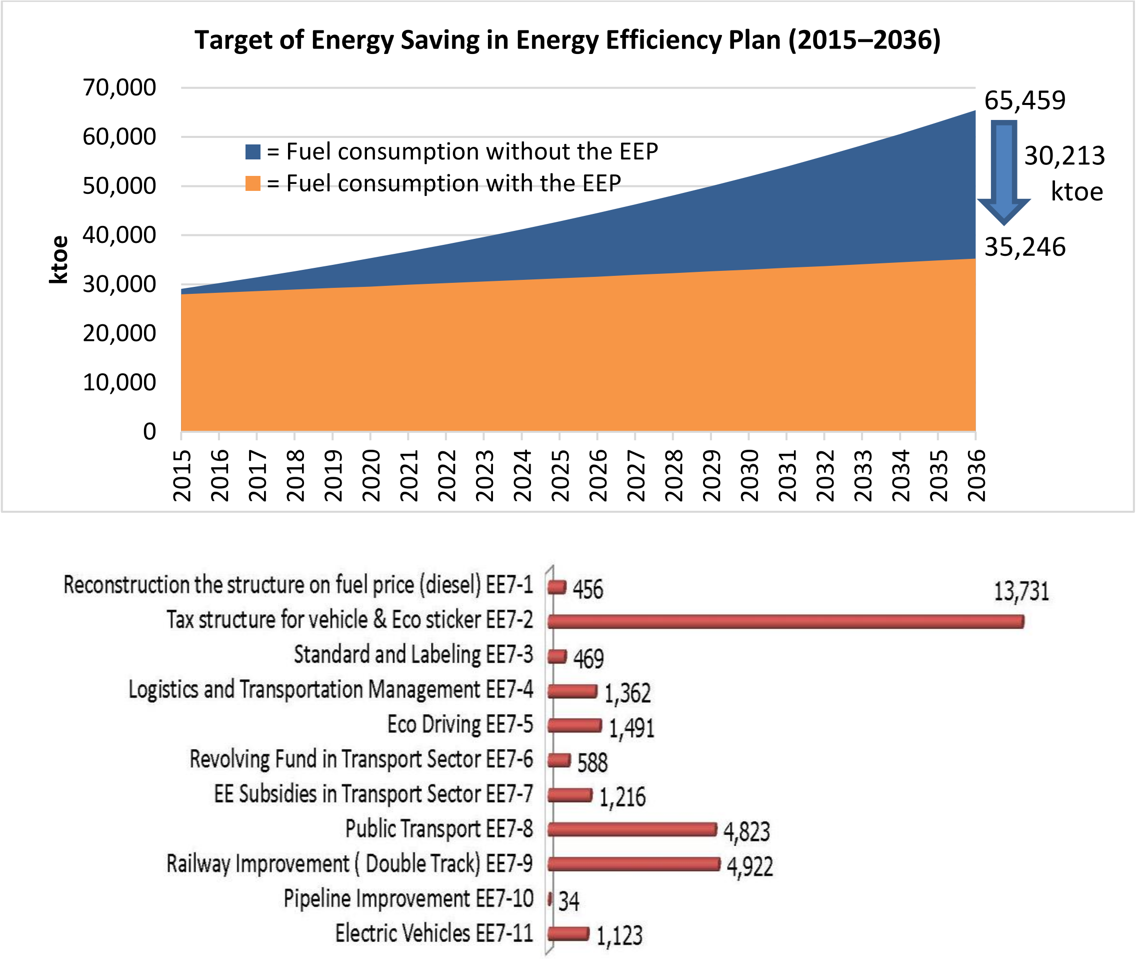


CPO = crude palm oil, MLPD = million litres per day.
Source: Thammanomai (2017).

1.1.4. Fuel Demand and Biofuel Supply Outlook Based on the National Plan

With Thailand's Integrated Energy Blueprint (2015–2036) being launched in 2015 (EPPO, 2016), fuel demand has been forecasted under the Energy Efficiency Plan 2015–2036 (EEP), with a targeted reduction of 30,213 kilotonnes of oil equivalent (ktoe) by 2036 through 11 initiatives, as shown in Figure 2.1.1-9 (Sunipasa, 2017). On the other hand, the biofuel outlook is forecasted under the Alternative Energy Development Plan 2015–2036 (AEDP) with a 2036 target of 11.30 ML/day of bioethanol consumption and 14 ML/day of biodiesel. However, there is no official biofuel supply outlook or target from now until 2036. Hence, bioethanol and biodiesel supplies have to be estimated for section 2.3.3.

Figure 2.1.1-9 Forecast of Transportation Fuel Demand in Energy Efficiency Plan (2015–2036)



EEP = Energy Efficiency Plan, ktoe = kilotonne of oil equivalent.
Source: Sunipasa (2018).

1.1.5. Current National Plans for Energy Consumption Reduction

As previously discussed, the relevant national plan to reduce energy consumption is the EEP with a target to reduce energy intensity by 30%. With a focus on transportation, the 11 initiatives shown in Fig. 2.1.1-9 and Table 2.1.1-2 are elaborated as follows.

1. The fuel price structure should be adjusted to reflect the true costs of fuel production, since the price of diesel fuel, which is deemed a key transportation fuel, has been closely monitored and often subsidised in order to keep it at an affordable level. This price manipulation has led to an imbalance of diesel fuel usage – which nowadays is also reflected in the high share of diesel-fuelled pickup trucks.
2. The vehicle excise tax structure has been changed from a system based on engine size to one based on CO_2 tailpipe emissions, which directly correlate with vehicle fuel economy (ICCT, 2016), from 2016 onwards.

3. The vehicle tyre labelling scheme shall be introduced to help customers choose suitable tyres for energy-saving purposes.
4. The logistic and transportation management personnel shall be systematically guided and trained by experts in order to help energy saving.
5. An eco-driving programme shall be introduced to help change driver behaviour and to raise awareness for the issue of energy saving.
6. A revolving fund shall be provided to support energy efficiency technology and activities in the transportation sector.
7. Financial mechanisms shall be introduced to spur investment in technology to improve energy efficiency, such as a standard offer programme (SOP) or demand side management (DSM).
8. The transportation infrastructure for both passengers (rail expansion, as well as non-motorised mode) and fuels (pipeline) shall be expanded in order to improve energy efficiency.
9. A double-track train network shall be introduced nationwide to help reduce energy inefficiency from passing trains waiting for clearance.
10. An electric vehicle infrastructure programme shall be prepared for introduction in Thailand, with a target of bringing 1.2 million electric vehicles to the road by 2036.

Table 2.1.1-2. 11 Measures for Energy Efficiency Planning in the Transportation Sector in Thailand

No.	Measure with energy saving target (ktoe)	2015	2021	2036	% share
1	Adjust fuel price structure		67	456	2
2	Adjust vehicle excise tax structure	813	4,242	13,731	45
3	Introduce vehicle tyre labelling		83	469	2
4	Implement logistics and transportation management	9	160	1,360	5
5	Expand ECO driving sill		22	1,491	5
6	Provide revolving fund for transportation sector		104	588	2
7	Provide financial mechanism (transport) SOP+DSM		394	1,216	4
8	Expand transportation infrastructure (passenger, fuel)	894	1,151	4,857	16
9	Introduce double-track train infrastructure		2,040	4,922	16
10	Introduce electric vehicles		75	1,123	4
	Total	1,716	8,338	30,213	100

DSM = demand side management, ktoe = kilotonne of oil equivalent, SOP = standard offer programme.
Source: Sunipasa (2017).

1.1.6. Current National Plans for Alternative Fuel Introduction

As previously discussed, the relevant national plan to introduce alternative fuel is the Alternative Energy Development Plan, with a target of 30% renewable energy by 2036. With a focus on transportation, a target of 8,712 ktoe from biofuel usage in transportation would come from 11.3 ML/day bioethanol, 14 ML/day biodiesel, 0.53 ML/day pyrolysis, and 4,800 tonnes per day of compressed biogas.

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1.2. Indonesia

Comprised of 17,508 islands that stretch over 5,000 kilometres, Indonesia's large and diverse population was 258 million in 2016 (BPS, 2017). Population growth in 2014 was 1.35%, but it is expected to slow in the future as the Government of Indonesia resumes its national family planning programme. The gross domestic product (GDP) is estimated at US$878.3 billion in 2014 (BPS, 2017), with the economic activity tending to focus in the Java–Bali region where the majority of the population live. The size of its economy is currently the largest in Southeast Asia with a steady annual growth rate of 4%–6% in the past decade (BPS, 2017).

The country is transitioning from a commodities export economy (majority oil and gas based) into one supported by domestic manufacturing and investment, particularly after becoming a net oil importer in 2004. With a steadily growing economy, it is important for Indonesia to harness and manage sustainable sources of energy. The Ministry of Energy and Mineral Resources (MEMR) therefore forecasts that energy demand will grow by around 7% per year, with electricity demand alone projected to nearly triple between 2010 and 2030 (Center for Data and Information Technology MEMR, 2015).

1.2.1. Current Energy Policy

Indonesia's National Action Plan (RAN-GRK), as stipulated in Presidential Regulation No. 61/2011, is based on the National Long-Term Development Plan (RPJMN) from 2010, long before the 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) in Paris in 2015. Therefore, the Government of Indonesia (2017) issued Presidential Regulation No. 22/2017 – or the so-called RUEN (General Planning for National Energy) – which not only focuses on emissions reductions but also comprehensively deals with infrastructure development in line with the dynamics of world climate change policy up to the years 2025 and 2050.

The recent RUEN regulation refers to the National Energy Policy (Kebijakan Energi Nasional, or KEN) in Government Regulation No. 79/2014. Within the KEN, the optimum target of new and renewable energy is set at 23% in 2025 and 31% in 2050. The new RUEN also aims to reduce the dependency on oil in the transportation sector to 83.5% in 2025 and 72.9% in 2015. This would be achieved by utilising more biofuel and natural gas and by encouraging the use of hybrid and electric vehicles through removal of the import duty on such vehicles. In addition to diversification of transport fuel, the RUEN also suggests various measures to build more public transport infrastructure such as high-speed railways and to develop a fuel economy standard for private vehicles before 2020.

To boost new and renewable energy penetration in the electricity sector, the MEMR issued Regulation No. 12/2017 on the Utilization of Renewable Energy Resources for Electricity Supply, which was further amended in MEMR Regulation No. 50/2017. The new regulations prescribe power purchase prices for all existing renewable energy (RE) types such as solar photovoltaic (PV), wind, hydropower, biomass, biogas, municipal waste, and geothermal. It uses the basic cost of electricity supply (CES) from the regional PLN (State Electricity Corporation) as its new reference price. These regulations obligate PLN to purchase power from RE plants at a maximum value of 85% of the regional CES and business-to-business agreements in areas where the regional CES is lower than the national CES (see Table 2.1.2-1).

Table 2.1.2-1 Electricity Purchase Tariff from Renewable Energy Plants (Government of Indonesia, 2017)

RE Type	Purchasing Method	Tariff	
		Regional CES > National CES	Regional CES ≤ National CES
Biogas	Reference price (for ≤ 10 MW)	Maximum 85% x regional CES	100% x regional CES
	Direct selection (for > 10 MW)	Price determined by direct selection process	
MSW	Reference price	Maximum 100% x regional CES	Mutual agreement
Geothermal	Reference price	Maximum 100% x regional CES	Mutual agreement
Solar PV	Auction based on award capacity	Maximum 85% x regional CES	100% x regional CES
Wind	Auction based on award capacity	Maximum 85% x regional CES	100% x regional CES
Hydro	Reference price	Maximum 85% x regional CES	100% x regional CES
	Direct selection	Price determined by direct selection process	
	Reference price (for ≤ 10 MW)	Maximum 85% x regional CES	100% x regional CES
	Direct selection (for > 10 MW)	**Price determined by direct selection process**	

CES = basic cost of electricity supply, MSW = municipal solid waste, MW = megawatt, PV = photovoltaic, RE = renewable energy.
Source: Ministry of Energy and Mineral Resources (2017), MEMR Regulation No. 12/2017.

Related to the above regulation, the Minister of Energy and Mineral Resources issued the reference CES through MEMR Decision No. 1404 K/20/MEM/2017. The government set the national CES at Rp983 (US$0.0739) per kilowatt-hour (kWh) for 2016, down from the purchasing reference by PLN for the period 1 April 2017 to 31 March 2018 (Wulandari, 2017).

As regards the oil and gas business, the government has issued two regulations. The first one is Government Regulation No. 27/2017 to revise Government Regulation No. 79/2010 on operating costs and income tax in the upstream oil and gas business. The second is MEMR Ministerial Regulation No. 52/2017 to govern the gross split mechanism for the national upstream oil and gas business. The cost recovery that usually becomes the burden of the state budget is eliminated, and all operating costs are borne by the contractor. The government meanwhile still owns the country's natural resources, with SKK Migas as the operations regulatory control body. The gross split uses a base split mechanism based on variable components and progressive components. Variable components include work area status, field location, reservoir depth, availability of supporting infrastructure, as well as CO_2 and H_2S content. The progressive components comprise the price of petroleum, price of natural gas, and the cumulative amount of oil and gas production. The initial profit sharing for petroleum is 57% government and 43% contractors; as for natural gas, it is 52% government and 48% contractors. These two regulations in 2017 are expected to encourage efficiency and simplification of contractor administration and management for better performance as well as to improve the investment, and to provide legal certainty to the upstream oil and gas business activities.

1.2.2. Energy Balance

As shown in Table 2.1.2-2, Indonesia's total primary energy supply in 2016 was about 1,556 million barrels of oil equivalent (BOE). Most of it comes from fossil fuels: oil, coal, and gas. The share of other RE resources in the energy mix was below 9%: mostly hydropower (2.1%), geothermal power (1.1%), and biofuel (6.1%).[1] The biofuel is in the form of biodiesel blended with automotive diesel oil at 15% volume or popularly known as B15. The intention of the Indonesian government to introduce the biofuel in a blended form with corresponding fossil fuel was to maximise biofuel penetration to the market while avoiding customer preference toward the use of fossil fuel. The use of traditional biomass meanwhile has been prevalent for basic cooking and thermal purposes amongst millions of rural households. This accounts for about 20% in the primary energy supply of the country.

Table 2.1.2-2 Energy Indicators of Indonesia

	Unit	2015	2016
Total primary energy supply	million BOE	1,553	1,556
Oil	%	35.25	35.19
Coal	%	23.47	23.43
Gas	%	18.00	17.97
Hydropower	%	2.27	2.27
Geothermal	%	1.05	1.05
Biomass	%	19.93	20.06
Biofuel	%	0.04	0.04
Final energy consumption	million BoE	1,143	1,058
Final commercial energy consumption (excl. biomass and non-energy use)	million BoE	756	691
Industry	%	34.97	30.88
Household	%	14.62	16.62
Commercial	%	5.44	5.80
Transportation	%	40.63	43.89
Other	%	4.34	2.81
Electrification ratio	%	88.3	91.16
Electricity consumption	million BOE	124.3	132.4

BOE = barrel of oil equivalent.

Note: Temporary data for the year 2016.

Source: The data were collected from Center for Data and Information Technology MEMR (2017).

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[1] Note that the share of biofuel here is misleading as it is in the form of B15 blend.

Indonesia's final energy consumption in 2016 reported by the MEMR was 1,058 million BOE with commercial energy use (excluding biomass and non-energy use) of about 691 million BOE. This figure has increased by nearly 50% since 2001. The share of this final commercial energy consumption is dominated by the transportation sector (43.89%), followed by the industry sector (30.88%), the household sector (16.62%), commercial use (5.80%), and other sectors (2.81%).

Total electricity consumption amounted 132.4 million BOE or 225,000 gigawatt-hours (GWh), mostly in the household sector, followed by the industry and commercial sectors. In the transportation sector, in contrast, the majority utilises oil as fuel products and much less electricity. The industry sector, apart from being a large consumer of electricity, mainly uses natural gas, oil, some coal, and biomass. The reduction of fossil fuel in the transportation sector and the use of traditional biomass are therefore necessary and feasible given the potential wealth of Indonesia's RE sources as presented in the following section.

1.2.3. Energy Resources

Indonesia's energy potential is diverse as it comprises oil, natural gas, coal, and renewables. Fossil energy in particular has been the driving force of economic growth in Indonesia. The coal reserve is about 120.5 billion tonnes; proven oil resources are at around 3.69 billion barrels and proven natural gas reserves at around 101.54 trillion cubic feet (tcf). This translates into 23 remaining years of oil reserves, 59 years of gas, and 146 years of coal at current production rates. Moreover, there is still abundant energy potential in the form of nonconventional gas such as coal bed methane (CBM) and shale gas.

Indonesia's RE sources are also considerable. Aside from holding 40% of the world's geothermal reserves (28,000 megawatts [MW]), the country also has significant potential for hydropower (75,000 MW), micro/mini hydropower (1,013 MW), solar (4.80 kWh/m^2/day), biomass (32,654 MW), and wind (3–6 m/s) (MEMR, 2004). Although relatively small in amount, uranium deposits are found in the Kalan region of Kalimantan.

Regarding the oil resources, Indonesia's fields are now depleting, discovery is slowing, and recovery is increasingly expensive. The MEMR estimated only 3.31 billion barrels of proven reserves in 2016. Crude oil production has been decreasing from 1.1 million barrels of oil per day (bpd) in 2004 to about 821.000 bpd in 2016. In the downstream oil business, Pertamina continues to dominate refining business, crude and fuel import, and other petroleum product supplies to the domestic market even after its monopoly over the retail market ended in 2004. In the upstream oil sector, however, Chevron is the largest domestic crude and condensate producer in Indonesia, followed by Pertamina and several international oil companies such as Total, Conoco Phillips, Exxon, and BP.

Indonesia consumed 1.48 million bpd of oil in 2015 for its domestic energy needs. This dependency, coupled with decreasing oil production, made Indonesia a net oil importer in 2004. Crude oil imports and refined products such as gasoline and transport diesel come are from Saudi Arabia, Malaysia, Nigeria, and Australia. The domestically refined output generally supplies the domestic market but only meets 70% of demand. As Indonesia exports its premium low sulphur crude oil production to trade partners including the Republic of Korea, Singapore, and Japan, domestic refineries consequently use cheaper crude oil imported from Saudi Arabia, Nigeria, and the United Arab Emirates. The refinery capacity, however, has remained static since 2000. The eight oil refineries, all owned and operated by Pertamina, have a current refining capacity of 1.16 million bpd. Pertamina, therefore, is trying to expand its capacity by cooperating with Kuwait Petroleum and Saudi Aramco to provide an additional 600,000 bpd as well as entering into exploratory agreements with Thailand's PTT Global Chemical Public Company Limited.

In the gas sector, Indonesia has 104.7 tcf proven and another 48-tcf potential gas reserves, mostly discovered in Sumatra, Kalimantan, Maluku, Papua, and the West Natuna offshore fields. The majority of the gas is exported, which makes Indonesia the world's fourth largest liquefied natural gas (LNG) exporter after Qatar, Malaysia, and Australia. The domestic consumption is mainly for PLN and heavy industries for fertiliser production, power, and industry. The gas producers are therefore required to supply at least 25% of the produced gas to the domestic market in accordance with the government's policy on domestic market obligation.

The production is expected to rise from 2.8 tcf in 2011 to 4.1 tcf in 2025, an average 2.3% increase per year. Future fields for production already in the construction stage include East Natuna (West Kalimantan), Donggi-Senoro (Central Sulawesi), and Sengkang (South Sulawesi). In addition, there is a substantial nonconventional gas resource of 337 tcf of CBM (Stevens, Sani, and Hardjosuwiryo, 2001). The recoverable resource potential of this CBM is expected to be 56 tcf. Exploration activities unfortunately are far behind the initial commitment, although the government through SKK Migas has granted 54 development licences. As of March 2014, only 84 CBM wells had been drilled by 18 production sharing contractors (Len, 2014), which falls well short of the minimum drilling obligations of 384 core hole and pilot wells expected in 2013, and far behind the 420 committed by 2015. Conflict with the production of coal and disposal of wastewater as well technical difficulties are potential issues in the production of CBM.

Indonesia is also beginning to develop shale gas in Sumatra, Kalimantan, Papua, and Java. The exploitation of these nonconventional gas resources could supply domestic gas demand as Indonesia's LNG production is tied to export contracts. The Gas Development Master Plan estimates a recoverable resource potential of 142.5 tcf. The first licence for shale gas was issued to Pertamina in May 2013 for a potential field in North Sumatra, and as many as 30 production sharing contracts had been issued by 2015. The shale projects may be struggling to be profitable as drilling is costlier than in the United States and the infrastructure is not effective.

In the coal sector, total domestic reserves are estimated at 124 billion tonnes with a proven reserve of 31 billion tonnes, 70% of which is bituminous and sub-bituminous (mostly in Kalimantan and Java) and 30% low-grade lignite (mostly in Sumatra) (BPPT, 2015). The majority of the mines are open pit with most mining activity centred on the islands of Sumatra and Kalimantan. The government estimates that the reserves-to-production ratio is 80 years.

Law No. 4/2009 on Mineral and Coal Mining predominantly governs this sector. This law mandates domestic market obligations for Indonesian coal producers and provides more transparent and standardised tenders and licences for mining blocks. Policy and central administrative responsibilities meanwhile remain in the hand of the MEMR and its Directorate General of Mineral and Coal, which have a mandate to work towards national goals set for coal per Presidential Decree No. 5/2006 on National Energy Policy and amended later by KEN Regulation No. 74/2014.

The majority of the coal produced is for export, and the domestic application is mostly for power generation. The figure in 2015 released by the MEMR shows that 461 million tonnes of coal were produced, with 366 million tonnes exported and 86 million tonnes utilised domestically. The coal price plummeted and the coal exports decreased in 2016. The strong performance of coal at the end of 2017 suggests an improvement in the export figures. The Indonesian benchmark coal price (Harga Batubara Acuan, or HBA) soared 9.6% month-on-month (m/m) to US$92.03 per tonne from US$83.97 in August 2017 (Indonesia Investments, 2017), which was the highest point since December 2016. Coal production is also buoyed by the increase of domestic consumption as the government has set up a 35,000 MW power plant development programme, in which the majority are coal-fired power plants.

In the biomass sector, Indonesia has significant potential for biomass energy generation from agricultural residues including rice husk, bagasse, rubber, and palm oil. The total biomass consumption in 2016 was 20% of the total energy mix in the country or nominally 307 million BOE (Center for Data and Information Technology MEMR, 2015). Its predominant use in the household sector has caused some concern as the inefficient stoves emit health-damaging pollutants into household environments, most directly affecting women and children. Indonesia is therefore partnering with the World Bank and launched the Clean Stove Initiative to scale up the access to clean and efficient cooking in Indonesia in 2012 (ASTAE, 2013). It focused on the 40% of the population located mainly in rural areas where the LPG conversion programme has limited impact and where the biogas option is unlikely to be suitable. The overall target of such an initiative would be delivering 10 million clean biomass-cooking stoves by 2020 and possibly transforming Indonesia's biomass-cooking stoves market towards achieving universal access to clean cooking by 2030.

Another potential use of biomass is for electricity generation, particularly from waste and oil palm. The resource potential from oil palm waste is about 246 million tonnes per year (Conrad and Prasetyaning, 2014). This value excludes oil palm fronds and oil palm trunk. Nevertheless, only around 60 MW of biomass-based power plants were operating on-grid as of 2012. The major challenge for commercial biomass utilisation is the availability of feedstock. To speed up the development of biomass-based power plants, the government issued Presidential Regulation No. 18/2016 to build waste-to-energy plants in seven major cities including Jakarta, Bandung, and Surabaya.[2]

In the electricity sector, Indonesia faces massive challenges in supplying electricity. A major electricity grid system covers the main islands of Java, Madura, and Bali. Other areas and islands have their own distributed electricity generation and transmission systems. Though out

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[2] This regulation by the Government of Indonesia in 2016 is currently on hold, as it was successfully challenged in the high court.

Indonesia access to the electricity grid has improved from 65% in 2010 (Anthony, 2010) to 91% in 2016, this means nearly 25 million people do not have access to grid electricity. In addition, there is over-reliance on fossil fuels (coal, oil, and natural gas) as 88% of the total electricity generated came from fossil fuels in 2014 (PT PLN Persero, 2015). Of the total generating capacity of about 30.3 GW, only 9% comes from hydropower and 3% comes from geothermal and other renewable sources. From the perspective of the national primary energy mix, the electricity sector consumed about 20% of the total 132 million BOE in 2016 (Center for Data and Information Technology MEMR, 2017). Against this backdrop, utilising biomass and waste as either solid or liquid to partially or fully substitute medium fuel oil for electricity generation, along with other small-scale renewable technologies (hydropower and solar PV), may improve the national electrification ratio. Moreover, not only will this plan have the potential to reduce the use of liquid fossil fuels for electricity generation, but also provide electricity in remote areas.

To meet the 8.7% growth in electricity demand, a series of two Fast Track Programs (FTP), each at 10,000 MW, was introduced. The first FTP was delivered through Presidential Decree No. 71/2006 (later amended by Presidential Decree No. 59/2009). To further accelerate the fulfilling of electricity needs, the government has initiated the 35 GW Program from 2015 to 2019. It also follows up on several delayed projects from FTP 1 and 2. The plant capacity allocated for PLN is 14 GW, transmission lines of 50 kilometres, and substations at 743 locations. Of the total 35 GW power projects, 55%–60% will come from coal-fired power plants, while gas power plants make up 12 GW and the remaining approximately 9 GW are from hydro and geothermal, with a small fraction of solar PV and wind.

In the biofuel sector, the potential resources include biogas and well-known liquid biofuels such as biodiesel and pure plant oil derived from crude palm oil, and bioethanol derived from cassava and sugar cane. Though still using first-generation biofuels technology, developing liquid biofuel is a viable way to reduce oil imports given the country's status as the world's largest producer of palm oil of 40 million tonnes per year in 2020.[3] In addition, the use of biofuels offers an alternative to reduce oil imports, maintain the palm oil prices at acceptable level, and reduce carbon emissions.

The RPJMN 2015–2019, through Presidential Regulation No. 2/2015, aims to produce 4,300–10,000 kilolitres of biodiesel and 340–930 kilolitres of bioethanol by 2019. Penetration into the biofuel market is largely due to the mandatory biofuel blending rate (MEMR Regulation No. 20/2014), as presented in Table 2.1.2-3.

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[3] Wright and Rahmanulloh (2016) reported that the post-2020 estimate is subject to the success of increasing crude palm oil yield per hectare as land expansion would be even more difficult. GAPKI (2016) projected that palm oil export may be reduced as domestic biodiesel increases.

Table 2.1.2-3 Biofuel Mandatory Regulation in Indonesia (%)

Biodiesel Sector	**July 2014**	**2015**	**2016**	**2020**	**2025**
Micro, fishery, agrobusiness, transport as PSO	10	10	20	30	30
Transport as non-PSO	10	10	20	30	30
Industrial and commercial	10	10	20	30	30
Power plant	20	25	30	30	30

Bioethanol Sector	**July 2014**	**2015**	**2016**	**2020**	**2025**
Micro, fishery, agrobusiness, transport as PSO	0.5	1	2	5	20
Transport as non-PSO	1	2	5	10	20
Industrial and commercial	1	2	5	10	20
Power plant	–	–	–	–	–

Other Biofuel (PPO/BioAvtur) Sector	**July 2014**	**2015**	**2016**	**2020**	**2025**
Industry (low- and medium-speed engine)	5	10	20	20	20
Transport (low- and medium-speed engine)	5	10	20	20	20
Air transport	–	–	2	3	5
Power plant	6	15	20	20	20

bioavtur = bio-aviation turbine, PPO = pure plant oil, PSO = public service obligation.
Source: Ministry of Energy and Mineral Resources (MEMR), Indonesia, 2014.

Currently, the government has implemented biodiesel blending B20 in the transportation and industry sector and B30 to B60 on electricity. The MEMR has also already launched a new market price index for biodiesel blended with subsidised fuel. The ministry is also preparing various stages to implement B30 in 2018 by conducting engine testing together with automotive engine manufacturers, automotive and expertise associations, as well as university and research institutions before full implementation in 2025.

As Indonesia has opted for mandatory biofuel regulation coupled with a biofuel blending scheme, the issue of the relatively higher price of biodiesel has been solved by implementing a levy on palm oil export. The levy of US$50 a tonne for palm oil and US$ 30 for processed products as of April 2015 collected by the newly formed Crude Palm Oil Fund Agency is used to offset the price difference due to the volatility of the biodiesel price when it is blended with diesel oil.

As for bioethanol, no fuel-grade ethanol has been produced after Pertamina ended its fuel ethanol-blending programme in 2010 due to inconsistent supply and price volatility. The price offered by Pertamina was too low despite a government effort to set up a monthly reference price of fuel-grade ethanol. Based on MEMR and the Indonesian Biofuel Producers Association (APROBI) data, there are only two companies that produce the fuel with a total capacity of 40 billion litres.[4] The MEMR Directorate General of Renewable Energy has been working on renewing the ethanol mandate for gasoline with octane value of 90 in several cities (Surabaya, Jakarta, and Bandung). However, this effort has fallen short due to the inability to seek a bioethanol subsidy in the 2017 fiscal year.

For pure plant oil, one issue is that its price has not been included in the palm oil fund scheme. Moreover, technical issues still remain in implementing pure plant oil blend with diesel oil in the electric utilities, particularly for the gas turbine application. In addition, the PLN as a state-owned enterprise for electricity has been trying to reduce its liquid fuel-based power plants and replace them with natural gas, coal, and geothermal power plants.

1.2.4. Energy Issues in the Transportation Sector

Presidential Decree No. 5/2006 on National Energy Policy (or KEN) is the Indonesian government's energy sector strategy. It emphasises diversification, environmental sustainability, and maximum use of domestic energy resources. The 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 at 22%, and coal at 30%, for a total of 400 million tonnes of oil equivalent by 2025 (Government of Indonesia, 2014). These KEN targets have become the government's point of reference for setting energy sector policy, and every government body will have to set their programmes in this sector accordingly.

Figure 2.1.2-1 presents a visual impression of the magnitude of the structural shifts proposed in the KEN. Compared to Indonesia's 2013 energy mix, coal generation is expected to triple by 2025, gas to more than double, and renewable energy to increase about eightfold. Independent

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[4] PT Molindo Raya and PTPN IX are the two companies in East Java that have fuel-grade ethanol production facilities.

analyses, however, suggest that growth may be somewhat less given the oil fuel subsidy has been removed and the electricity tariff has been raised. A World Energy Outlook 2013 special report by the International Energy Agency forecasts a primary energy demand of 282 million tonnes of oil equivalent by 2025 (IEA, 2013).

As transportation was the largest sector using commercial final energy in 2016, properly managing it will be a key factor to meet the country's energy mix, particularly the 23% of renewable energy. Almost all of the energy consumption in the transportation sector is in the form of oil fuel and about 92% is consumed in the road transportation subsector (Center for Data and Information Technology MEMR, 2015). Increasing oil consumption every year would require more energy subsidies and consequently an increase of crude oil and oil fuel import.

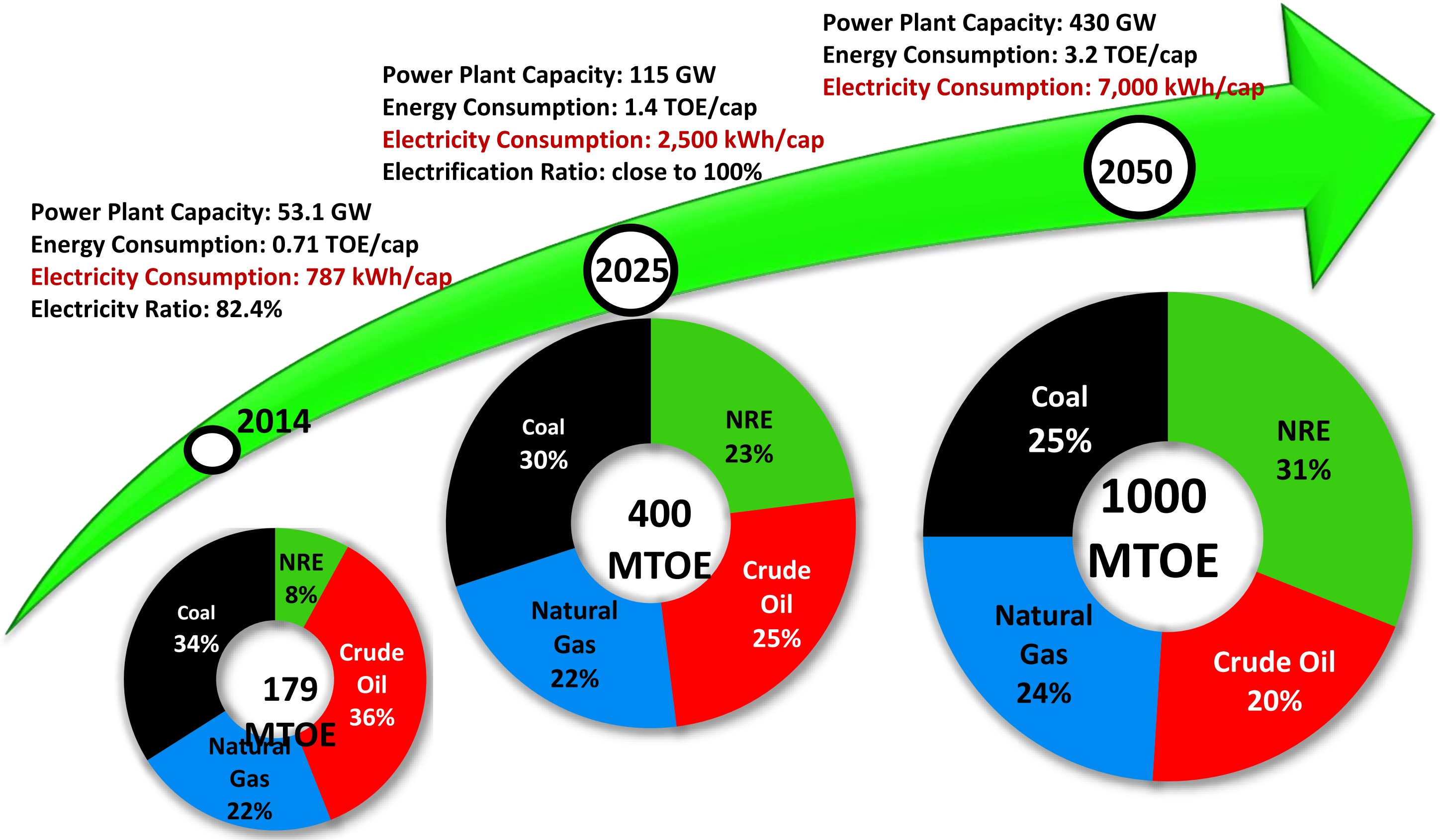
The rapid growth of motor vehicles, about 11% per year in the period 2000–2013 (BPS, 2015), is the primary contributor to the high growth rate of final energy consumption in the transportation sector. Private vehicles, including passenger cars and motorcycles, and commercial transport (buses and trucks) dominate the increase in motor vehicles. In Jakarta, for example, the number of private vehicles is 96.5% and serves 44% of the city's total commuting population. Public transport, on the other hand, comprises merely 3.5% and serves 56% of the city commuters (BPPT, 2015). Only 3% of public transport vehicles use the train or electric railway network of greater Jakarta. The subsidised prices of certain types of gasoline and diesel oil also contribute to the high growth of motor vehicles and oil fuel consumption in the road transportation subsector. The lack of convenient public transport has also exacerbated the situation.

This condition should be improved by removing the oil subsidy, substituting oil fuel with biofuel, gas, and electric vehicles, as well as shifting from primary use of private vehicles to mass transportation. The partial removal of oil fuel subsidies at the end of 2015, though it did not curtail the oil consumption growth, has reduced the burden on the state budget by Rp130 trillion in 2015.

The government has also been attempting to promote the shift from oil-based fuel to biofuel and gas in the transportation sector. Though faced with technical and commercial difficulties, the biofuel drive for transportation has been relatively successful for the past 10 years. The government has issued various policies tackling technical issues, setting up the biofuel standard, as well as trying to manage the price policy.

In the case of biodiesel, increasing the uptake in the market requires promoting higher-blend biodiesel such as B30. Thus, consensus with car manufacturers in implementing a higher blend should be explored further, either by carrying out a road or chassis dynamometer test by the government along with car manufacturers with emphasis on the long-term effect on the engines and preferably a distance of more than 100,000 kilometres. Moreover, a higher blend of biodiesel could be achieved by improving biodiesel quality via partial hydrogenation (H-FAME).

Figure 2.1.2-1 Energy Projection of Indonesia up to 2025 and 2050



GW = gigawatt, kWh = kilowatt-hour, MTOE = million tonnes of oil equivalent, NRE = new and renewable energy, TOE/cap = tonne of oil equivalent per capita.
Note: Projections according to National Agency for Assessment and Application of Technology (BPPT) Energy Outlook referring to the General Planning for National Energy (RUEN).
Source: BPPT (2015).

To ensure the quality and customer confidence, Indonesia could implement a scheme similar to the BQ-9000 programme in the United States. It is important for the biodiesel quality to meet the standard at every stage of the value chain to maintain customer confidence in the biodiesel quality so that it does not cause them engine trouble. In addition, Pertamina and other fuel retailer companies should build more adequate biodiesel blending facilities to ease the supply problem. This is particularly urgent in areas outside the island of Java.

In the case of ethanol for fuel transport, reintroducing the low-ethanol E5 blend is the key. The government should firmly mandate the fuel retailers to market E5 as the fuel subsidy has been partially removed. For the long-term measures, opening more sugar cane plantations in areas outside Java, particularly in Papua, Sulawesi, or Kalimantan, is necessary to increase the domestic supply of the raw material of ethanol. Success in forming Crude Palm Oil Fund Agency could be emulated for the case of ethanol by forming a similar agency to support the sugar cane products.

To increase pure plant oil consumption as mandated in the ministerial regulation, blending with diesel oil should be further promoted. This can be achieved by conducting tests on PLN’s power plant facilities along with the government research institutions, as well as a consultation with the original equipment manufacturers prior to such tests. Moreover, the Crude Palm Oil Fund Agency should expand its role in supporting the sustainable crude palm oil products to include pure plant oil from palm oil.

Despite promising greenhouse gas savings and energy security, the reliance on the domestic palm oil industry and sugar cane plantation for Indonesia’s biofuel growth presents enormous environmental and social costs. Given the recent expansion in oil palm plantation at the expense of tropical forest area (US EPA, 2012), additional plantation dedicated for biofuels will likely follow a similar trend. This plantation expansion suggests that there may be potential impacts due to land use change. Instead of being renewable and environment-friendly, this plan would potentially contribute significantly to greenhouse gases along with other potential impacts such as diverting land from food crops to energy crops, de-afforestation, and social change. Moreover, potential conflicts may arise between local people and companies seeking to build dedicated biofuel feedstock plantations over land use. Many warn that expanding domestic biofuel feedstock production will not only lead to the destruction of the forest but also hasten social conflict.

While conversion of oil fuel to biofuel has been relatively successful, the gas conversion in the transportation sector is another matter. It has faced various difficulties since its inception, centring on technical and infrastructure difficulties. Gas conversion has actually been carried out through implementation of compressed natural gas buses for the bus network in Jakarta since 2008 (600 in 2008 and another 3,000 in 2016). Taxis using compressed natural gas have also been around since the late 1980s but failed within 2 years due to limited gas infrastructure that made taxi drivers reluctant to drive CNG taxis as they have to travel quite distance to refill the gas. In 2007, there was a renewed effort to have a conversion kit but was again hindered by lack of gas filling stations. It is therefore important to fix the inadequate gas transportation and distribution infrastructure. This may be a key to the success of gas conversion from fuel oil and the future development of the gas subsector.

Another measure to curb the oil fuel consumption in the transportation sector is to promote electric vehicles, particularly motorcycles. This is a particularly effective measure to reduce gasoline consumption, since motorcycles consume a majority of the gasoline and the number of motorcycles comprised almost 85% of the total 104 million vehicles in the country (BPS, 2015). Promoting electric vehicles has been included in the RUEN regulation, and additional presidential regulation special for electric vehicles is being formulated. The plan to introduce electric vehicles in Indonesia has received positive responses from various parties including academia, the ministry of industry, and PT PLN. This aspiration may require a boost for the local electric vehicle industry, supporting infrastructure such as charging stations, an adequate power generation and electricity grid, and research in electric-based transportation.

In addition to shifting the use of oil fuel in the transportation sector to other fuels for achieving the fossil oil reduction target, a viable alternative may be an integrated approach of oil reduction measures. The RUEN has recommended measures including construction of mass transportation infrastructure in the large cities, with the aim of reaching a market share of 30% for public transportation by 2025. The strategy also recommends mass rapid transit, light rail transit, and trams in 13 large cities. Moreover, the government plans to develop a fuel economy standard for private vehicles and to mandate it by 2020.

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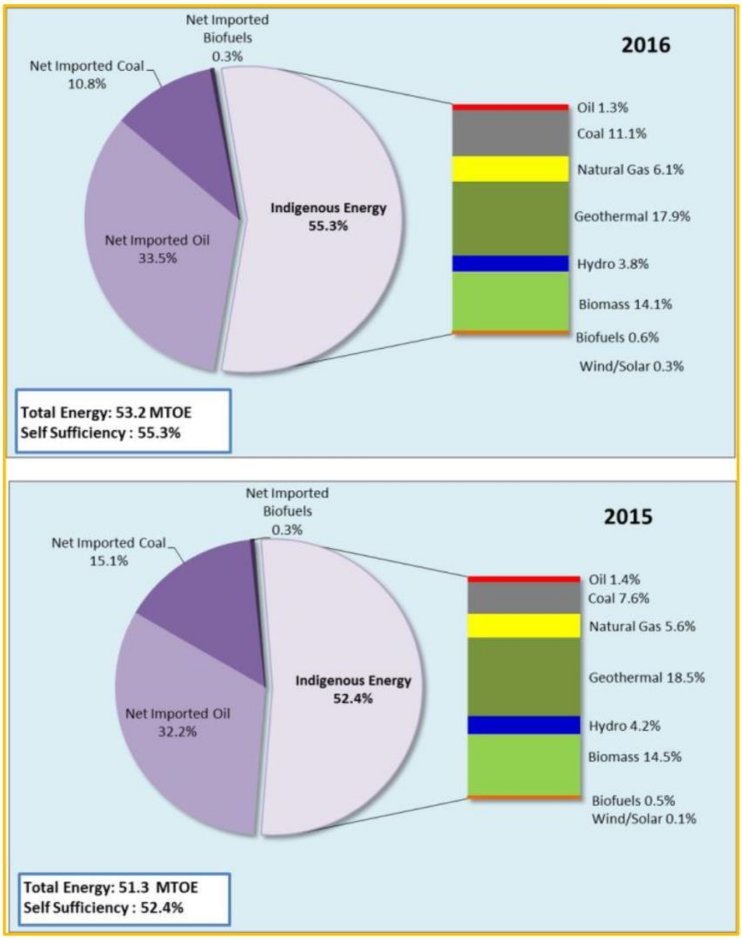
1.3 Philippines

1.3.1. Philippine Energy Demand and Supply Situation, 2016

a. Total Primary Energy Supply

The country's total primary energy supply (TPES) reached 53.2 million tonnes of oil equivalent (Mtoe) in 2016, 3.7% higher from its 2015 level of 51.3 Mtoe. This was due to the 9.4% increase in aggregate indigenous energy resources from 26.9 Mtoe in 2015 to 29.4 Mtoe in 2016, offsetting the 2.5% reduction in net energy importations. Higher domestic production from coal, natural gas, and renewable energy, particularly biofuels, solar, and wind, was reported during the same period (Figure 2.1.3-1).

Figure 2.1.3-1. Total Primary Energy Mix in the Philippines by Fuel Shares, 2015–2016



Mtoe = million tonnes of oil equivalent.
Source: Philippine Energy Plan 2016-2030.

The bulk of the country's energy requirement continued to be derived from oil accounting for 34.9% of the primary energy supply mix, followed by coal and geothermal with shares of 22.0% and 17.9%, respectively. In terms of growth, natural gas production from Malampaya Well registered a 14.6% hike in levels during the same period. Similarly, a large increase was also seen in the total primary oil supply, by 7.8% from 17.2 Mtoe in 2015 to 18.5 Mtoe in 2016. This was due to the increase in net importations.

Meanwhile, the total primary coal supply grew considerably slower at a rate of 0.6% to reach 11.7 Mtoe in 2016 from its previous level of 11.6 Mtoe. The same trend is exhibited by aggregate renewable energy sources, which recorded a sluggish 0.5% increase in production level between 2015 and 2016. From amongst the renewable supply, combined solar and wind energy grew by 133.6%; biofuels and geothermal production increased by 18.1% and 0.2%, respectively. On the other hand, hydro energy production was lower by 6.4% in 2016 vis-à-vis 2015.

The country's energy self-sufficiency reached 55.3%, 2.9%age points higher than the 2015 level of 52.4%.

b. Indigenous Energy

Total indigenous energy production increased by 9.4% from 26.9 Mtoe in 2015 to 29.4 Mtoe in 2016. Notable upsurges were reported for solar (691.9%), coal (52.0%), wind (30.3%), biofuels (18.1%), and natural gas (14.6%), coupled with modest growth from geothermal (0.2%) and biomass (0.9%). These energy resources augmented the country's domestic energy supply to meet the total energy requirements during the period despite lower domestic production for oil (1.8%) and hydro (6.4%).

c. Fossil Fuels

Oil

The country's combined oil production, including condensate, dropped by 1.8%, from 715.0 kilotonnes of oil equivalent (ktoe) in 2015 to 702.4 ktoe in 2016, while its share in the contribution to total indigenous energy supply stood at 1.3%. The reduction is attributable to the lower production output reported in Nido and Galoc oil fields during the same period.

Coal

The country's indigenous coal supply, with a share of 11.1% to total domestic energy production, accelerated by 52.0% to 5.9 Mtoe in 2016 from 3.9 Mtoe in the previous year. The bulk of the hike in production came from the country's major coal producer, Semirara Mining and Power Corporation (SMPC), which accounts for a 98.9% share in the total coal production of the country. SMPC's 2016 production set a new record high of 12,087 million metric tonnes run-of-mine coal, which was 54.6% higher vis-à-vis 2015. Private coal mines in Cebu likewise recorded a 20.9% increase in aggregate production. On the other hand, coal mines in Bicol, Surigao, and Zamboanga, as well as small-scale mines located throughout parts of the country, with a combined share of 0.8% to the country's total coal production, suffered cuts of almost half their 2015 levels.

Natural Gas

As of the end of 2016, Malampaya, the country's lone producing natural gas field, produced 3.3 Mtoe of natural gas, equivalent to a 6.1% share in the overall total indigenous energy production during the year. This level translated to double-digit growth of 14.6% compared with the 2015 level of production at 2.9 Mtoe as the Malampaya gas field recovered from its maintenance shutdown in the previous year. Its domestic production supplies 100% of the country's natural gas requirements.

d. Renewable Energy

Geothermal

For 2016, the share of geothermal energy in the total indigenous energy supply reached 32.4% (equivalent to a 17.9% share in TPES). Geothermal production posted a minimal increase of 0.2% from its 2015 level of 9.5 Mtoe. The minimal increase may be attributed to the newly rehabilitated 6-megawatt (MW) binary plant in Macban.

Hydro

The country's hydropower production contributed 6.9% to the total indigenous energy supply in 2016 (equivalent to a 3.8% share in TPES). Hydropower production has been declining since 2013, further aggravated by the strong El Niño phenomenon (drought) during the first half of the year (January–May 2016), which adversely affected the water level in Lake Lanao resulting in a 6.4% decline in hydropower generation from around 2.2 Mtoe in 2015 to 2.0 Mtoe in 2016. The country experienced the most severe drought on record that started in late 2015 and lasted until June 2016.

Solar

Solar energy production increased about nine times its 2015 level of 11.9 ktoe to reach 94.3 ktoe in 2016, accounting for a 0.2% share in the total energy mix in 2016. The robust increase – from 146.3 MW in 2015 to 4,118 MW in 2016 – was brought about by the massive addition to solar installed capacity. The country can look forward to solar's significant contribution to the energy mix in the future as 166 solar projects, with a total potential capacity of 4,081 MW, were awarded in 2016.

Wind

Production of wind energy stood at 83.9 Mtoe, 30.3% more than its 2015 level of 64.4 ktoe, albeit a marginal contribution of 0.2% to TPES. As of December 2016, 58 wind projects were awarded, which would bring in total additional capacity of 1,039 MW.

Biomass

Biomass continued to account for around one-fourth (25.5%) of the indigenous energy supply in 2016, increasing by 0.9% from its 2015 level of 7.4 Mtoe. The sluggish growth is attributed to the declining popularity of biomass as a conventional fuel in the household sector for cooking and heating, despite remaining a ready and substitute fuel for more expensive sources of energy in the industry and commercial sectors.

On the other hand, the contribution of biomass to the power sector gradually increased, as its level of fuel input to electricity generation grew more than twofold (101.6%) its 2015 level to reach 281.9 ktoe in 2016. The heightened promotion of the use of renewable energy resulted in a total of 67 biomass projects awarded as of the end of 2016, with an additional aggregate capacity of more than 300 MW.

1.3.2. Current Status of Transportation Fuel Supply

Oil

Inventory

Actual crudes and petroleum products inventory in December 2016 closed at 20,742 MB (thousand barrels) or an equivalent of 51-day supply – 37 days for crude oil and products in country stocks and 14 days in transit. This was higher by 15.2% from the financial year (FY) 2015 level of 18,005 MB. For the financial year ending December 2016, the average inventory was recorded at 47 days – 38 days in country stock and 9 days in transit.

The government continued to enforce the Minimum Inventory Requirement given the continuing risks faced by the downstream oil industry sector, such as geopolitical instability and supply delivery problems to areas affected by calamities (e.g. typhoon, flood, earthquake).

As such, updates on the status of oil supply to areas heavily affected by typhoons were provided to the National Disaster Risk Reduction and Management Council to ensure continuous supply.

The current Minimum Inventory Requirement for refiners is in-country stocks equivalent to 30 days, while a supply equivalent to 15 days stock is required for bulk marketers and 7 days for liquefied petroleum gas (LPG) players.

Crude Oil Supply

The country imported various types of crude oil in 2016 and reached 78,772 MB, a slight increase of 0.9% from 78,060 MB in 2015.

Eighty-seven percent of the total crude mix (68,537 MB) was sourced from the Middle East, of which 36.1% (28,438 MB) came from Saudi Arabia, the top supplier of crude oil to the country. This is followed by Kuwait with a 33.6% share of the total crude mix and the United Arab Emirates with a 13.3% share. On the other hand, 6.7% (5,256 MB) of crude oil was imported from the Russian Federation. The remaining 6.3 % was sourced from the Association of Southeast Asian Nations (4,980 MB) and from local production (135 MB).

Petroleum Products and Ethanol Imports

FY 2016 petroleum product imports totalled 86,108 MB, an increase of 12.9% from 76,276 MB in 2015.

In terms of volume, diesel oil import grew by 24.6% compared with the 2015 import. Kerosene/avturbo, LPG, and gasoline imports also rose by 19.9, 19.7, and 3.7%, respectively. On the other hand, fuel oil import dropped by 15.3%.

The other industry players accounted for a majority of the product imports with 73.5% of the total import volume, up by 8.9% to 63,319 MB from 58,132 MB in 2015. The oil majors (Petron, Chevron, and Pilipinas Shell) accounted for the remaining 26.5%, which increased by 25.6% from 18,144 MB in the previous year to 22,789 MB.

The local refiners (Petron and Pilipinas Shell) accounted for 16.0% of the total product imports, which included blending stocks, as against a 84.0% share by direct importers.

The product import mix comprised mostly of diesel oil at 41.0%, gasoline at 18.2%, LPG at 13.5%, fuel oil at 8.3, kerosene/avturbo at 8.2%, and other products at 10.7%.

Total gasoline imports reached 43.5% of gasoline demand, while diesel oil imports reached 54.5% of diesel demand. LPG imports, on the other hand, reached 68.6% of LPG demand. Total product import was 55.4% of the total product demand.

The import share of the oil majors in the total demand was 14.7%, while the other players' share was 40.7%. As for the refiners, their import share in the total demand was 8.9%, while 46.5% was attributed to direct importers.

Meanwhile, a total of 1,632 MB of ethanol was imported for fuel use during the year, which dropped by 14.3% from 1,904 MB of 2015. Republic Act No. 9367 or the Biofuels Act of 2006 mandated that all gasoline to be sold in the country should be E10 (gasoline with 10% bioethanol content).

Moreover, petroleum coke for smelting plants (400 megatonnes) was also imported during the year as well as butane in canisters (208 megatonnes).

Crude Run and Refinery Production

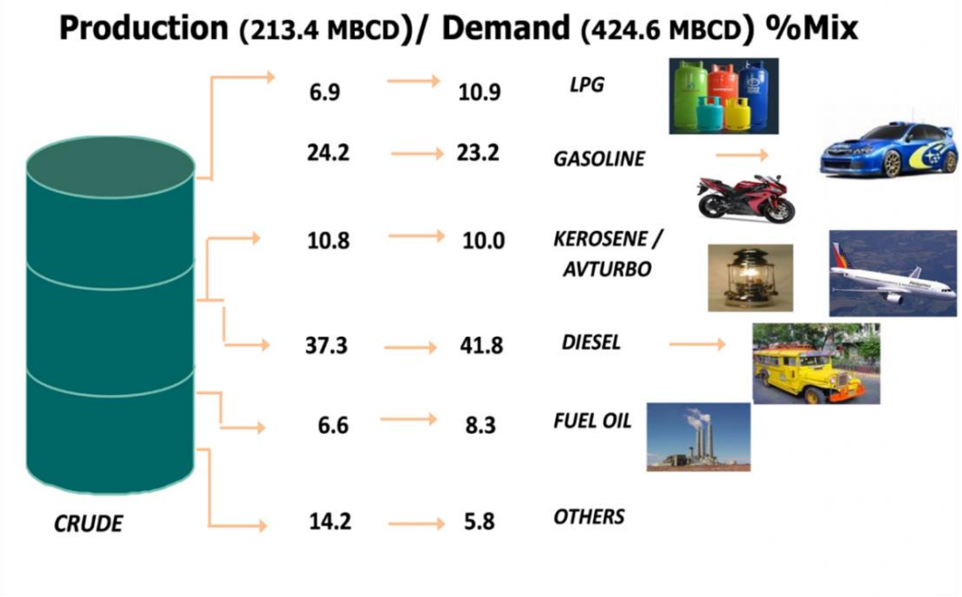
The country's current maximum working crude distillation capacity is 285 MB per stream day.

Total crude processed as of the end of 2016 was up by 2.0% from 77,478 MB in 2015 to 79,016 MB. Refinery utilisation during the period also increased by 1.7% from 74.4% in the previous year to 75.7% in 2016.

Consequently, local petroleum refinery production output also grew by 3.1% from 75,751 MB to 78,113 MB. The FY 2016 average refining output was 213.4 MB per day.

Compared with FY 2015, gasoline output posted an increase of 10.8%, which may be attributed to the expanded refinery of one local refiner, now capable of producing more white petroleum products. Kerosene and avturbo output also rose by 10.2%. Similarly, LPG and diesel oil rose by 1.1 and 0.6%, respectively. However, fuel oil output dropped by 18.4%.

Figure 2.1.3-2 Production and Demand Mix in the Philippines in Fiscal Year 2016



LPG = liquefied petroleum gas, MBCD = thousand barrels of oil per calendar day.
Source: Philippine Energy Plan 2016-2030.

Diesel oil continued to dominate the production mix with a share of 37.3%, followed by gasoline and kerosene/avturbo with 24.2% and 10.8% shares, respectively. Meanwhile, LPG and fuel oil had 6.9% and 6.6% shares, respectively (Figure 2.1.3-2).

Petroleum Product Demand

The year-to-date (YTD) December 2016 total demand of finished petroleum products grew by 8.5% to 155,414 MB from 143,226 MB in YTD December 2015. This can be translated to an average daily requirement of 424.6 MB compared with the previous year's level of 392.4 MB.

Compared with YTD December 2015 figures, diesel oil demand posted an increase of 10.5%. LPG, kerosene/avturbo, and gasoline demand were also up by 14.0%, 12.7%, and 10.0%, respectively. Likewise, naphtha rose by 22.6% vis-à-vis the previous year. However, fuel oil demand decreased by 11.7%.

The total product demand mix comprised mostly diesel oil at 41.8%, gasoline at 23.23%, LPG at 10.9%, kerosene/avturbo at 10.0%, fuel oil at 8.3%, and naphtha and other products at 5.8% (Fig. 2.1.3-2).

Petroleum Product Exports

The country's total petroleum product exports as of the end of 2016 dropped by 1.5% from 13,988 MB in 2015 to 13,771 MB.

Compared with the previous year, condensate, the top exported products for the period, registered an increase of 5.3%. Likewise, exports of propylene, pygas, and gasoline rose by 46.2%, 10.3%, and 8.2%, respectively. However, fuel oil and naphtha exports were down by

46.4% and 13.1%, respectively. Other petrochemical products such as mixed xylene and benzene dropped by 7.0% and 21.5%, respectively.

The total export mix comprised of condensate (28.8%), naphtha (11.8%), gasoline (13.2%), fuel oil (11.5%), propylene (10.8%), pygas (9.7%), mixed xylene (5.1%), mixed C4 (3.4%), toluene (3.1%), benzene (1.2%), and reformate (1.1%).

The oil refiners' exports accounted for 58.0% of the total export mix, while the export of other players accounted for the remaining 42.0%.

Crude Oil Exports

A total of 1,804 MB crude oil from Galoc (Palawan Light) was exported during 2016, a decrease by 26.1% from 2,441 MB in 2015.

Total Petroleum Products

The major oil companies (Petron Corp., Chevron Philippines Inc., and Pilipinas Shell Petroleum Corporation) had a 57.8% market share of the total demand, while the other industry players (including PTT Philippine Corp. (PTTPC), Total Phils., Seaoil Phil. Inc., TWA Inc., Phoenix, Liquigaz, Petronas, Prycegas, Micro Dragon, Unioil, Isla Gas, Jetti, Eastern Petroleum, JS Union, JS Phils. Corp., Petrotrade, South Pacific, Marubeni, SL Harbour, Perdido, and Filoil Logistics Corp.) as well as the end users who imported directly most of their requirement captured 42.2% of the market.

Meanwhile, the local refiners (Petron Corporation and Pilipinas Shell) captured 51.0% of the total market demand, while 49.0% was credited to direct importers and end users.

Liquefied Petroleum Gas

The other players' market share, with the inclusion of South Pacific in early 2016, increased to 63.4%. The remaining 36.6% was credited to the oil refiners. Amongst the other LPG players, Liquigaz had the biggest market share with 23.3%, followed by Pryce Gases with a share of 12.7% and Isla Gas with a share of 12.66%.

The FY 2016 estimated total oil import bill amounting to $7,451.9 million was 13.5% lower than in FY 2015 when it was $8,612.0 million. This was attributed to lower import cost (for both crude and petroleum products) despite an increase in the petroleum product import volume. The total oil import cost consisted of 55.4% finished products and 44.6% crude oil.

Total import of crude oil amounted to $3,321.0 million, down 17.9% from $4,043.1 million in FY 2015 due to the lower cost, insurance, and freight (CIF) price per barrel of $42.159/bbl compared to $51.795/bbl in 2015.

Meanwhile, the total product import cost went down by 9.6% to $4,130.9 million at an average CIF cost of $47.973/bbl, whereas in 2015 it was $4,568.9 million at an average CIF cost of $59.899/bbl. The average dollar rate for 2016 was $47.5 compared to $44.36 in 2015.

On the other hand, the country's petroleum export earnings for the period fell by 23.2% from $878.7 million in 2015 to $675.0 million in 2016. This was due to the decreased volume of crude exported for the period and lower free on board (FOB) price per barrel vis-à-vis 2015 figures.

Overall, the country's 2016 net oil import bill amounting to $6,776.8 million was down by 12.4% from $7,733.3 million in 2015.

Natural Gas

The Philippines had 3,772 billion cubic feet (BCF) of proved natural gas reserves and 109 million barrels (MMB) of condensate, which can be found mostly in the basins of Northwest Palawan and Cagayan. Potential resources for natural gas stand at 68 BCF, while undiscovered mapped resources from the 14 sedimentary basins all over the country will reach 8,303 BCF of natural gas.

From 2012 to 2015, production of natural gas from Malampaya Field was recorded at 515.05 BCF with associate condensate of 16.57 MMB during the same period. Additional production of 73.67 BCF of natural gas and 2.19 MMB of condensate was also realised during the first half of 2016.

In 2013, the Department of Energy (DOE) in partnership with the World Bank completed the Natural Gas Master Plan Update, which included the objective to establish a natural gas investment and transactional framework focusing on liquefied natural gas (LNG). Likewise, in 2014, the DOE commissioned the Philippine National Oil Company to engage the Public–Private Partnership (PPP) Center to conduct a feasibility study on the 105-kilometre Batangas–Manila Natural Gas Pipeline (BatMan 1) to supplement the study by the Japan International Cooperation Agency on the technical aspect for the LNG entire chain (LNG facilities, regasification, pipeline, and offtake facilities) including a social and environmental impact study. Further, to open the country to the LNG market, in 2015 the DOE granted an extension of about 12 months to the provisional permit issued for the imminent completion of the country's first LNG Terminal Hub and merchant power plant in Pagbilao, Quezon owned by Energy World Corporation (EWC).

As of the end of 2015, natural gas posted a total actual production of 126,192 million standard cubic feet (MMSCF), with a shortfall of about 3.2% as compared to the previous year when it was 130,351 MMSCF. Similarly, natural gas consumption also decreased by 6.1% from a total of 125,611 MMSCF in 2014 to 117,926 MMSCF in 2015. Such decreases can be attributed to the implementation of planned and unplanned shutdown activities both in the facilities of Malampaya as well as on the customer side such as the gas-fired power plants and refinery. As of the second semester of 2016, fuel production recorded a total of 73,665 MMSCF, while total consumption was at 70,534 MMSCF.

Power generation accounts for 97.7% of the total annual consumption, while the industry sector accounts for about 2.3% (Table 2.1.3-1). Transportation sector consumption, however, is greatly affected by the deferment of the commercial operation of the 31 compressed natural gas (CNG) buses under the DOE's Natural Gas Vehicle Program for Public Transport (NGVPPT) due to the suspended operation of the existing CNG daughter refilling station in Mamplasan, Biñan, Laguna.

Currently, the only source of natural gas in the country is the Malampaya gas field, which has an average production of 380 MMSCF per day. Apparently, two projects will be implemented to ensure a stable supply of natural gas for the Luzon Electricity Grid, Malampaya Phases 2 and 3.

In 2013, Malampaya Phase 2 was completed upon the successful installation of two production wells. On the other hand, Malampaya Phase 3 involves design, fabrication, and installation of a new depletion compression platform and is expected to commence operation in 2016. It will also allow additional volumes of natural gas to be committed to new customers.

In 2015, the main consumers of natural gas in the country were still the three natural gas-fired power plants in Luzon, which consumed around 115,788.1 MMSCF of gas, and the Pilipinas Shell Petroleum Corporation refinery, which consumed around 2,137.7 MMSCF of gas. Additional market participation in terms of power generation is expected in the gas industry by 2016 through the entry of the 100 MW Avion Gas Power Plant and the additional 450 MW San Gabriel Power Plant.

Furthermore, to ensure sustainability of the natural gas supply, the DOE is considering the importation of LNG as a major option to meet the demand of the industry. At present, the DOE is entertaining proposals from various private parties that will bring LNG into the country.

Table 2.1.3-1 Natural Gas Production and Consumption in the Philippines

(million standard cubic feet, mmcsf)

Production	**Consumption**			**Total**
	Power (1994–2016)	**Industry (2005–2016)**	**Transportation (2008–2014)**	
1,803,550	1,705,616	31,675	184	1,737,475

Source: Philippine Energy Plan 2016-2030.

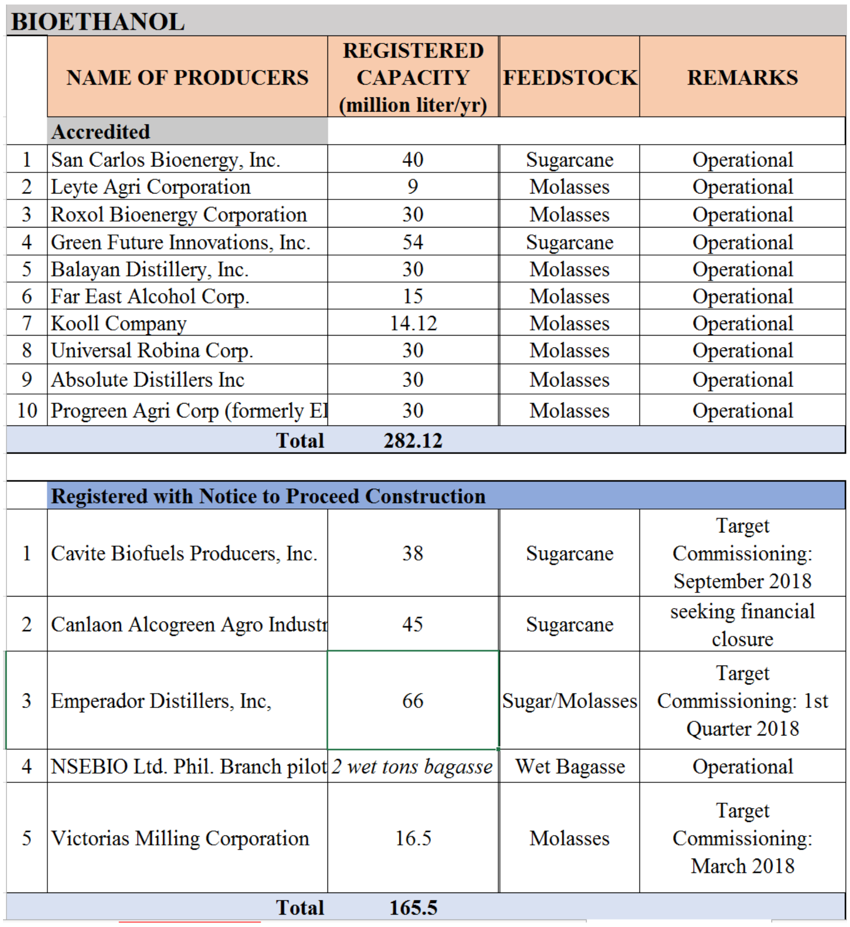
1.3.3. Current Status of Biofuel Supply in the Transportation Sector

The country embraces the development of biofuels with the anticipation of achieving energy security, augmenting farmers' income, generating rural employment, and reducing greenhouse gas (GHG) emissions that can contribute to mitigating the effects of climate change. In 2007, the passage of Republic Act 9367, otherwise known as the Biofuels Act of 2006, together with Department Circular No. 2007-05-0006, or its Implementing Rules and Regulations, mandated the use of biofuels and established the National Biofuels Program to ensure a sustained investment climate for production, distribution, and utilisation of biodiesel and bioethanol. Since then, the government has been constant in promoting the use of biofuels as an alternative and clean fuel in the transportation sector.

As a result, the total number of biofuel producers has increased continuously, from 11 producers in 2011 to a total of 16 in 2014. At present, the country already has 21 biofuel producers located nationwide, 10 of which are bioethanol producers with registered total annual capacity of 282.12 million litres (Table 2.1.3-2) and 11 are biodiesel producers with total registered annual capacity of about 574.90 million litres (Table 2.1.3-3).

Three more bioethanol production plants with a combined capacity of 120.5 million litres will be added by the third quarter of 2018, bringing the total production capacity to 402.62 million litres (Table 2.1.3-2).

Table 2.1.3-2 List of Accredited Bioethanol Producers and Registered Bioethanol in the Philippines

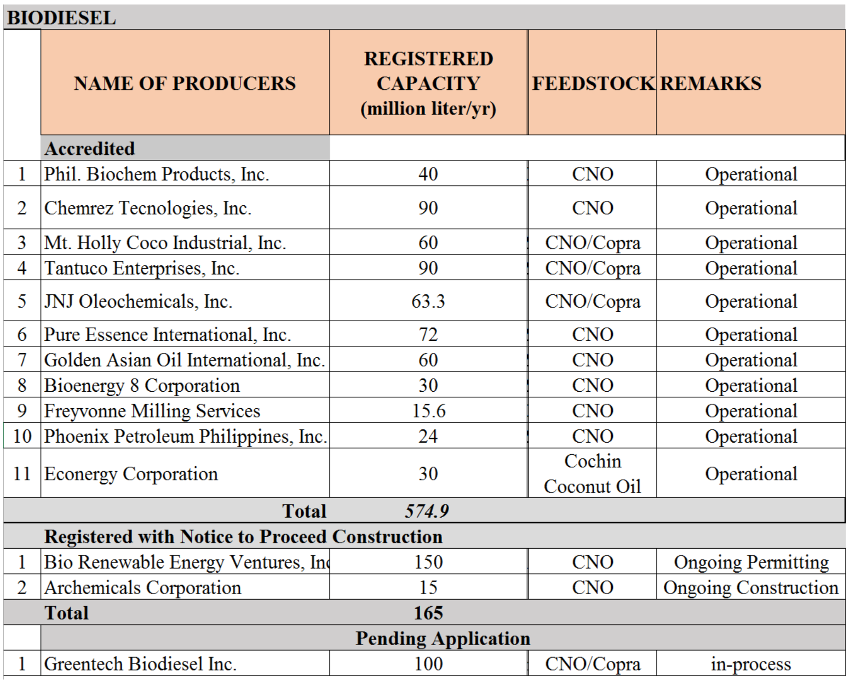


BIOETHANOL

	NAME OF PRODUCERS	REGISTERED CAPACITY (million liter/yr)	FEEDSTOCK	REMARKS
	Accredited			
1	San Carlos Bioenergy, Inc.	40	Sugarcane	Operational
2	Leyte Agri Corporation	9	Molasses	Operational
3	Roxol Bioenergy Corporation	30	Molasses	Operational
4	Green Future Innovations, Inc.	54	Sugarcane	Operational
5	Balayan Distillery, Inc.	30	Molasses	Operational
6	Far East Alcohol Corp.	15	Molasses	Operational
7	Kooll Company	14.12	Molasses	Operational
8	Universal Robina Corp.	30	Molasses	Operational
9	Absolute Distillers Inc	30	Molasses	Operational
10	Progreen Agri Corp (formerly El	30	Molasses	Operational
	Total	**282.12**		
	Registered with Notice to Proceed Construction			
1	Cavite Biofuels Producers, Inc.	38	Sugarcane	Target Commissioning: September 2018
2	Canlaon Alcogreen Agro Industr	45	Sugarcane	seeking financial closure
3	Emperador Distillers, Inc,	66	Sugar/Molasses	Target Commissioning: 1st Quarter 2018
4	NSEBIO Ltd. Phil. Branch pilot	*2 wet tons bagasse*	Wet Bagasse	Operational
5	Victorias Milling Corporation	16.5	Molasses	Target Commissioning: March 2018
	Total	**165.5**		

Source: Renewable Energy Management Bureau, Department of Energy, Philippines.

Table 2.1.3-3 List of Accredited Biodiesel Producers and Registered Biodiesel Projects in the Philippines



BIODIESEL				
	NAME OF PRODUCERS	REGISTERED CAPACITY (million liter/yr)	FEEDSTOCK	REMARKS
	Accredited			
1	Phil. Biochem Products, Inc.	40	CNO	Operational
2	Chemrez Tecnologies, Inc.	90	CNO	Operational
3	Mt. Holly Coco Industrial, Inc.	60	CNO/Copra	Operational
4	Tantuco Enterprises, Inc.	90	CNO/Copra	Operational
5	JNJ Oleochemicals, Inc.	63.3	CNO/Copra	Operational
6	Pure Essence International, Inc.	72	CNO	Operational
7	Golden Asian Oil International, Inc.	60	CNO	Operational
8	Bioenergy 8 Corporation	30	CNO	Operational
9	Freyvonne Milling Services	15.6	CNO	Operational
10	Phoenix Petroleum Philippines, Inc.	24	CNO	Operational
11	Econergy Corporation	30	Cochin Coconut Oil	Operational
	Total	***574.9***		
	Registered with Notice to Proceed Construction			
1	Bio Renewable Energy Ventures, In	150	CNO	Ongoing Permitting
2	Archemicals Corporation	15	CNO	Ongoing Construction
	Total	**165**		
	Pending Application			
1	Greentech Biodiesel Inc.	100	CNO/Copra	in-process

Source: Renewable Energy Management Bureau, Department of Energy, Philippines.

In 2016, the total production of biodiesel was 225.87 million litres, while total sales were 217.70 million litres. As of the end of 2017, the total biodiesel production stood at 222.13 million litres, while total sales were 203.48 million litres.

The total actual production of bioethanol in 2016 stood at 230.18 million litres with total sales of 226.88 million litres. Production and sales increased significantly by 37.11% and 34.71%, respectively, as compared to 167.87 million litres and 168.42 million litres in 2015. As of 2017, total production was pegged at 234.65 million litres and total sales at 234.90 million litres (Table 2.1.3-4).

Table 2.1.3-4 Biodiesel and Bioethanol Production and Sales in the Philippines, 2016-2017

	Accredited		**2016 (million litres)**		**2017 (million litres)**	
	# of projects	**Annual capacity**	**Production**	**Sales**	**Production**	**Sales**
Biodiesel	11	574.9	225.87	217.70	222.13	203.48
Bioethanol	10	282.12	230.18	226.88	234.65	234.90

Source: Renewable Energy Management Bureau, Department of Energy, Philippines.

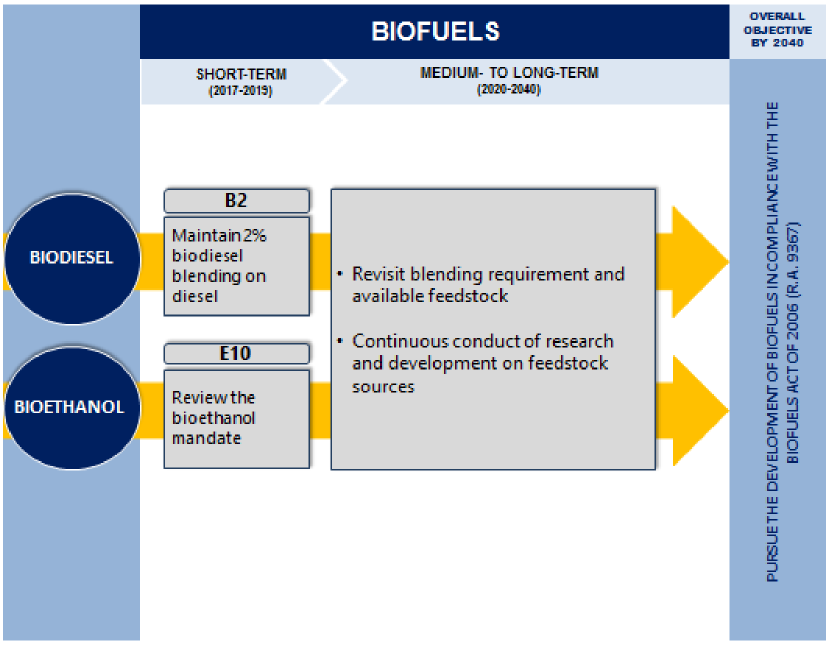
1.3.4. Research and Development Support

In terms of research and development (R&D), the DOE initiated a partnership with the academe to implement biofuel projects using alternative feedstocks such as sweet sorghum, cassava, macro-algae, and nipa sap. As such, from 2012 to 2015, four projects were implemented to introduce and develop alternative feedstocks of biofuels in the country: (1) Village Scale Production of Hydrous Ethanol as Feedstock for R&D in Biofuel Trials and Anhydrous Ethanol Production, implemented by Mariano Marcos State University; (2) Bioethanol Production from Macro-algae and Socio-ecological Implications, implemented by the University of the Philippines-Visayas Foundation Inc. (UP-VFI); and (3) Bioethanol Production Potential of Different Cassava Varieties under Northern Mindanao Condition and Development of a Pilot-Scale Cassava Bioethanol Plant, implemented by Xavier University, which are already completed; and (4) Establishment of a Community-Based Bioethanol Industry and Continued Research and Development on the Feasibility of Hydrous Bioethanol as Biofuel Blend Using Nipa Sap, which started implementation in 2016 and also is being undertaken by Mariano Marcos State University.

1.3.5. Road Map

The DOE has come up with a road map that will facilitate the implementation of the scheduled blending of biofuels from 2017 to 2040 in compliance with the Biofuels Act of 2006 (Figure 2.1.3-3).

Figure 2.1.3-3 2017–2040 Road Map of Biofuels in the Philippines



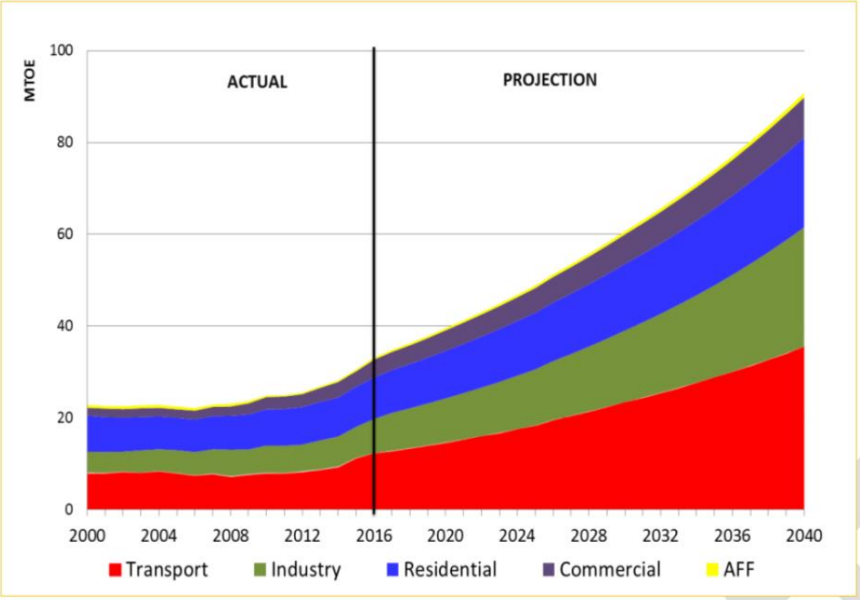
Source: Philippine Energy Plan 2017–2040.

Accordingly, under the road map, for the short term (2017–2019), biodiesel will maintain the current 2% blending level, while that of bioethanol will be at 10%. For the medium- to long-term planning period, the DOE together with the National Biofuels Board will embark on revisiting or re-evaluating the blending requirement with due consideration of the availability of feedstock. Furthermore, continuous R&D of biofuel feedstock sources will be implemented.

Fuel Demand and Biofuel Supply Outlook Based on the Philippine Energy Plan 2017–2040

The country's total final energy consumption (TFEC) is expected to increase at an average rate of 4.3% annually, from 33.1 Mtoe in 2016 to 91.0 Mtoe in 2040 (Figure 2.1.3-4).

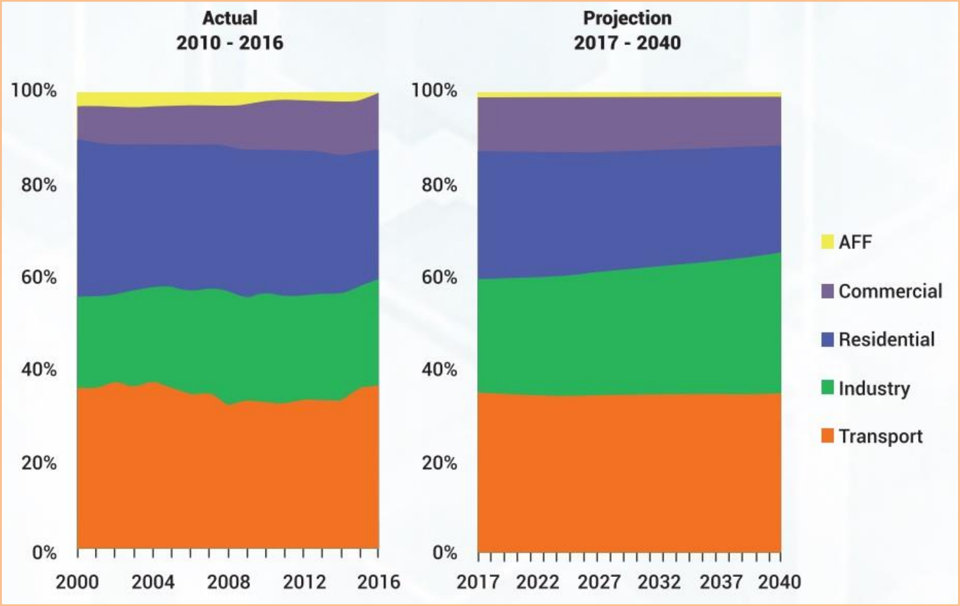
Figure 2.1.3-4 Total Final Energy Consumption in the Philippines by Sector, 2000–2040



Source: Philippine Energy Plan 2017–2040.

The transportation sector will continue as the biggest energy-consuming sector with a 38.2% average share across the entire planning horizon. Both the transportation and industry sectors account for the bulk in terms of contribution to the increase in TFEC levels between 2016 and 2040 (Figure 2.1.3-5).

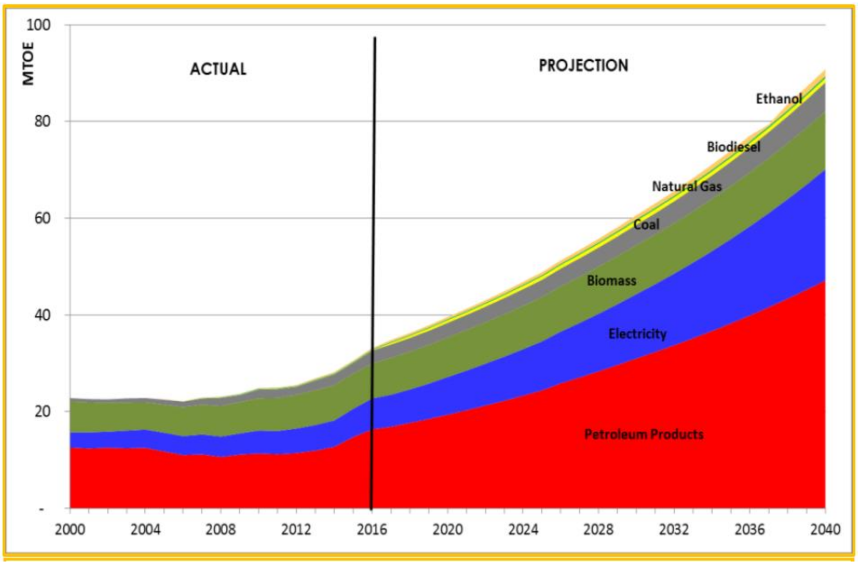
Figure 2.1.3-5 Total Final Energy Consumption in the Philippines by Sectoral Share (Actual 2000–2016, Clean Energy Scenario 2017–2040)



Source: Philippine Energy Plan 2017–2040.

Petroleum products will continue to account for the bulk of TFEC, with an average share of 50.5% in the demand mix (Figure 2.1.3-6). Despite the volatility of oil prices in the international market, demand for petroleum products will increase by an average of 4.5% per year from 2016 to 2040. Diesel and gasoline will continue to be the most widely-used petroleum products, with average shares of 44.0% and 34.8% in the total oil demand, respectively. Transportation will remain the major petroleum-consuming sector with an average share of 71.9% in the total oil demand for the entire planning period.

Figure 2.1.3-6 Final Energy Consumption in the Philippines by Fuel, 2000–2040



Mtoe = million tonnes of oil equivalent.
Source: Philippine Energy Plan 2017–2040.

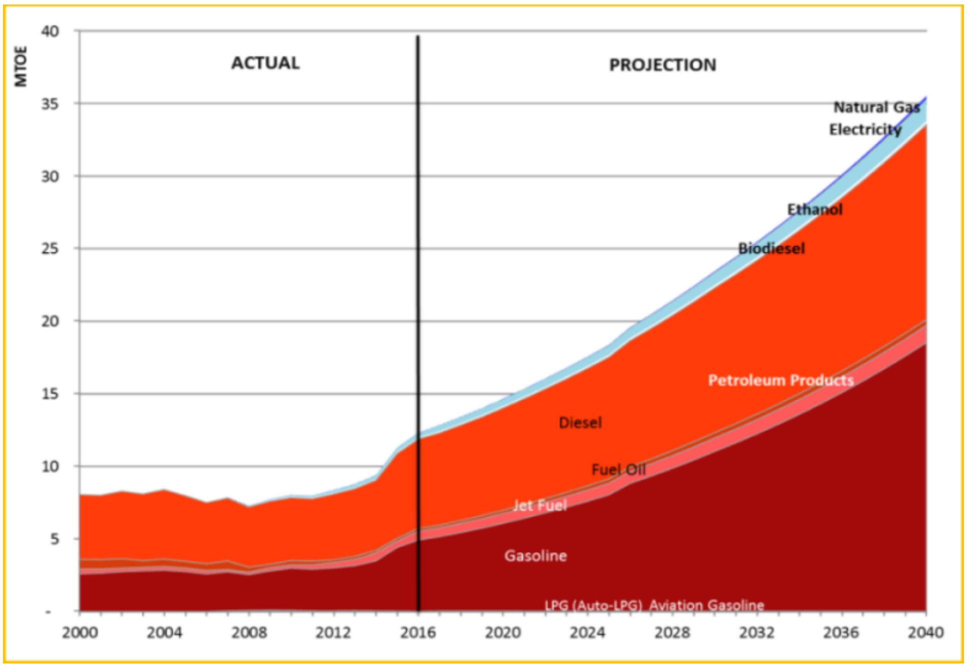
The continuous implementation of the mandated biofuels blend for gasoline and diesel products will hike up total biofuel demand from 0.5 Mtoe in 2016 to 1.8 Mtoe in 2040. This translates to a 3.5% and 6.7% increase in the demand for biodiesel and bioethanol, respectively.

In line with the government's 'Build, Build, Build' initiative, we expect an aggressive transportation infrastructure climate with the construction of more railways, urban mass transport, airports, seaports, bridges, and roads. As such, the transportation sector will continue to dominate the country's total energy demand, with an annual average share of 38.2% in TFEC. The sector's energy requirement is projected to grow at a yearly rate of 4.5%, from its demand level of 12.3 Mtoe in 2016 to 35.5 Mtoe in 2040. The bulk of this energy demand will be used for land transport, which covers about 80.0% of domestic traffic and 60.0% of freight traffic.

With the implementation of Executive Order 82, or the Comprehensive Automotive Resurgence Program, aimed at improving the automotive industry to sustain the robust growth in domestic automotive sales and strengthen local production, it is anticipated that the Philippines will become a regional automotive manufacturing hub in Southeast Asia by 2020. With these developments, the transportation sector will continue to rely on oil as its major fuel, constituting the bulk (95.2%) of the sector's total energy requirement for the next 25 years. Gasoline demand, particularly for passenger cars, will account for an average share of 48.3% of the sector's total oil demand, posting average yearly increments of 5.7% to reach 18.5 Mtoe in 2040. However, the entry of electric vehicles (including e-trikes and hybrid vehicles) and use of a consistent bioethanol blend are expected to limit the rise in gasoline consumption. On the other hand, as a significant portion of diesel consumption will be displaced by the projected penetration of additional CNG-fuelled buses and higher biodiesel target blend, its demand level will still increase by a modest 3.3% to reach 13.4 Mtoe by 2040 with an average share of 45.8% of the total (Figure 2.1.3-7).

The biodiesel supply for the entire planning period will contribute 0.3% to TPES, as levels rise by 3.4% per year to reach 0.4 Mtoe in 2040. On the other hand, bioethanol production will increase by 6.7% per year – from 0.3 Mtoe in 2016 to 1.5 Mtoe in 2040. It is expected to contribute an average 0.8% share in TPES.

Figure 2.1.3-7. Transport Energy Demand in the Philippines by Fuel, 2000–2040



Mtoe = million tonnes of oil equivalent.
Source: Philippine Energy Plan 2017–2040.

Table 2.1.3-5 Biodiesel Demand Outlook of the Philippines, 2018–2040

Year	Diesel demand (million litres)	% blend target	Supply requirement (million litres)
2018	10,365.72	2	207.31
2019	10,730.13	2	214.60
2020	11,149.34	5	557.47
2025	13,812.06	5	690.60
2030	16,575.44	5	828.77
2035	19,502.28	5	975.11
2040	22,804.11	5	1,140.21

Source: Renewable Energy Management Bureau, Department of Energy, Philippines.

Table 2.1.3-6 Bioethanol Demand Outlook of the Philippines, 2018–2040

Year	Gasoline demand, (million litres)	% blend target	Supply requirement, (million litres)
2018	7,573.11	10	757.31
2019	7,999.54	10	799.95
2020	8,476.11	10	847.61
2025	11,266.27	10	1,126.63
2030	15,518.58	10	1,551.86
2035	20,185.21	10	2,018.52
2040	26,163.83	10	2,616.38

Source: Renewable Energy Management Bureau, Department of Energy, Philippines.

Tables 2.1.3-5 and 2.1.3-6 show the biodiesel and bioethanol supply requirement, respectively, which would reach 1,140 million litres and 2,616 million litres by 2040.

1.3.6. Current National Plans for Reduction of Energy Consumption

The government has continuously implemented the National Energy Efficiency and Conservation Program (NEECP), launched in 2004, as the banner programme for on the various initiatives on energy efficiency and conservation initiatives. This programme includes the following:

- Energy Efficiency Standards and Labelling Program
- Government Energy Management Program
- Energy Management Services/Energy Audits
- Fuel Conservation and Efficiency in Road Transport
- Power Conservation and Demand Management (Power Patrol).

The DOE approved the implementation of the Energy Efficiency and Conservation Roadmap in July 2014, which specifies a direction towards an energy-efficient economy by 2040. The road map identifies short-, medium-, and long-term action plans across key energy-consuming sectors. The road map will provide more sustainable and long-term policy directions on energy efficiency and conservation.

The DOE has pursued the accreditation of energy service companies to promote emerging business industries in the economy. As of 2015, there were 15 accredited energy service companies to help accelerate the implementation of energy efficiency and conservation measures in the private sector. The DOE also offers audit services to manufacturing plants, commercial buildings, and other energy-intensive companies to evaluate the energy utilisation efficiencies of equipment, processes, and operations and to recommend energy conservation measures for adoption by these companies.

The DOE has also implemented the Philippine Industrial Energy Efficiency Project in partnership with the United Nations Industrial Development Organization and the Department of Trade and Industry with the Global Environmental Fund providing the project funding. The project will introduce the application of ISO 50001 to select industry sectors, such as chemicals, food and beverage, iron and steel, and pulp and paper. The project could generate about 2 million megawatt-hours (MWh) of energy savings.

1.3.7. Current National Plans for Alternative Fuel Introduction

To pursue diversified low-cost transport fuel in the country and to contribute to mitigating the adverse effects of climate change, the government is implementing programmes such as the NGVPPT, Auto-LPG, and the Market Transformation through the Introduction of Energy Efficient Electric Vehicles Project. These projects intend to reduce the country's dependence on imported oil as well as provide people a cheaper and more environment-friendly fuel that will serve as an alternative to fossil fuels.

a. Natural Gas Vehicle Program for Public Transport – Compressed Natural Gas (Buses)

The government is extending the NGVPPT's pilot phase implementation of 200 CNG buses until 2018. Moreover, the successful introduction of CNG utilisation for transport is dependent on the competitive pricing of CNG against the diesel price. With the current pump price of diesel hovering around ₱21.00–₱25.00, the NGVPPT will require a form of government incentive until the programme moves to the commercial phase, where the number of CNG buses will be sufficient to make CNG more competitive with diesel.

Moreover, the DOE will continuously coordinate with the legislative body, academe, and concerned national government agencies for the provision of incentives, capacity-building activities, policies and guidelines, establishment of a CNG tank requalification facility, and development of emergency response protocols for CNG vehicles to support the deployment of CNG buses under the programme. In addition, a continuous information, education, and communication campaign and other promotional activities will be regularly conducted throughout the planning horizon to sustain awareness about the programme.

b. Auto-Liquefied Petroleum Gas Programme

The DOE in its effort to pursue the auto-LPG programme has come up with an action plan that will facilitate the formulation and establishment of necessary support to mainstream the use of auto-LPG in the transportation sector:

- R&D on the expanded applications of LPG in other sectors, including agriculture (farming and fishing subsectors)
- Lobby for the legislation providing incentives for the importation and/or manufacturing of original manufactured LPG-fuelled vehicles

- Development of rules and guidelines to encourage the establishment of support infrastructure such as auto-LPG refilling stations, after-sales services, and manufacture of parts.

c. Market Transformation through Introduction of Energy Efficient Electric Vehicles Project

In partnership with the Asian Development Bank and the Clean Technology Fund, the DOE has implemented the Market Transformation through Introduction of Efficient Electric Vehicles Project, or E-Trike Project, to promote energy efficiency and clean technologies in the transportation sector. It aims to reduce the sector's annual petroleum consumption by 2.8% (based on 20 MMB annual consumption in 2010) and to avoid CO_2 emissions of estimated 259,008 tonnes annually by shifting to 100,000 electric tricycles (e-trikes).

The project has procured 3,000 e-trikes, but difficulty in securing commitments from the local government units decelerated the programme. The DOE has come up with a medium-term action plan that will assist the electric vehicles (EV) industry to take off, which includes (1) a campaign for the passage of bills that will bring down the cost of EV acquisition, either through importation for the initial market penetration or sourcing out locally in the medium term; and (2) continuation of EV promotional activities.

1.3.8. Electric and Hybrid Vehicles – Non-Project Grant Aid for the Introduction of Japanese Advanced Products and Its System (Next-Generation Vehicle Package)

In 2013, the Government of Japan coordinated with the Department of Foreign Affairs and 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.

Under the terms of the grant aid, next-generation vehicles such as hybrid vehicles, plug-in hybrid EVs, and EVs, including charging stations, will be procured in Japan through the Japan International Cooperation System. The grant covers the procurement and delivery of vehicles to agreed destinations. However, all taxes shall be shouldered by the government as its counterpart as well as the corresponding maintenance and other operating expenses for the distribution and deployment of the vehicles.

Target beneficiaries of said grant aid include Philippine National Police stations in the provinces of Leyte and Samar, which were devastated by typhoon Haiyan (known locally as Yolanda); national government agency regional offices in Region 8 that are instrumental to emergency response operations and rehabilitation; and national government agencies that could assist in the conduct of research, performance testing, and promotion of alternative fuel vehicles were also allotted with vehicles for promotional purposes. The distribution of hybrid vehicles was already completed in 2017. Meanwhile, eight units of plug-in hybrid EVs had already been delivered, while the charging station was inaugurated in December 2017.

1.3.9. Other Energy Technologies

The DOE shall continuously monitor emerging and mature energy technologies in other countries that can be adopted for domestic application. As such, thorough evaluation, testing, and validation will be done for domestic applications, specifically in the transportation sector. In the medium term, the DOE will embark on the following identified energy technologies for evaluation and validation:

- cellulosic biomass feedstock for bioethanol production and woodchips production of efficient domestic cook stove using wood chips;
- fuel derived from petroleum-based waste materials such as plastics and rubbers;
- efficient biomass-based stoves for domestic cooking; and
- micro-energy harvesting technologies.

Once the technologies are assessed and approved to be locally applicable, the programme for performance testing and demonstration for said technologies will be developed for possible commercialisation.

The long-term goal of the government is to deploy efficient and applicable alternative fuel energy technologies for transport and non-transport purposes. It envisions that by 2040, alternative fuel vehicles will be mainstreamed in the country's transportation sector.

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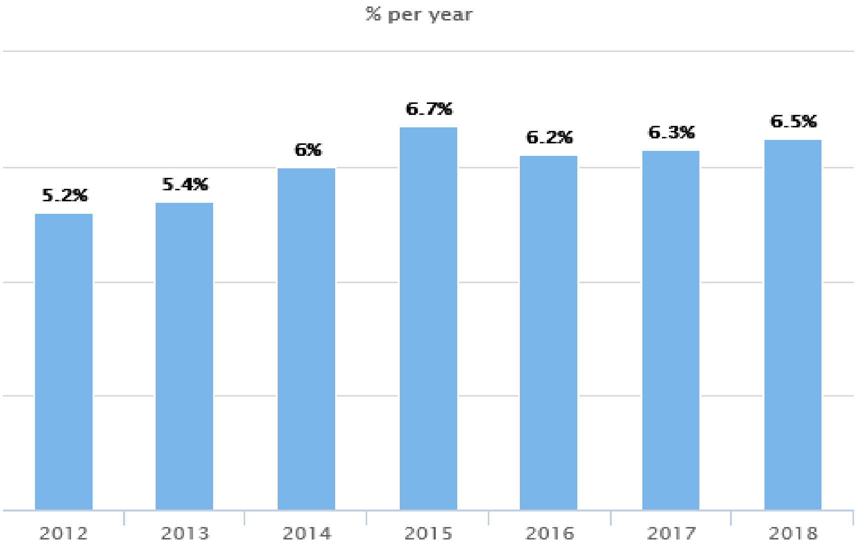
1.4 Viet Nam

Viet Nam is a country with a population of 92.7 million (2016). The United Nations (UN) estimates that by July 2018 the country's population will be 96.49 million (World Population Review, 2018). The actual gross domestic product (GDP) growth rate in 2017 was 6.81%, which is more than the expected rate of 6.3% projected by the Asian Development Bank (ADB), as shown in Figure 2.1.4-1. It is the highest growth rate in the past 6 years. With this growth rate, the GDP per capita is US$2,385, an increase of US$170 compared to 2016.

Figure 2.1.4-1 Gross Domestic Product Growth of Viet Nam, 2012–2018



Note: 2018 figure is projected.
Source: ADB (2017).

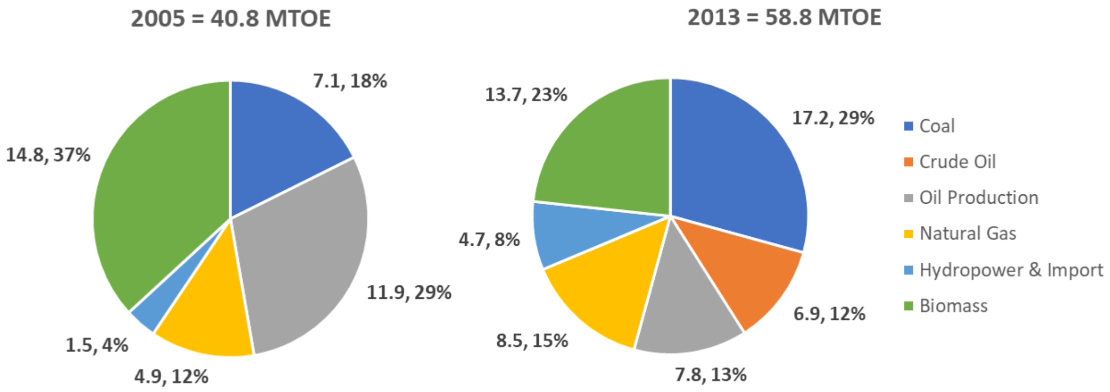
As a growing country, the government has released many policies that relate to energy saving and energy efficiency, power development planning, CO_2 reduction strategies, intended nationally determined contributions, and so on. The following are some important ones:

- Decree No. 153/2004/QĐ-TTg: Strategic direction for sustainable development in Viet Nam
- Decree No. 1427/QD-TTg, 02/10/2012: Approval on the National Target Program on Energy Efficiency and Conservation for the Period 2012–2015
- Decree No. 177/2007/QĐ-TTg: Project of Biofuels Development to 2015 and the Vision to 2025
- Decree No. 1993/QD-TTg: Approving the National Green Growth Strategy: Period 2011–2020
- Nationally Determined Contribution in 2015 specifying the national contribution (target) for the period 2021–2030 covering the entire economy
- Decree No. 428/QD-TTg, approved the adjustment of the National Power Development Plan VII (PDP 7 rev) for the period of 2016–2020, vision to 2030.

1.4.1. Current Status of Energy Supply

Viet Nam's total primary energy supply in 2013 was 58.8 million tonnes of oil equivalent (Mtoe), which is a slight increase of 1.3% from the 2012 level and 44% higher compared to the 2005 level according to government's energy statistics source. Energy sources in 2013 were diversified: 29% of the supply came from coal, 25% from oil, 15% from natural gas, 8% from hydropower and electricity import, and 23% from biomass (Figure 2.1.4-2). Viet Nam has been a net energy exporter; however, the trade surplus has significantly decreased over the last decade with implementation of the government's export restriction policy for natural resources, together with the promotion of domestic capacity development in the transformation and manufacturing sectors. Viet Nam's energy consumption has been driven by energy infrastructure extensions, encouraging economic growths rates (6.1% per year on average during 2005–2013 for GDP) along with structural change towards larger contributions from industry and services sectors, and improvement of household income over the past 2 decades. Per capita primary energy consumption and supply steadily increased until 2010, then levelled off. It reached 0.65 tonnes of oil equivalent per person in 2013, equal roughly to 25% of the Asia-Pacific Economic Cooperation (APEC) region's average (APERC, 2016).

Figure 2.1.4-2 Total Primary Energy Supply of Viet Nam, 2005 vs 2013



MTOE = million tonnes of oil equivalent.
Source: APERC (2016).

Transportation has witnessed rapid growth, with road transport accounting for the highest share of passenger and cargo transportation, followed by waterborne transport.

Viet Nam's total final energy consumption increased from 43,202 kilotonnes of oil equivalent (ktoe) in 2008 to 47,873 ktoe in 2012. The changes in final energy consumption per energy type from 2008 to 2012 are shown in Table 2.1.4-1.

Table 2.1.4-1 Energy Consumption in Viet Nam by Type

Fuel type	2008	2009	2010	2011	2012
Coal	8,289	8,966	9,893	9,647	8,390
Oil	13,819	15,851	17,080	15,297	14,896
Gas	540	639	493	894	1,438
Electricity	5,844	6,615	7,461	8,140	9,063
Non-commercial energy	14,710	14,704	13,875	13,938	14,086
Total	**43,202**	**46,775**	**48,802**	**47,916**	**47,873**

Source: MoNRE (2015).

In 2014, Viet Nam's total electricity supply was 145.5 terawatt-hours, increasing over 11% from its 2013 level (Table 2.1.4-2). Of this total electricity output, over 41% came from hydropower plants and other renewables, 57% from thermal power plants, and less than 2% from import (MOIT, 2016).

Viet Nam's power system is the third largest in the Association of Southeast Asian Nations (ASEAN), with a total installed power capacity of over 34.5 gigawatts in 2014. During 2005–2014, over 22.4 gigawatts were newly built, which corresponded to an average growth of nearly 13% per year. Development of renewable power sources recorded the highest growth at 15.1% per year on average.

Table 2.1.4-2 Installed Power Capacity and Generation in Viet Nam, 2013

Power Type	Capacity (MW)	Share (%)	Generation (GWh)	Share (%)
Large Hydro (>30 MW)	**13,260**	**43.2**	**51,945**	**40.8**
Coal thermal	7,116	23.2	26,863	21.1
Gas turbine	7,446	24.3	42,745	33.6
Oil thermal	912	3.0	249	0.2
Diesel	70	0.2	7	0.0
Other Renewables	**1,884**	**6.1**	**5,511**	**4.3**
Small-hydro	*1,670*	*5.4*	*4,989*	*3.9*
Wind	*56*	*0.2*	*62*	*0.05*
Biomass	*150*	*0.5*	*460*	*0.36*
Biogas/MSW	*4*	*0.01*		
Solar power	*4*	*0.01*		
Total	**30,688**	**100**	**127,320**	**100**

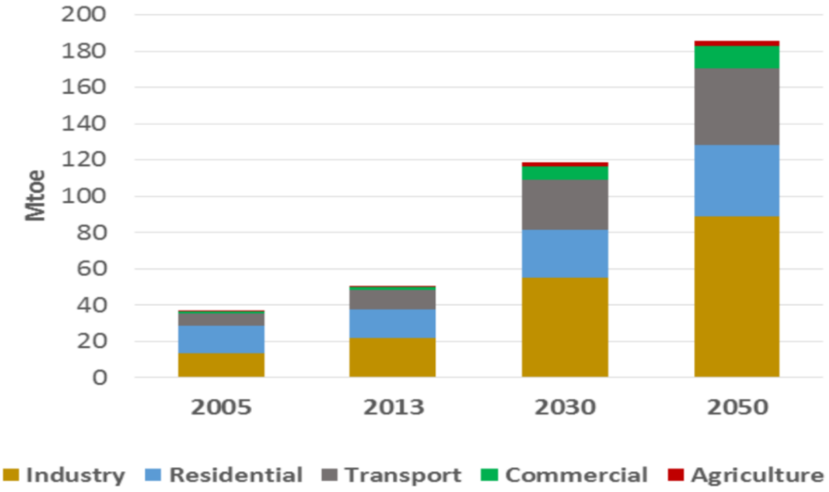
GWh = gigawatt-hour, MSW = municipal solid waste, MW = megawatt.
Source: MOIT (2016).

Viet Nam's total final energy consumption (TFEC) in 2013 was 50.6 Mtoe, up 2.6% from 2012 and 36% higher than the 2005 level (VNEEP, 2015). The demand structure by fuel has changed significantly, with a reduction in the share of biomass (non-commercial energy) and a rise in modern fuels, including oil, coal, gas, and especially electricity. During 2005–2013, electricity demand grew over 13% per year on average, reflecting progress in industrialisation and modernisation of the economy.

1.4.2. Energy Demand

Viet Nam is forecasting economic growth (GDP) between 6.5% and 7.6% per year over the period to 2030 (MOIT, 2015). Under the Energy Efficiency Scenario, Viet Nam's final energy demand is projected to double to 119 Mtoe in 2030 and 186 Mtoe in 2050 (Government of Viet Nam, 2015). This corresponds to an average growth rate of 5% per year during 2013–2030, then lower at 2% per year during 2030–2050. Industry remains the highest-consuming sector throughout the forecast period, with a share increase to 46% in 2030 and 48% in 2050. Transport demand continues to grow quickly and surpasses residential demand, with a share of 23% in 2030–2050. The share of residential demand drops significantly to 22% in 2030 and 21% in 2050. Contributions from the commercial and agriculture sectors rise slightly from 4% in 2013 to about 8% in 2030 and 9% in 2050 (Figure 2.1.4-3).

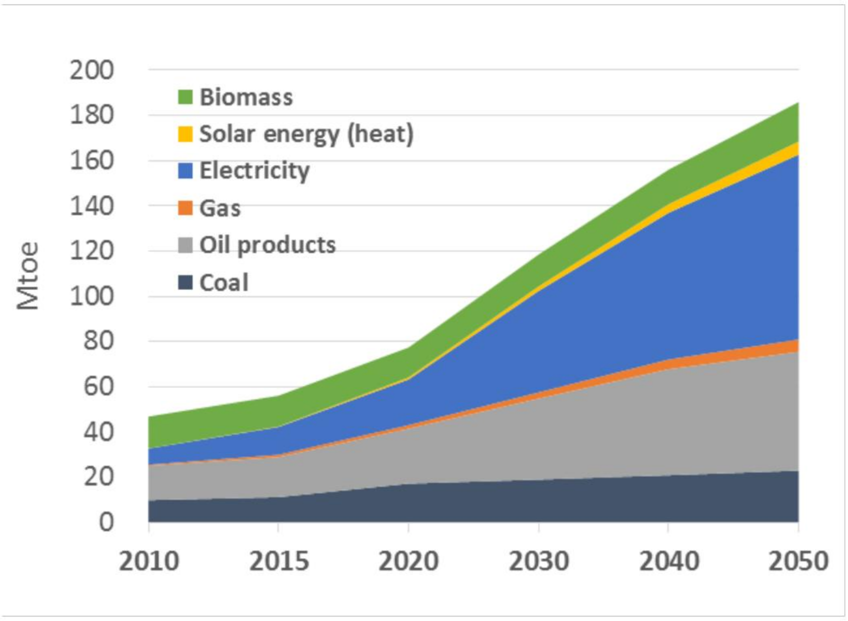
Figure 2.1.4-3. Final Energy Demand in Viet Nam by Sector, 2005–2050



Mtoe = million tonnes of oil equivalent.
Source: Government of Viet Nam (2015).

Final demand for electricity is forecasted to continue to increase strongly at over 10% per year to 2020 and then grow between 6% and 9% per year over the period 2020–2030. Meeting this demand will require an investment of around US$42 billion to 2030, with 58% required for generation and 42% for transmission and distribution (MOIT, 2015). Oil demand will increase faster than the past growth rate: 6.5% per year to 2020 and 4% per year over the period 2020–2030, compared to a rate of 3.5% per year during 2010–2015 (Figure 2.1.4-4).

Figure 2.1.4-4. Final Energy Demand in Viet Nam by Fuel, 2010–2050



Mtoe = million tonnes of oil equivalent.
Source: Government of Viet Nam (2015).

Other assumptions on power generation according to a business-as-usual (BAU) scenario given in the Intended Nationally Determined Contributions (MoNRE, 2015) is presented in Table 2.1.4-3.

Table 2.1.4-3 Assumptions on Power Generation in Viet Nam According to the Business-as-Usual Scenario

			Unit: billion kWh
	2010	**2020**	**2030**
Large-scale hydropower	27.8	64.6	64.6
Coal-fired thermal power	17.9	163.5	422.4
Gas-fired thermal power	45.3	81.5	107.8
Renewable energy	3.3	3.3	3.3
Nuclear power	0	6.9	70.1
Imported energy	0	9.9	26.4
Total	**94.3**	**329.7**	**694.6**

kWh = kilowatt-hour.
Source: MoNRE (2015).

1.4.3. Revised Power Development Plan 2011–2020, Vision 2030

On 18 March 2016, by Decision No. 428/QD-TTg, the Prime Minister approved the adjustment of the National Power Development Master Plan for the Period 2011–2020 with the Vision to 2030 (PDP 7 rev). Compared to PDP 7 of July 2011, the most obvious change of PDP 7 rev is a stronger emphasis on renewable energy development and on power market liberalisation.

The specific objectives of PDP 7 rev are as follows:

- Provide adequate electricity for the domestic demand, satisfy socioeconomic development objectives with average GDP growth rates of 7% during 2016–2030:
    - Commercial electricity: 235 billion–245 billion kilowatt-hours (kWh) in 2020, 352 billion–379 billion kWh in 2025, and 506 billion–559 billion kWh in 2030
    - Electricity production and import: 265 billion–278 billion kWh in 2020, 400 billion–431 billion kWh in 2025, and 572 billion–632 billion kWh in 2030
- Prioritise the development of renewable energy sources for electricity production; increase the proportion of electricity generated from renewable energy sources (excluding large-scale, medium-scale, and pumped storage hydropower) up to around 7% in 2020 and above 10% in 2030.
- Construct the power transmission grid with flexible operation and high automation capabilities from electricity transmission to distribution; develop unmanned substations and substations with 50% human participation to increase the capacity of the electricity industry.
- Accelerate the programme of electrification in rural and mountainous areas to ensure that in 2020 most of the rural households have access to electricity.

Table 2.1.4-4 compares the proportion of power sources as outlined in both PDP 7 as of July 2011 and PDP 7 rev as of March 2016 over the decade from 2020 to 2030. As per the PDP 7 rev structure, the data are presented on the basis of % age share of total electricity production. As indicated in Table 2.1.4-4, coal is projected to be the main source for electricity production, while renewable energy shows an upward trend.

Table 2.1.4-4. Structure of Power Sources in Total Electricity Production in Viet Nam (%)

Power Sources	2015	2020		2025		2030	
		PDP7	PDP7 rev	PDP7	PDP7 rev	PDP7	PDP7 rev
Renewable Energy	3.7%	4.5%	6.5%	-	6.9%	6.0%	10.7%
Coal	34.4%	46.8%	49.3%	-	55.0%	56.4%	53.2%
Gas Turbine	30.0%	24.0%	16.6%	-	19.1%	14.4%	16.8%
Hydro	30.4%	19.6%	25.2%	-	17.4%	9.3%	12.4%
Import	1.5%	3.0%	2.4%	-	1.6%	3.8%	1.2%
Nuclear	-	2.1%	-	-	-	10.1%	5.7%

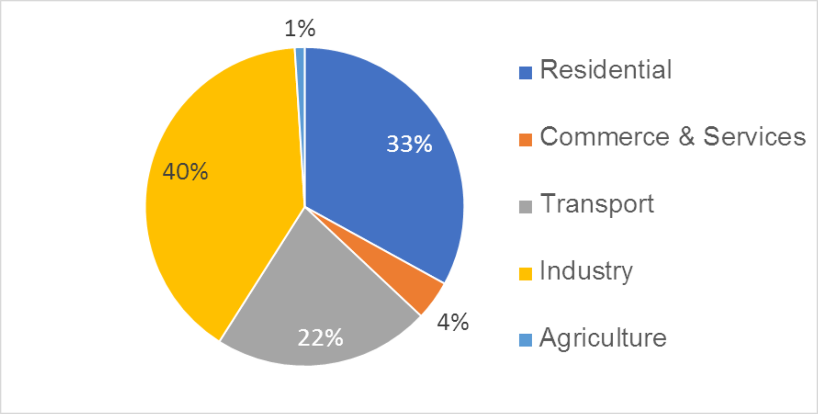
Source: Data extracted from (VN PDP, 2016).

1.4.4. Current Status of Transportation Fuel Supply and Mitigation Scenario in the Transportation Sector

The on-road vehicle population consists of about 3 million cars and 46 million motorcycles. In 2010, the transportation sector ranked third after the industry and residential sectors in terms of share of total energy consumption, constituting of 22% of the overall energy consumption (Figure 2.1.4-5). The share of the transportation sector in the total energy consumption has increased from 14.7% in 2000 to 22% in 2010. Figure 2.1.4-6 illustrates the trend in gasoline and diesel fuel consumption in the road transportation sector from 1980 to 2010. It shows that the road transportation sector consumed slightly more diesel fuel compared to gasoline fuel in the past 2 decades. In a BAU scenario, the proportion of diesel consumption is projected to rise from 48% in 2010 to 71% in 2040 (World Bank, 2013).

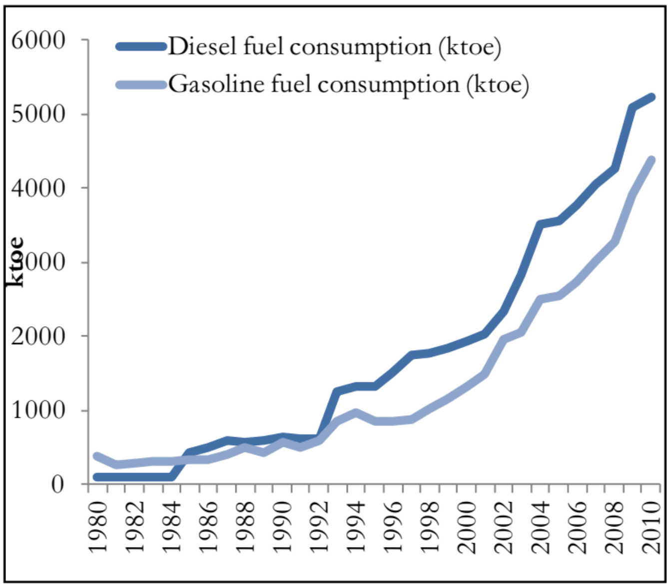
Besides diesel and gasoline fuels, the use of ethanol E5 has been mandated since 1 January 2018 and E10 is intended to be sold to the market soon, expected to be available in the market in 2019 and nationwide in 2020. With E5 fuel mandated, gasoline RON92 was banned and replaced by RON92 E5. RON95 gasoline serves as a premium fuel for luxury vehicles. Euro 5 diesel fuel was also introduced to the market by Petrolimex in January 2018. Compressed natural gas (CNG) is a potential fuel for the transportation sector. This fuel is now used for buses in Ho Chi Minh City and is being considered for use for freights in southern Viet Nam. In the north, expecting the CNG source from Thai Binh province to be exploited, CNG will be introduced for the transportation sector.

Figure 2.1.4-5 Share of Final Consumption in Viet Nam by Economic Sector, 2010



Source: World Bank (2013).

Figure 2.1.4-6 Road Transport Diesel and Gasoline Consumption in Viet Nam, 1980–2010

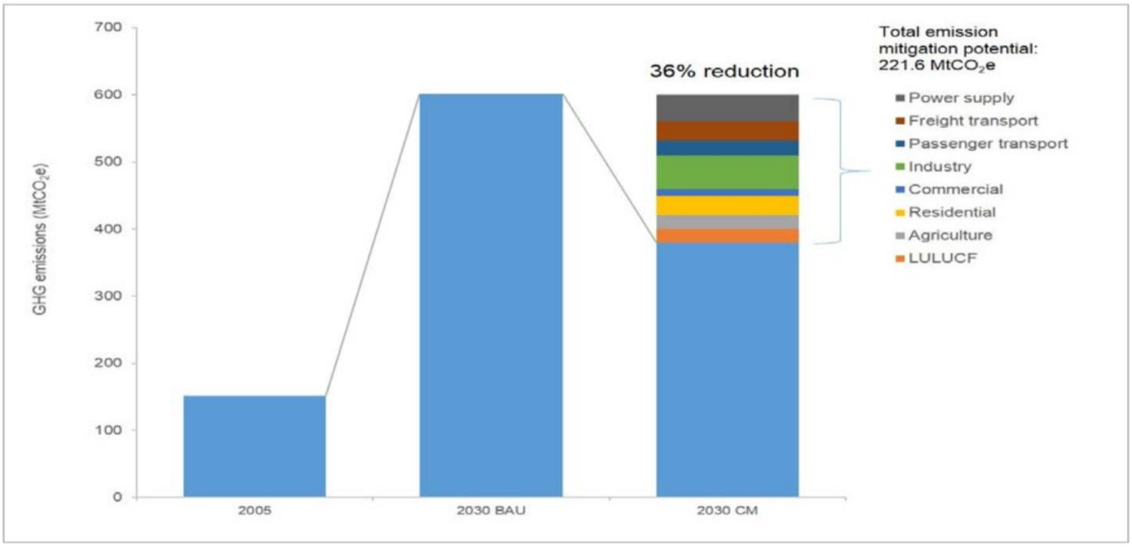


ktoe = kilotonne of oil equivalent.
Source: World Bank (2013).

Diversification of the transport fuel modes is also being considered to pursue greenhouse gas (GHG) emissions reduction targets. Nguyen et al. (2012) projects a 23 million tonnes of carbon dioxide equivalent (tCO2e) and 29 million tCO2e emissions reduction in 2030 from passenger transport and freight transport, respectively, by adopting a selection of low-carbon measures. In 2005, freight transport relied on roads, carrying 71% of the total weight volume, while the rest was transported by maritime (27%) and rail (2%). Considering a growth in emissions from freight transport due to rapid development in the industry sector, the proposed countermeasures include a modal shift from trucks to rail (increase from 2% to 5%) and maritime transport (increase from 27% to 30%), which reflects an emissions reduction of 4.0 metric tonnes of carbon dioxide equivalent (MtCO2e), as well as improvement of the efficiency of vehicles being used.

The switch to biofuel from oil reflects emissions reductions of 23.9 MtCO2e and 1.1 MtCO2e, respectively.

Figure 2.1.4-7 Greenhouse Gas Emissions and Mitigation Potential in Viet Nam



Source: Nguyen et al. (2012).

In another study in 2011, the World Bank outlined several mitigation opportunities in Viet Nam and their theoretical emissions reductions. Since motorcycles are responsible for a large fraction of vehicular emissions in Viet Nam and passenger car ownership is projected to increase as income levels increase, the improvement in fuel efficiency must remain a priority for Viet Nam, including a modal shift from road freight to inland waterways, coastal shipping, and railways (World Bank, 2011). The study indicated that such mitigation opportunities in the transportation sector can theoretically lead to a reduction of 18.37 MtCO2e annually, while its feasible medium-term (2015) goals could reduce 5.49 MtCO2e annually.

1.4.5. Current National Plans for Reduction of Energy Consumption and Greenhouse Gas

Assumptions based on power generation according to BAU in the Intended Nationally Determined Contributions in 2015 (MoNRE, 2015) project that the share of GHG emissions from the transportation sector will be 22.5%, 22.5%, and 13% for the years 2010, 2020, and 2030, respectively.

Table 2.1.4-5 Greenhouse Gas Inventory in 2010 and Projections for 2020 and 2030 for the Energy Sector in Viet Nam

GHG source categories	2010 (MtCO2e)	2020 (MtCO2e)	2030 (MtCO2e)
1 Total	**139.9**	**389.2**	**675.4**
1A Fuel combustion	***123.0***	***355.7***	***620.3***
1A1 Energy industries	41.1	171.3	404.4
1A2 Manufacturing industries and combustion	38.1	69.3	92.5
1A3 Transport	31.8	87.9	87.9
1A4a Commercial/institutional	3.3	8.4	12.1
1A4b Residential	7.1	16.5	20.5
1A4c Agriculture/forestry/fishing	1.6	2.3	2.9
1B Fugitive emissions	***16.9***	***33.5***	***55.1***
1B1 Solid fuels	2.2	16.0	18.5
1B2 Natural oil and gas	14.7	17.5	36.6

GHG = greenhouse gas, MtCO2e = metric tonne of carbon dioxide equivalent.
Source: MoNRE (2015).

For GHG mitigation scenarios, the Intended Nationally Determined Contributions in 2015 specify the national contribution (target) for 2021–2030, covering Viet Nam's entire economy as follows:

- Unconditional contribution: With domestic resources, by 2030, Viet Nam will reduce GHG emissions by 8% compared to BAU.[1]
    - Emission intensity per unit of GDP will be reduced by 20% compared to the 2010 levels.
    - The level of forest cover will increase to 45%.
- Conditional contribution: With international support and the implementation of new mechanisms under the Global Climate Agreement, by 2030, Viet Nam will reduce GHG emissions by 25% compared to BAU as follows:
    - Energy (including transport and communications), agriculture (including land use and forestry), and waste can make the greatest contributions.
    - The cost of adaptation is estimated in excess of 3–5% of GDP by 2030.
    - Investments from the private sector and international support are required.

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[1] Viet Nam's BAU scenario for GHG emissions was developed based on the assumption of economic growth in the absence of climate change policies. The BAU starts from 2010 (the latest year of the national GHG inventory) and includes the energy, agriculture, waste, and land use, land-use change, and forestry (LULUCF) sectors.
− GHG emissions in 2010: 246.8 million tCO2e
− Projections for 2020 and 2030 (not including industrial processes):
o 2020: 474.1 million tCO2e o 2030: 787.4 million tCO2e

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1.5. Malaysia

Malaysia is the fourth largest economy in the region (IMF, 2017). It has a total land mass of 330,803 square kilometres and consists of 13 states and three federal territories. Malaysia's economy has been fuelled by its natural resources and rapid development across the country.

1.5.1. Current Status of Energy Supply

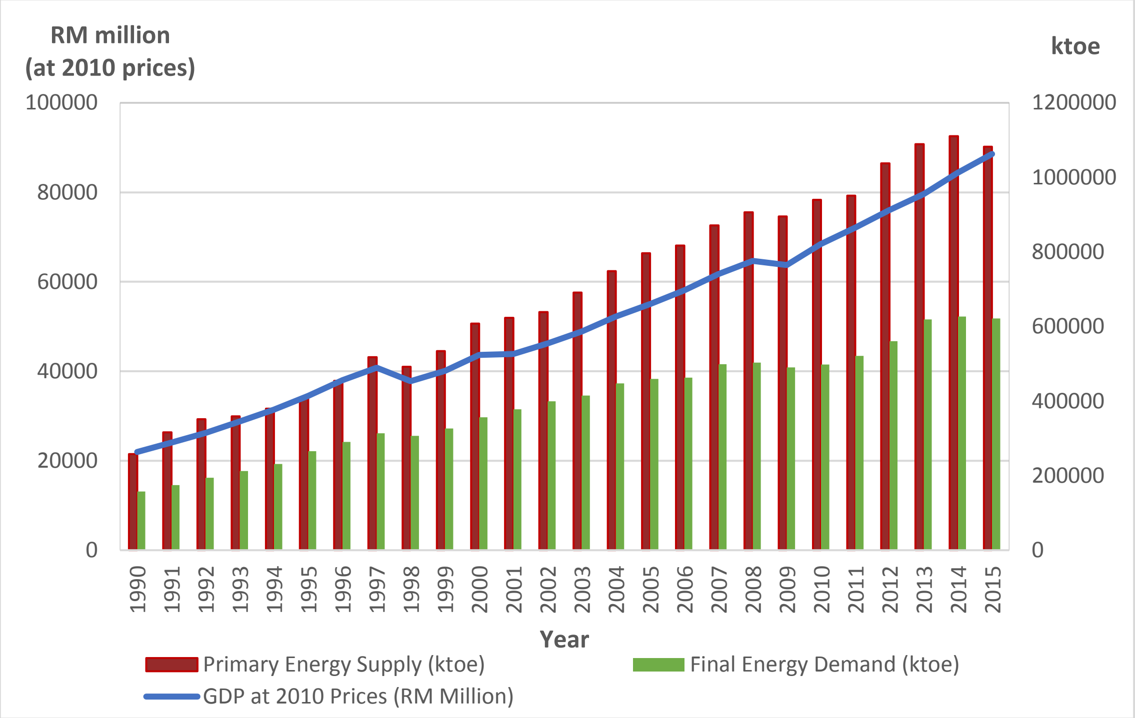
Since the Energy Commission of Malaysia has not yet released the latest information of the National Energy Balance, a summary of Malaysia's energy balance in 2015 is discussed. Fig. 2.1.5-1 shows the variation of gross domestic product (GDP), total primary energy supply, and final energy consumption from 1990 until 2015 (Energy Commission, 2017). The annual GDP growth rate in Malaysia averaged 5.7% from 1990 to 2015. In addition, according to the *World Economic Outlook* report, Malaysia's economy experienced a surge in GDP growth to 6.2% in the third quarter of 2017 as compared to 5.8% in the preceding quarter (IMF, 2017). This stronger economic growth during the third quarter of 2017 was amongst the fastest in Asia in terms of GDP growth, ahead of Singapore, Indonesia and the Republic of Korea. Favourable performances by the services, manufacturing, and construction sectors dominated the growth in GDP.

The annual growth rate of total primary energy supply for Malaysia from 1990 to 2015 was 5.9%. In 2015, the total primary energy supply showed a reduction of 2.5% with 90,187 kilotonnes of oil equivalent (ktoe) compared with 92,528 ktoe in 2014. The decline was mainly caused by lower production of natural gas, which is the primary energy source. Natural gas registered a decrease of 1.9% in 2015 to 39,364 ktoe. However, the export of crude oil and petroleum products increased in 2015, led by a decrease and subsequent reversal in commodity prices. Crude oil production increased by 9.8% in 2014 to 32,440 ktoe in 2015. In addition, the total supply of coal and coke increased by 13.3% to 17,406 ktoe in 2015. The supply of hydropower also showed an increase of 17.9% to 3,582 ktoe in 2015.

Moreover, the annual growth rate of final energy consumption from 1990 to 2015 was 5.6%. Final energy consumption in 2015 decreased by 0.8% to register 51,806 ktoe in 2015. The decline was led by the performance of the transportation sector, which was affected by the economic slowdown during the year. The transportation sector is the largest energy consumer with a 45.2% share of total energy consumption. The sector's energy consumption decreased by 3.7% to 23,435 ktoe in 2015. The decline was a result of the lower consumption of petroleum products (i.e. diesel, aviation turbine fuel, and aviation gasoline fuel). The industrial sector, as the second largest energy consumer with a 27.0% share, increased consumption by 6.3% compared to the preceding year. The positive growth in the industrial sector was mainly supported by construction activities and infrastructure projects. This was followed by the residential and commercial sector, with its share of 14.6% of the total energy consumption, which increased consumption by 1.3% compared to the previous year. This rise was mainly attributed to growth in electricity and liquefied petroleum gas supply. The non-energy use is the use of the products resulting from the transformation process for non-energy purposes.

The use of energy products, with its share of 11.4%, showed a slight decrease of 4.7%, or a total of 5,928 ktoe. The agriculture sector consumed the least energy and recorded a negative growth of 14.4% at 895 ktoe, which was caused by lower crude palm oil output.

Figure 2.1.5-1: Variation of GDP, Total Primary Energy Supply, and Final Energy Consumption in Malaysia, 1990–2015



GDP = gross domestic product, ktoe = kilotonne of oil equivalent, RM = Malaysian ringgit.
Source: Energy Commission of Malaysia (2017).

1.5.2. Current Status of Transportation Fuel Supply

Malaysia has spent heavily on refining activities by gearing up its capacity to become a net oil product exporter. To date, Malaysia has six refineries with a combined capacity of about 584,000 barrels per day (bbl/d). In addition, it is currently developing Pengerang Integrated Petroleum Complex in Johor as a part of Malaysia's goal to compete with the oil refinery and storage hub in Singapore. The refinery plants and their capacity are listed in Table 2.1.5-1.

Table 2.1.5-1. Official Refineries in Malaysia and Their Capacity

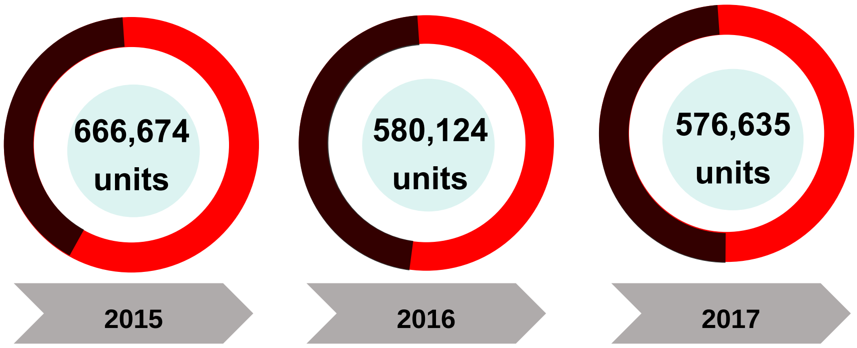
Refinery Plant	Refinery Capacity (bbl/d)
Melaka II Refinery (Petronas and ConocoPhillips)	170,000
Hengyuan Port Dickson Refinery (Hengyuan Refining Company)	156,000
Melaka I Refinery (Petronas)	100,000
Petron Port Dickson Refinery (Petron)	88,000
Kertih Refinery (Petronas)	40,000
Kemaman Bitumen Refinery (TIPCO)	30,000
Pengerang Integrated Petroleum Complex (Petronas and Saudi Aramco) – in progress	300,000 (expected)
Total	**884,000**

bbl/d = barrel per day.

Source: Export fov (2018).

Figure 2.1.5-2 shows the sales of new vehicles in the Malaysian market from 2015 to 2017 (Lim, 2018). Sales of new vehicles dropped from 666,674 units in 2015 to 580,124 units in 2016 and further to 576,635 units in 2017. This decline was due to depreciation of the Malaysian ringgit, high living cost, higher prices of new vehicles, and difficulties to secure vehicle loans. Amongst the new vehicles purchased, those with gasoline-powered engines accounted for about 80% of the market. These are the most common vehicles in Malaysia. Meanwhile, sales of diesel-powered vehicles such as trucks, buses, and pickups are growing slowly.

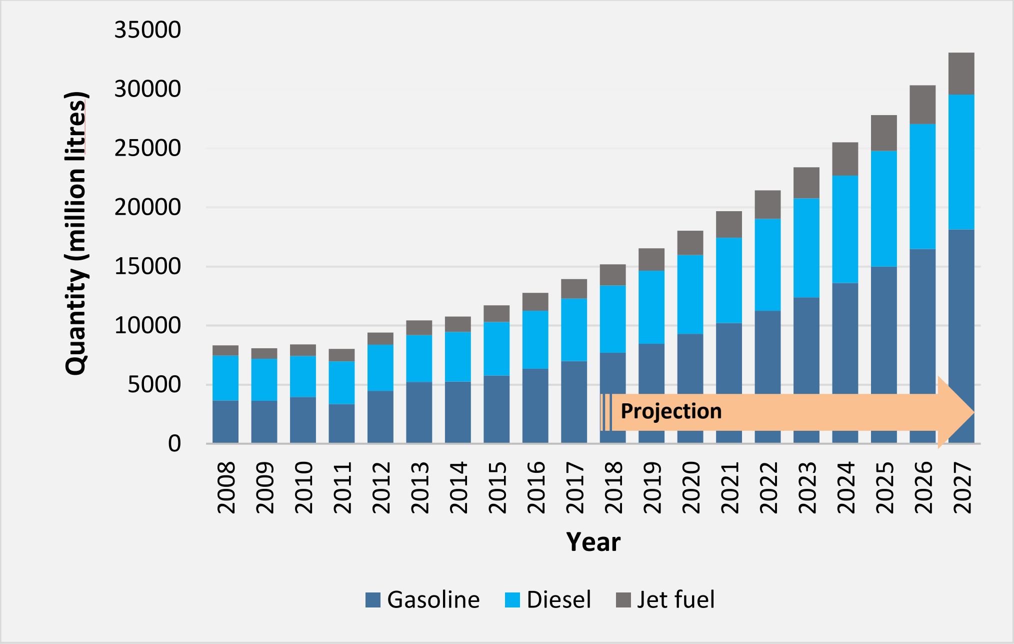
Figure 2.1.5-2: Sales of New Vehicles in the Malaysian Market, 2015–2017



Source: Lim (2018).

In addition, there are two common types of gasoline available in Malaysia: RON95 and RON97. However, high-grade fuels with higher octane ratings, such as Blaze 100 Euro 4M (Petron Malaysia) and V-Power Racing (Shell Malaysia), have officially been marketed in selected pump stations in Malaysia. As for diesel fuel, there are two types available in the market as options to consumers: B7 biodiesel blend and Euro 5 diesel. However, use of Euro 5 diesel as road diesel has been lower due to its higher price compared with B7. Figure 2.1.5-3 presents the fuel use history and projected use in the country. Fuel consumption steadily increased from 2008 to 2017 and is forecasted to increase further for the next 10 years. Amongst the fuel types, gasoline fuel accounts for about 50% of the total fuel use.

Figure 2.1.5-3: History and Projections of Fuel Use in Malaysia



Source: Wahab (2017).

1.5.3. Current Status of Biofuel Supply in the Transportation Sector

Biodiesel produced in Malaysia is derived from crude palm oil, which is abundant and low cost. Meanwhile, ethanol is produced from palm oil mill effluent, but the production is not significant due to high capital investment and production costs as well as lack of advanced technology. However, ethanol is excluded as an alternative fuel under the Malaysian Biofuel Industry Act.

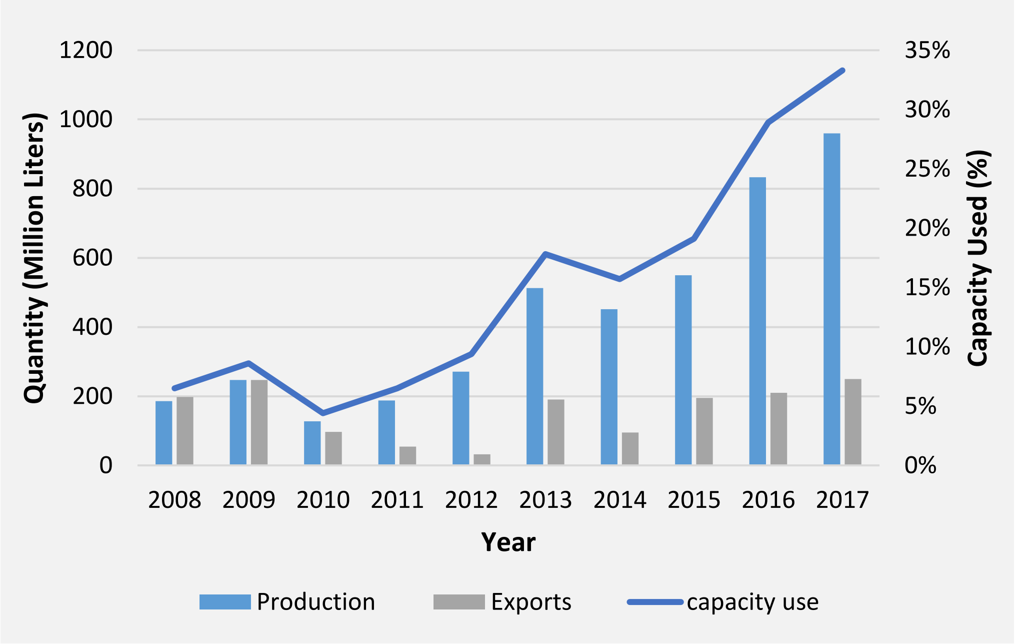
As of 2017, there were 17 biodiesel plants operating in Malaysia, as listed in Table 2.1.5-2. The production of biodiesel in the country has steadily increased since 2014 from 451 million litres to 960 million litres in 2017 (Figure 2.1.5-4). In fact, this is far from the nameplate production capacity of 2.5 billion litres. The biodiesel production does not meet the demand, even though it has the potential to do so. Biorefineries in Malaysia only use about a third of the total capacity. Biodiesel is also produced for export. Due to underutilisation of operations, the Government of Malaysia has not issued new licences for biofuel processing plants. Instead, some of the plants produce other oleochemical products, such as fatty acids, soaps, noodles, glycerine, and so on.

Table 2.1.5-2. Biodiesel Plants in Malaysia

Biodiesel Plant	Location
Carotech Berhad (Chemor Plant)	Chemor, Perak
Carotech Berhad (Lumut Plant)	Lumut, Perak
Carotino Sdn. Bhd.	Pasir Gudang, Johor
Felda Global Ventures Downstream Sdn. Bhd.	Kuantan, Pahang
Future Prelude Sdn. Bhd.	Port Klang, Selangor
Global Bio-Diesel Sdn. Bhd.	Lahad Datu, Sabah
KL – Kepong Oleomas Sdn. Bhd.	Port Klang, Selangor
Malaysia Vegetable Oil Refinery Sdn. Bhd.	Pasir Gudang, Johor
Nexsol (Malaysia) Sdn. Bhd.	Pasir Gudang, Johor
PGEO Bioproducts Sdn. Bhd.	Pasir Gudang, Johor
Senari Biofuels Sdn. Bhd. (Global Bonanza)	Kuching, Sarawak
Sime Darby Biodiesel Sdn. Bhd. (Carey Island)	Pulau Carey, Selangor
Sime Darby Biodiesel Sdn. Bhd. (Panglima Garang)	Teluk Panglima Garang, Selangor
SPC Bio-Diesel Sdn. Bhd.	Lahad Datu, Sabah
Vance Bioenergy Sdn. Bhd.	Pasir Gudang, Johor
YPJ Palm International Sdn. Bhd.	Pasir Gudang, Johor

Source: Wahab (2017).

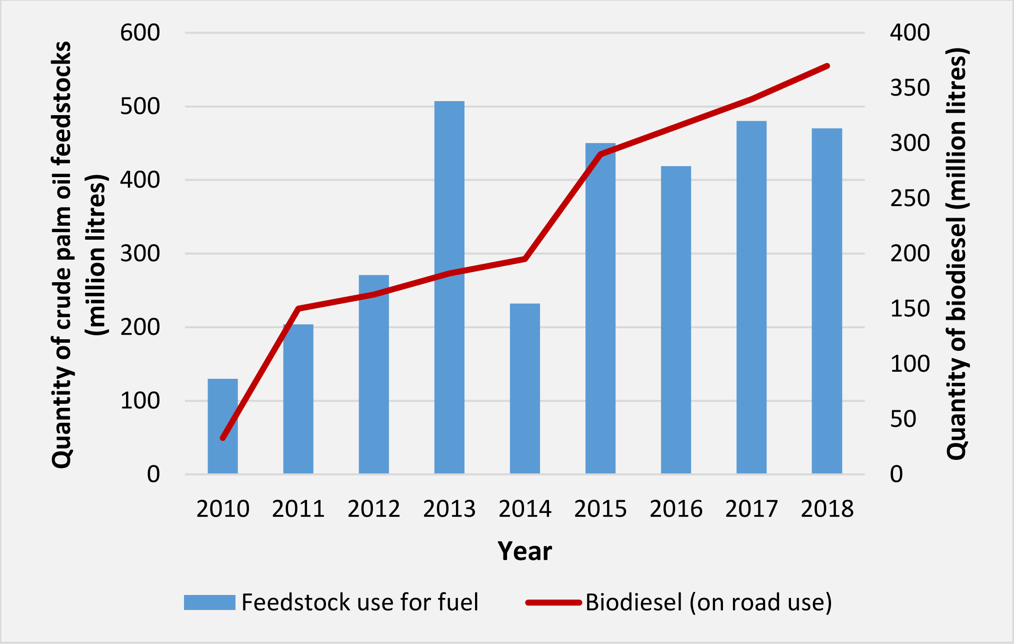
Figure 2.1.5-4: Production of Biodiesel in Malaysia



Source: Malaysian Palm Oil Board.

B5 biodiesel was first introduced in 2011 in the state of Negeri Sembilan, Selangor, Kuala Lumpur, Putrajaya, and Malacca, followed by Johor in 2013. Nationwide implementation, both in Peninsular Malaysia and East Malaysia, was achieved at the end of 2014. Figure 2.1.5-5 shows that the consumption of biodiesel for transportation in Malaysia significantly increased to 290 million tonnes in 2015 from 195 million tonnes in 2014. In 2015, the B7 mandate was fully implemented throughout the country to replace B5 blend, causing the consumption of biodiesel for transportation fuel to drastically increase. However, the delay of the B10 mandate in 2016 reduced the forecasted consumption of biodiesel. The total biodiesel consumption in 2016 was about 315 million litres and the crude palm oil feedstock use for biodiesel production was about 369 million tonnes. The forecast of the consumption of biodiesel was 340 million litres in 2017 and 370 million litres in 2018.

Figure 2.1.5-5: Consumption of Biodiesel in Malaysia



Source: Malaysian Palm Oil Board.

1.5.4. Fuel Demand and Biofuel Supply Outlook Based on National Plan

The Government of Malaysia launched the Eleventh Malaysia Plan (2016–2020) to support the palm oil industry in Malaysia. Under this plan, the B15 mandate will be implemented nationwide by 2020 for the road sector, though details are lacking. To date, the government has continuously postponed the implementation of the B10 mandate due to protests from the automobile manufacturers over engine warranties and high palm oil prices in 2016.

Malaysia’s biodiesel production is projected to remain flat in 2018 due to delays of the B10 mandate for transportation and the B7 blend for industry in 2017. According to projections in the Global Agricultural Information Network (GAIN) Report (Wahab, 2017), with the average blend rate in 2018 forecasted at 7%, the total consumption of biodiesel will be 370 million litres and the total production of biodiesel will be 470 million litres, equivalent to 414,000 tonnes of crude palm oil feedstock. At the 28th Global Palm and Lauric Oils Conference 2017 in Kuala Lumpur, it was estimated that Malaysia will produce about 900,000 tonnes of biodiesel in 2017, which was an increase of up to 80% from half a million tonnes the previous year's estimate (MBA, 2017). The biodiesel plants in Malaysia are currently working at below 25% of their utilisation capacity.

1.5.5. Current National Plans for Reduction of Energy Consumption

To promote efficient use of energy in Malaysia, Prime Minister Najib Razak launched the National Green Technology Policy on 24 July 2009. The policy is based on four pillars (energy, environment, economy, and social) and aims to accelerate the national economy and promote sustainable development. Malaysia is committed to reducing greenhouse gas emissions intensity (per unit GDP) by 35% by 2030 relative to the emissions intensity in 2005, as part of its commitment under the Kyoto Protocol and the Paris Agreement. Focusing on the transportation sector in Malaysia, the following are initiatives to reduce energy consumption and emissions of harmful gases:

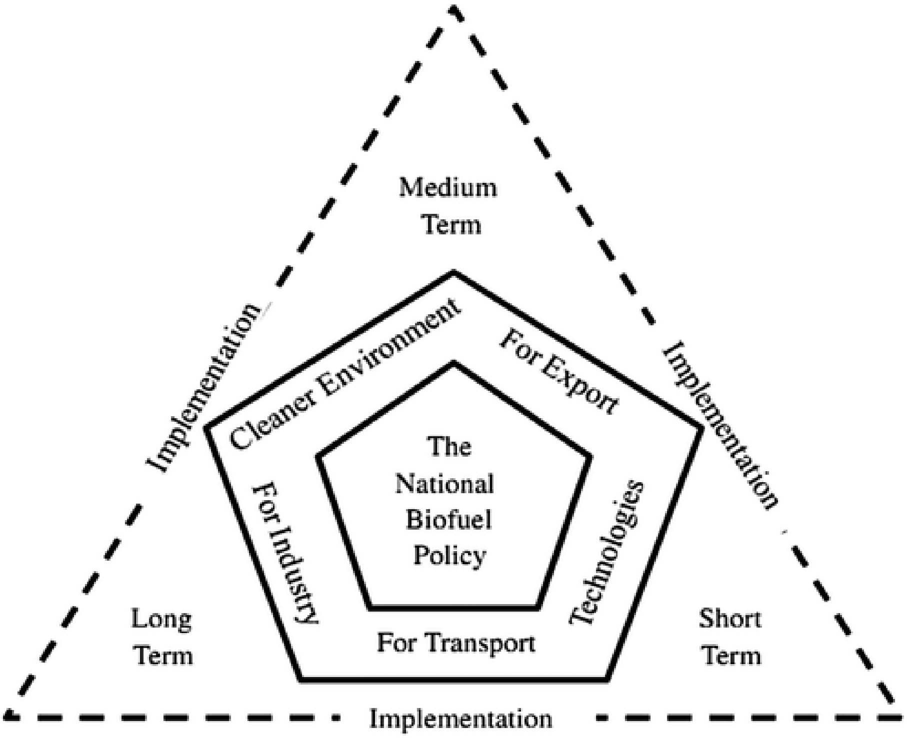
1. Encourage people to mix and match their transport modes. Commuters should be encouraged to use public transport to reduce congestion within the cities and minimise pollution.
2. Adopt energy-efficient vehicles, especially for public transport such as buses and taxis. Such vehicles can reduce dependency on fossil fuel and fuel wastage as well as minimise the environmental effects of harmful gases and black smoke.
3. Improve and add public transport in cities. This includes mass rapid, light rail, and bus rapid transit.
4. Encourage sustainable energy use for transportation such as EURO 4M, EURO 5 standards for clean fuel, and B15 rollout by 2020.
5. Add refining capacity of petroleum products installed in Pengerang, Johor.
6. Establish liquefied natural gas technology to improve energy efficiency and reduce fuel import.
7. Improve industrial technology and efficiency by contributing to research and development, thus translating innovation to wealth.
8. Adopt green-based development and practices by providing relevant policy and institutional frameworks for green growth.

1.5.6. Current National Plans for Alternative Fuel Introduction

The need to develop an alternative, cheaper, sustainable, and locally available fuel supply is a priority for the country. Since 1982, the government has invested in research and development of biodiesel technology conducted by the Malaysian Palm Oil Board, the Standards and

Industrial Research Institute of Malaysia, and local universities. The government has introduced a range of policies in order to improve biofuel policies. The National Biofuel Policy was launched in 2006 to strengthen the palm oil industry and reduce dependency on fossil fuels. Figure 2.1.5-6 shows the strategic dimensions and implementation of the policy (Rahyla, Radin Firdaus, and Purwaningrum, 2017). Subsequently, the Malaysian Biofuel Industry Act, which is aligned with the objective the National Biofuel Policy, was enacted by the Malaysian Parliament in 2017 to provide a mandatory regulation to implement the biodiesel blend mandate and licensing of activities related to the biofuel industry.

Figure 2.1.5-6: Strategic Dimensions and Implementation of the National Biofuel Policy in Malaysia



Source: Rahyla, Radin Firdaus, and Purwaningrum (2017).

As discussed in the previous section, the Government of Malaysia is working to increase the palm oil biodiesel blending requirements through the B15 mandate by 2020, which is highlighted in the Eleventh Malaysia Plan. Thus far, the phased implementation of the B10 biodiesel programme for the transportation sector has been indefinitely postponed. The government is making efforts to convince stakeholders of the compatibility of the B10 blend, including by providing tax exemptions to petrol stations.

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2. Simulation of Transportation Energy by Energy Mix Model

2.1. Objective and Scope

The objective of this study is to investigate the potential of a diversified transportation energy mix and its effective use up to 2030. It covers five countries (Thailand, Indonesia, Malaysia, the Philippines, and Viet Nam) in the Association of Southeast Asian Nations (ASEAN) by considering their respective economy, energy status, and automotive market scale (Table 2.2.1-1).

Table 2.2.1-1. Economic, Energy, and Automotive Market Information of the ASEAN Member States

	Data	Year	Units	Country									
				Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Mynmar	Philippines	Singapore	Thailand	Vietnam
Economics	Area	2014	Sq.km.	5,765	181,035	1,904,567	236,797	329,847	676,578	300,000	683	513,113	331,689
	Population	2013	Million	0.4	15	250	6.7	30	53	98	5	67	90
	GDP	2013	Billion USD	16	15	868	11	313	56	272	298	387	171
	GDP per capita	2013	USD	38,563	1,007	3,475	1,661	10,538	1,103	2,765	55,182	5,779	1,910
	GDP Growth	2013	%	−1.8%	7.4%	5.8%	8.5%	4.7%	8.3%	7.2%	3.9%	1.8%	5.4%
Energies	Crude Oil Proved Reserve	2011	Billion Barrels	1.1	–	3.7	–	4	0.1	0.1	–	0.5	4.4
	Natural Gas Proved Reserve	2011	Trillion Cubic Feet	14	–	103	–	83	10	3.5	–	8.4	25
	Total Petroleum Production	2012	'000 Barrels/day	9	–	946	–	561	16	172	1,099	1,197	150
	Domestic Use	2012	'000 Barrels/day	18	29	1,698	3	670	25	310	192	1,152	453
	Import												
	Refined Product	2012	'000 Barrels/day	8	29	699	3	303	9	152	1,914	67	298
	Crude Oil	2012	'000 Barrels/day	–	–	374	–	200	–	136	1,078	803	–
	Export												
	Refined Product	2012	'000 Barrels/day	–	–	79	–	236	–	12	1,685	234	35
	Crude Oil	2012	'000 Barrels/day	142	–	401	–	245	1	26	0	45	314
	Natural Gas Production	2013	Billion Cubic Feet	440	–	2,486	–	2,260	463	103	–	1,476	311
	Natural Gas Consumption	2013	Billion Cubic Feet	105	–	1,381	–	1,125	162	103	340	1,846	311
	Electricity Generation	2012	Billion Kilowatthour	4	1	185	12	127	10	70	45	156	118
	Electricity Consumption	2012	Billion Kilowatthour	4	3	167	3	119	8	61	44	156	108
	Primary Energy Production	2012	Quadrillion BTU	0.8	0.0	16.3	0.1	3.8	0.6	0.5	0.0	2.6	2.6
	Primary Energy Consumption	2012	Quadrillion BTU	0.2	0.1	6.4	0.1	3.1	0.3	1.3	3.1	5.1	2.3
	Number of refinery	2014	Units	1	–	8	–	6	3	2	3	8	1
	Crude Distillation Capacity	2012	'000 Barrels/day	9	–	1,012	–	539	57	273	1,357	584	140
		2014	'000 Barrels/day	na	–	1,095	–	591	na	290	1,514	1,242	140
Auto Market	Vehicle Ownership Rate		Units/'000 people	510	21	69	20	361	7	30	149	206	23
	Vehicle Stock number		Units										
	Vehicle Sales in 2014	2014	Units	18,114	–	1,208,019	–	666,465	–	234,747	47,443	881,832	133,588
	Motocycle Sales in 2014	2014	Units	–	–	7,908,941	–	442,749	–	790,425	8,145	1,701,535	–
	Vehicle Production in 2014	2014	Units	–	–	1,298,523	–	596,418	–	88,845	–	1,880,007	121,084

ASEAN = Association of Southeast Asian Nations.
Sources: World Bank, International Monetary Fund, Energy Information Administration, ASEAN Centre for Energy, ASEAN Automotive Federation.

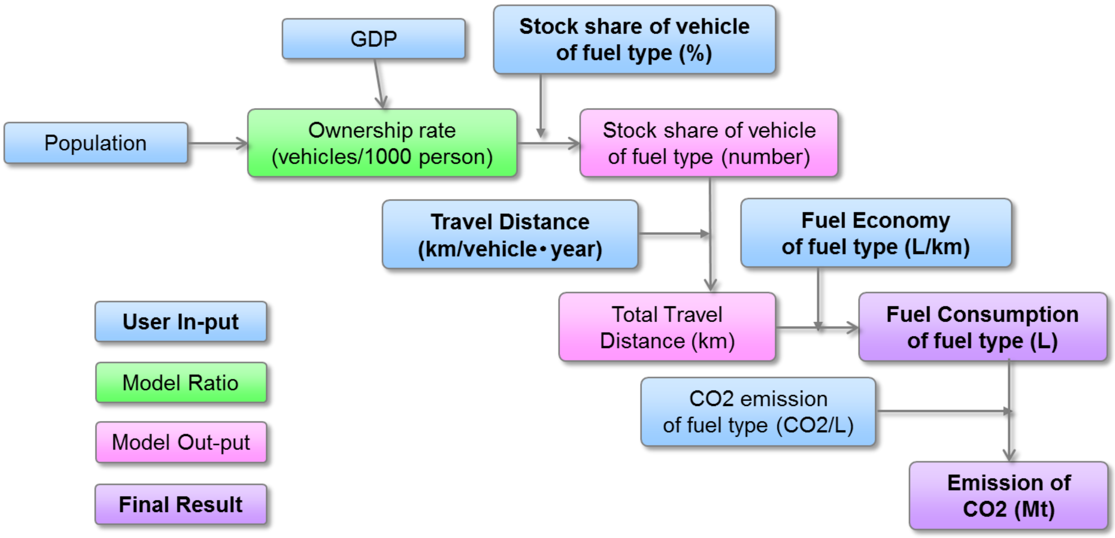
The study looked at existing energy policies, fuel supply and demand status related to road transportation, petroleum products (gasoline and diesel fuel) and alternative fuels such as natural gas and biofuels (ethanol and biodiesel), as well as oil refining/biofuel production capacity, amongst others. To correct for gaps between oil reduction targets and business-as-usual (BAU) consumption as well as required amounts of biofuel to achieve introduction targets and possible supply, measures to minimise these gaps or to achieve policy targets were investigated and proposed.

2.2. Methodology

Using the Energy Mix Model, we simulated the energy consumption trend of road transportation up to 2030. The simulation model of each country was developed by Toyota Motor Corporation (in corporation with Mizuho Information & Research Institute, Inc.) based on the IEA/SMP Model.

The calculation flow of energy consumption is shown in Figure 2.2.2-1, which enables estimation of CO_2 emissions of road transportation by using the CO_2 emission factor of each type of fuel. The IEA/SMP Model deals with data for transportation energy globally, but we modified and established a fit-for-road transportation country base Energy Mix Model.

Figure 2.2.2-1. Calculation Flow of Energy Consumption by Energy Mix Model



CO2 = carbon dioxide, GDP = gross domestic product, km = kilometre, L = litre, Mt = megaton.
Source: Authors.

For the simulation, ASEAN Member States provided specific data based on statistical data and literature for each country, including vehicle registration numbers, actual fuel economy varies depending on the usage condition of a vehicle, and mileage travelled annually by vehicle/fuel type. In addition, we collected and studied information on energy policies, supply ability of domestic resources, and oil refining/biofuel production capacity.

The following are the steps of our investigation:

1) Estimate BAU energy consumption trend up to 2030
2) Estimate energy consumption trend after energy policies (energy conservation, alternative energy introduction, etc.) are implemented
3) Examine possibility of achieving energy policy target at the same time based on supply ability of petroleum products, biofuels, etc.
4) Once gaps between BAU and policy targets become clear, investigate measures to minimise them by considering supply ability of domestic resources (oil, natural gas, raw materials for biofuels), together with oil refining/biofuel production capacity for mitigating energy issues in each country

2.3. Results and Discussion

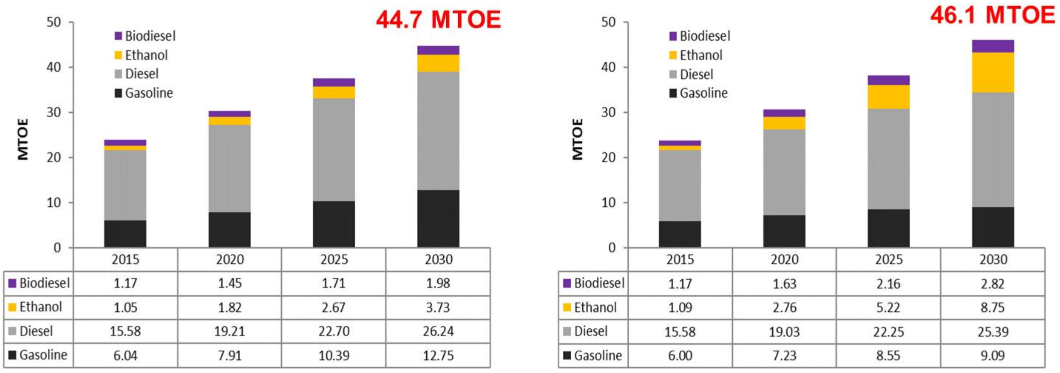
1) Thailand

Policies of Thailand related to transportation energy are the Alternative Energy Development Plan (AEDP 2015–2036) and the Energy Efficiency Plan (EEP 2015-2036). The AEDP promotes use of biofuels by aiming to reach 11.3 million litres per day of ethanol (up to E20/E85) and 14 million litres per day of biodiesel (up to B10/B20) by 2036. The EEP encourages energy conservation, and the Ministry of Energy projects that a 46.2% reduction of energy consumption compared to BAU is required in the transportation sector by 2036. We evaluate the appropriateness of target setting for road transportation and difficulty in achieving policy targets.

1-1) Oil Consumption and Biofuel Introduction Potential

The Energy Mix Model of Thailand estimates total energy consumption of road transportation in terms million tonnes of oil equivalent (MTOE) up to 2030. The results of the simulation for both the BAU and biofuels cases are shown in Figure 2.2.3-1. Total energy consumption for the biofuels case increased because of lower calorific value of biofuels compared to gasoline/diesel fuel after a large amount of biofuels is introduced by 2030.

Figure 2.2.3-1. Total Energy Consumption of Road Transportation in Thailand



a) Business as usual **b) Biofuels case**

a) Business as usual

	2015	2020	2025	2030
Biodiesel	1.17	1.45	1.71	1.98
Ethanol	1.05	1.82	2.67	3.73
Diesel	15.58	19.21	22.70	26.24
Gasoline	6.04	7.91	10.39	12.75

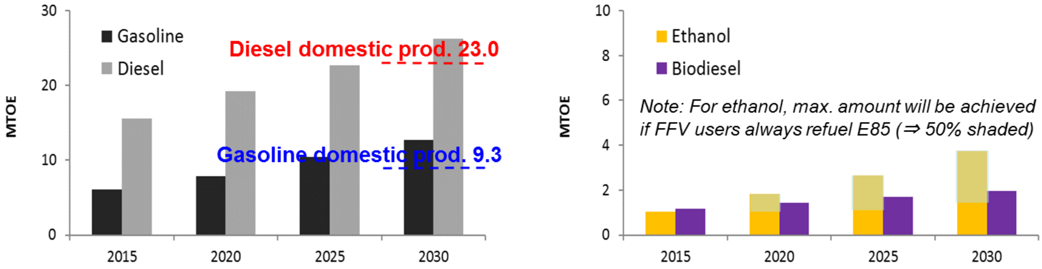
b) Biofuels case

	2015	2020	2025	2030
Biodiesel	1.17	1.63	2.16	2.82
Ethanol	1.09	2.76	5.22	8.75
Diesel	15.58	19.03	22.25	25.39
Gasoline	6.00	7.23	8.55	9.09

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figures 2.2.3-2 and 2.2.3-3 show gasoline/diesel fuel and biofuel consumption of the BAU case and biofuels case, respectively. The supply ability of each type of fuel is shown in the corresponding graph.

Figure 2.2.3-2. Fuel Consumption of Business-as-Usual Case in Thailand

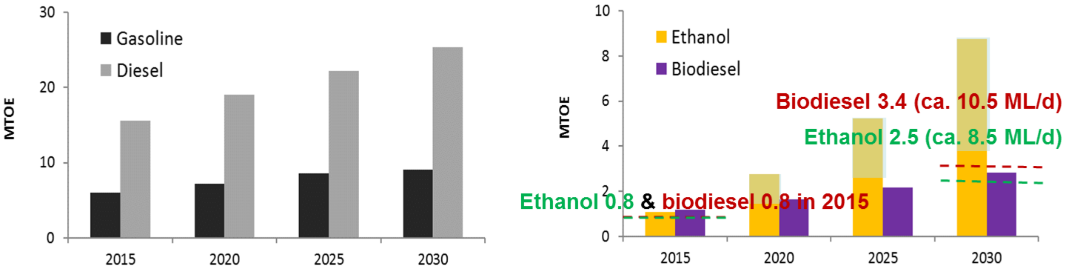


a) Gasoline/diesel fuel

b) Biofuels

FFV = flexible fuel vehicle, MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-3. Fuel Consumption of Biofuels Case in Thailand



a) Gasoline/diesel fuel

b) Biofuels

ML/d = megalitre per day, MTOE = million tonnes of oil equivalent.
Source: Authors.

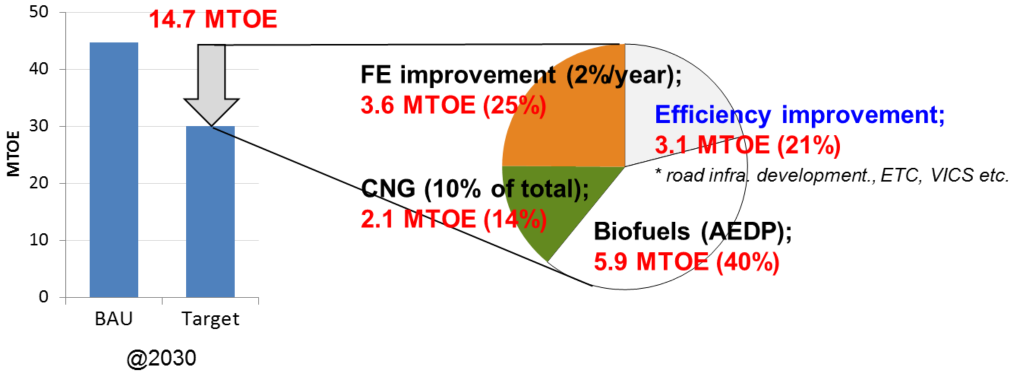
The transportation sector in Thailand consumes more diesel fuel than gasoline. This imbalance in gasoline and diesel fuel consumption is one of the energy issues; if the difference in gasoline and diesel fuel consumption becomes too big, it will affect the healthy operations of oil refineries.

As shown in Figures 2.2.3-2 and 2.2.3-3, the introduction volume of ethanol for the gasoline blend is larger than that of biodiesel for the diesel fuel blend, especially once the AEDP target is fully implemented (biofuels case), and the imbalance between gasoline and diesel fuel consumption will worsen compared to the level today (the blending mandate is E10/E20 and B7). We believe that the biofuel introduction target setting of the AEDP is inadequate, and full implementation of the AEDP target is not recommended. On the other hand, according to the current ethanol production ability projection, it may be difficult to secure sufficient ethanol to fulfil the AEDP target, but the government is making an ongoing effort to increase raw material production for ethanol. The biodiesel production ability projection shows sufficient capability, if the raw material supply is secured.

1-2) Oil Reduction (Energy Conservation) Potential

The required energy reduction – or oil reduction in the case of road transportation – by the EEP in the transportation sector by 2030 is 14.7 MTOE. Figure 2.2.3-4 shows the estimates of the allocation of oil reduction measures based on the AEDP target, compressed natural gas (CNG) use, possible oil reduction by fuel economy (FE) improvement of new vehicles, and remaining portion.

Figure 2.2.3-4. Evaluation of Oil Reduction Potential Based on the Energy Efficiency Plan Requirement in Thailand



AEDP = Alternative Energy Development Plan, BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, FE = fuel economy, MTOE = million tonnes of oil equivalent, VICS = vehicle information and communication system.
Note: Target is an assumption based on EEP 2015-36.
Source: Authors.

The biofuel introduction target of the AEDP will reduce oil consumption by 5.9 MTOE, CNG (set to be the same as the current CNG utilisation ratio, that is approximately 10% of current total energy consumption) can replace 2.1 MTOE of oil, and FE improvement of new vehicles (at a reasonable level of 2% improvement per year) will reduce consumption by 3.6 MTOE. In order to fulfil the requirement, a further 3.1 MTOE of oil reduction has to be achieved through efficiency improvement of the traffic system, such as road infrastructure development and traffic flow management (electronic toll collection, vehicle information and communication system, etc.) to increase the average traffic speed. A so-called integrated approach of oil reduction measures is required, which includes not only direct replacement of oil by alternative fuels and reduction of oil consumption by FE improvement of new vehicles, but also conservation of oil through efficiency improvement of the traffic system.

Achieving the energy conservation target of the EEP by 2030 will mean an estimated CO_2 emissions reduction of road transportation of 37.1 kilotonnes of CO_2 (kt-CO_2), equivalent to the reduction of oil use of 43.3 kt-CO_2 and 6.2 kt-CO_2 through CNG use.

1-3) Summary

Energy issues, today and in future (up to 2030)

1) Increasing import dependency of oil and gas
2) For fossil fuels, the imbalance between gasoline and diesel fuel consumption (diesel fuel consumption is much larger compared to gasoline consumption) is an issue; reducing diesel fuel consumption should be prioritised.
3) For biofuels, supply ability of ethanol is optimistic compared to that of biodiesel in the future. However, prioritising the reduction of diesel fuel requires securing sufficient biodiesel production.
4) To introduce higher blending of biodiesel, implementation of hydrotreated vegetable oil (HVO) in addition to fatty acid methyl esters (FAME) is necessary to realise higher blending without any vehicle warranty issues.

Possible measures

1) Achieving the oil reduction target requires an integrated approach of oil reduction measures through efficiency improvement of the traffic system, such as infrastructure development and traffic flow management.
2) An effective measure for reducing diesel fuel consumption is to discourage excessive use of pickups (equipped with diesel engine).
3) Furthermore, securing feedstock for biodiesel (for diesel fuel blend) is important, and promoting HVO use is appropriate.
4) A new funding system to support increased biofuel utilisation is required, because the current status of relying on the Oil Fund system is no longer sustainable.

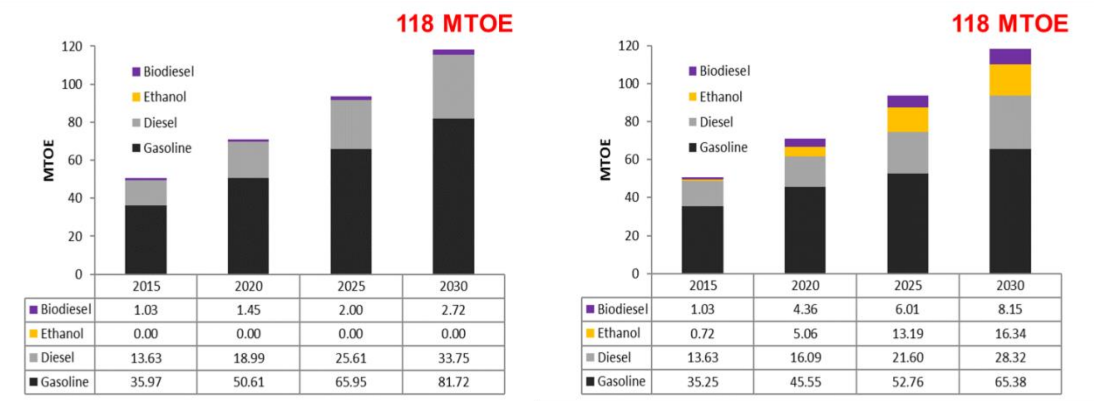
2) Indonesia

The National Energy Policy (or KEN) defines the national energy mix of primary energy consumption. Based on the statistics of the demand and supply of petroleum products in Indonesia, 68% of total oil consumption is estimated to be consumed by road transportation. The General Planning for National Energy (or RUEN) specifies the direction and measures for achieving the KEN target in each sector, together with the introduction target of alternative fuels. According to the Ministry of Energy and Mineral Resources, examples of planned targets related to the transportation sector include mandatory blending of E20 and B30 aiming for total biofuel usage of 5.73 million kilolitres (kL) in 2025, introduction of 2 million units of CNG vehicles aiming for natural gas utilisation of 289 million standard cubic feet per day (mmscfd) until 2025.

2-1) Oil Consumption and Biofuel Introduction Potential

The Energy Mix Model of Indonesia estimates the total energy consumption of road transportation up to 2030. The results of the simulation for both the BAU case and biofuels case are shown in Figure 2.2.3-5.

Figure 2.2.3-5. Total Energy Consumption of Road Transportation in Indonesia



a) Business as usual

	2015	2020	2025	2030
■ Biodiesel	1.03	1.45	2.00	2.72
■ Ethanol	0.00	0.00	0.00	0.00
■ Diesel	13.63	18.99	25.61	33.75
■ Gasoline	35.97	50.61	65.95	81.72

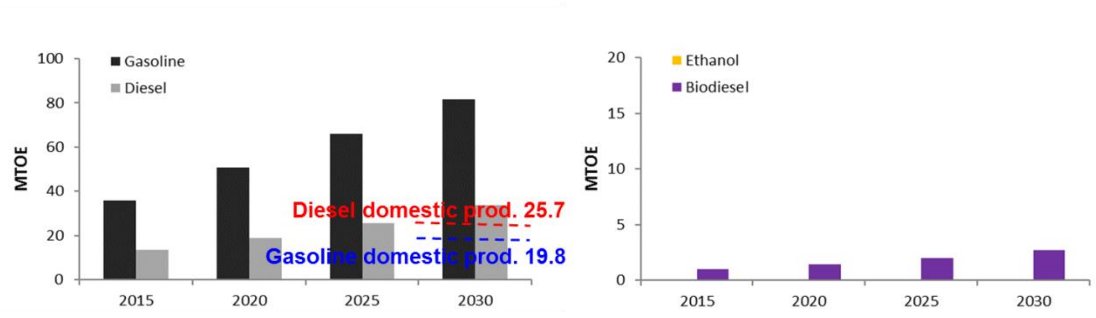
b) Biofuels case

	2015	2020	2025	2030
■ Biodiesel	1.03	4.36	6.01	8.15
■ Ethanol	0.72	5.06	13.19	16.34
■ Diesel	13.63	16.09	21.60	28.32
■ Gasoline	35.25	45.55	52.76	65.38

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-6 shows gasoline/diesel fuel and biofuel consumption of the BAU case, and Figure 2.2.3-7 shows those of the biofuels case. The supply ability of each type of fuel is shown in the corresponding graphs.

Figure 2.2.3-6. Fuel Consumption of Business-as-Usual Case in Indonesia



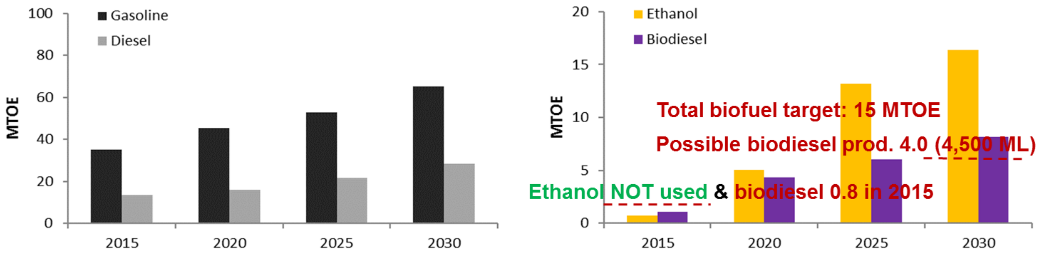
a) Gasoline/diesel fuel

b) Biofuels

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-7. Fuel Consumption of Biofuels Case in Indonesia

a) Gasoline/diesel fuel b) Biofuels



ML = megalitre, MTOE = million tonnes of oil equivalent.
Source: Authors.

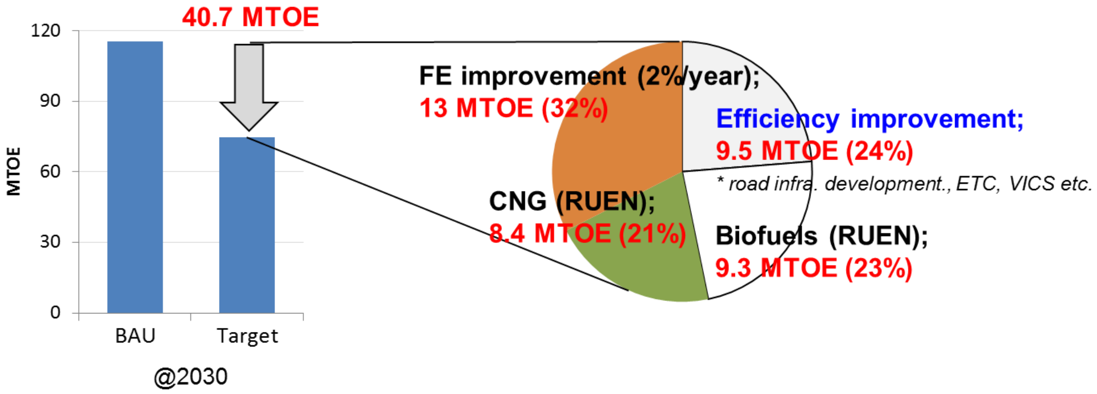
In Indonesia, gasoline consumption is higher than that of diesel fuel in the transportation sector. It is said that approximately 60% of gasoline is consumed by the large number of motorcycles in the country. One energy issue is the imbalance between gasoline and diesel fuel consumption. If the difference in gasoline and diesel fuel consumption becomes too big, it will affect the healthy operations of oil refineries. Domestic refining capacity is below demand, and Indonesia relies on petroleum products import currently, but once the domestic refining capacity fulfils demand in the future (through new refinery projects), this imbalance between gasoline and diesel fuel consumption will be a problem.

Ethanol is currently not used and therefore not considered in the BAU case (Figure 2.2.3-6). According to the biofuel blending mandate of the Ministry of Energy and Mineral Resources Regulation No. 20 of 2014, both ethanol and biodiesel are planned to be used. However, only biodiesel is promoted to increase the blending ratio in practice (already B20) and the imbalance between gasoline and diesel fuel consumption in future will become worse. As shown in Figure 2.2.3-7 (biofuels case), the required volume of ethanol for the gasoline blend is larger than that of biodiesel for the diesel fuel blend once the biofuel blending mandate is fully implemented. We believe that introduction of both ethanol and biodiesel is necessary to mitigate the energy issue of road transportation, but securing sufficient ethanol to fulfil the blending mandate domestically is difficult and the government needs to come up with concrete planned countermeasures. Nevertheless, the biodiesel production projection may meet the blending mandate.

2-2) Oil Reduction (Energy Conservation) Potential

The required oil reduction by the KEN for road transportation (68% of total oil consumption) by 2030 is 40.7 MTOE. Figure 2.2.3-8 shows the estimates of the allocation of oil reduction measures of alternative fuels based on the RUEN introduction target, possible oil reduction by FE improvement of new vehicles, and the remaining portion.

Figure 2.2.3-8. Evaluation of Oil Reduction Potential Based on the KEN Requirement in Indonesia



BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, FE = fuel economy, MTOE = million tonnes of oil equivalent, RUEN = General Planning for National Energy, VICS = vehicle information and communication system.
Note: reduction by each measure are assumptions based on RUEN transport sector.
Source: Authors.

The targeted biofuel and CNG introduction of the RUEN can replace 9.3 MTOE and 8.4 MTOE of oil, respectively, and the FE improvement of new vehicles will reduce 13 MTOE. In order to fulfil the oil reduction requirement, a further 9.5 MTOE oil reduction has to be achieved through efficiency improvement of the traffic system, such as road infrastructure development and implementation of traffic flow management (electronic toll collection, vehicle information and communication system, etc.). An integrated approach of oil reduction measures including efficiency improvement of the traffic system is required for the sake of energy conservation in the transportation sector.

The CO_2 emissions reduction of road transportation is estimated to be 101.4 kt-CO_2 (sum of –128.2 kt-CO_2 through reduction of oil use and +26.8 kt-CO_2 through CNG use) under the condition of achieving the primary energy consumption mix by the KEN by 2030.

2-3) Summary

Energy issues, today and in future (up to 2030)

1) Increasing import dependency of oil and lack of domestic refining capacity compared to demand

2) For fossil fuels, the imbalance between gasoline and diesel fuel consumption (gasoline consumption is much larger compared to diesel fuel consumption) is an issue; reducing gasoline consumption should be prioritised.

3) For biofuels, supply ability of biodiesel is sufficient, but that of ethanol is more difficult. Prioritising the reduction of gasoline introduction of ethanol requires securing its production/supply.
4) To introduce higher blending of biodiesel, implementation of HVO in addition to FAME is necessary to realise higher blending of biodiesel without any vehicle warranty issues.

Possible measures

1) Achieving the oil reduction target requires an integrated approach of oil reduction measures through efficiency improvement of the traffic system, such as infrastructure development and traffic flow management.
2) Utilising domestic gas for public transportation including taxis, as well as fixed route logistic trucks.
3) As motorcycles consume the majority of gasoline, an effective measure to reduce gasoline consumption is promoting electric motorcycles.
4) A funding system to support ethanol (for the gasoline blend) is necessary by encouraging cellulosic ethanol and promotion of HVO.

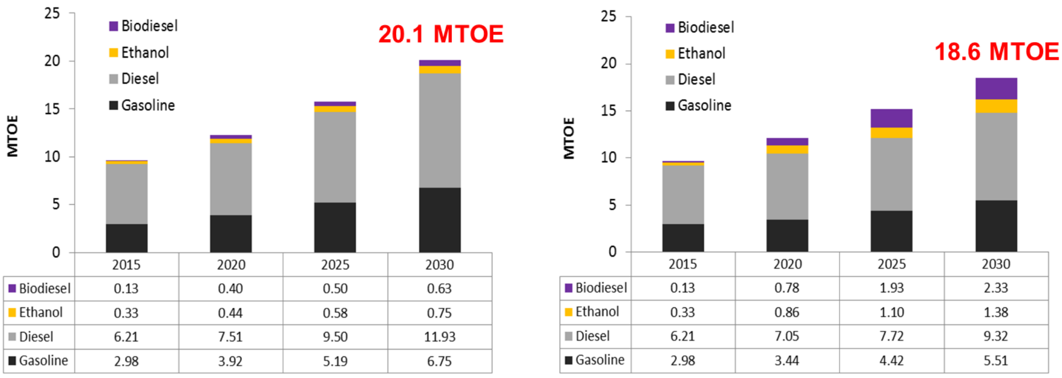
3) Philippines

The low-carbon scenario (LCS) of the current Philippine Energy Plan (PEP 2012-2030) lays out the target of the reduced energy consumption and sustainable energy mix. According to the LCS for the transportation sector, road transportation accounts for approximately 75%–80% of total transportation energy consumption in 2030, and use of alternative fuels including biofuels, CNG/LPG, and electricity for electric vehicles are promoted. The Department of Energy’s National Biofuels Program 2013–2030 is also planning to introduce ethanol and biodiesel up to E20 and B20 respectively until 2025.

3-1) Oil Consumption and Biofuel Introduction Potential

The Energy Mix Model of the Philippines estimated the total energy consumption of road transportation up to 2030. The results of the simulation for both the BAU case and biofuels case are shown in Figure 2.2.3-9. By following the LCS for the transportation sector, it takes into account not only the increased use of biofuels but also energy conservation in the biofuels case.

Figure 2.2.3-9. Total Energy Consumption of Road Transportation in the Philippines



a) Business as usual

b) Biofuels case

a) Business as usual

	2015	2020	2025	2030
■ Biodiesel	0.13	0.40	0.50	0.63
■ Ethanol	0.33	0.44	0.58	0.75
■ Diesel	6.21	7.51	9.50	11.93
■ Gasoline	2.98	3.92	5.19	6.75

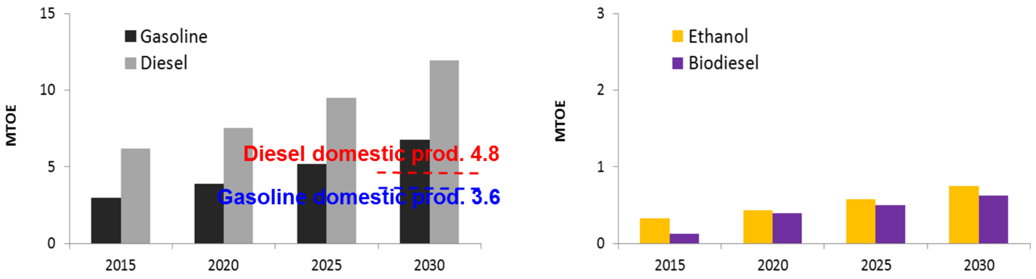
b) Biofuels case

	2015	2020	2025	2030
■ Biodiesel	0.13	0.78	1.93	2.33
■ Ethanol	0.33	0.86	1.10	1.38
■ Diesel	6.21	7.05	7.72	9.32
■ Gasoline	2.98	3.44	4.42	5.51

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-10 shows the gasoline/diesel fuel and biofuel consumption of the BAU case, and Figure 2.2.3-11 shows those of the biofuels case. The supply ability of each type of fuel is shown in the corresponding graphs.

Figure 2.2.3-10. Fuel Consumption of Business-as-Usual Case in the Philippines

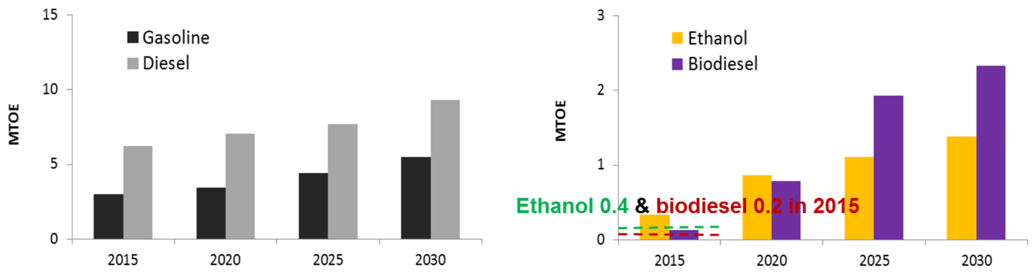


a) Gasoline/diesel fuel

b) Biofuels

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-11. Fuel Consumption of Biofuels Case in the Philippines


a) Gasoline/diesel fuel

b) Biofuels

Ethanol 0.4 & biodiesel 0.2 in 2015

MTOE = million tonnes of oil equivalent.
Source: Authors.

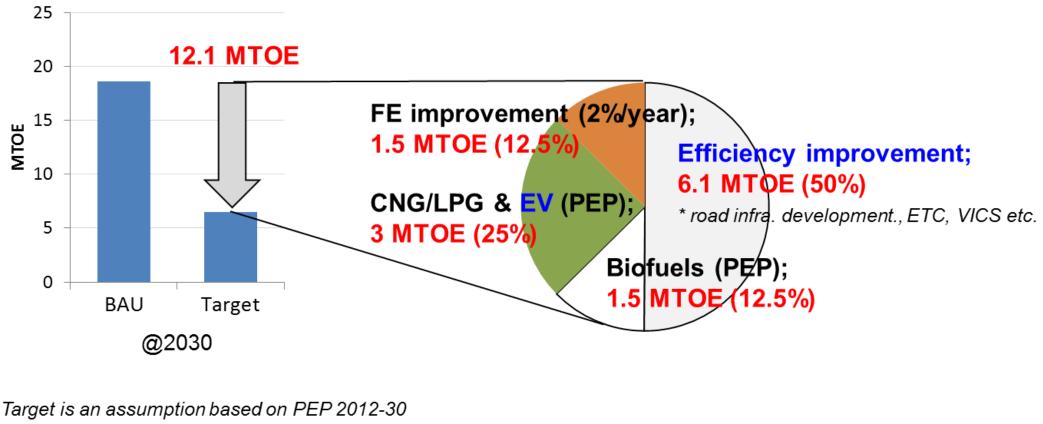
In the Philippines, diesel fuel consumption is higher than that of gasoline in the transportation sector. However, the gap between gasoline and diesel fuel consumption is within the acceptable level. The domestic refining capacity is below demand and the Philippines like Indonesia relies on petroleum products import.

The ethanol-blended gasoline E10 is being introduced nationwide by using imported ethanol, partially as domestic production capacity is not sufficient. Securing biodiesel production is more difficult, and we estimate a slow implementation of the National Biofuels Program (B5) in the BAU case (Figure 2.2.3-10). The required biodiesel amount will be larger than that of ethanol in the future once the National Biofuels Program is fully implemented as shown in Figure 2.2.3-11 (biofuels case). We expect achieving the biofuel introduction target to be very difficult as raw material production in the Philippines is limited, especially for biodiesel. The government needs to make concrete plans for biofuel introduction with countermeasures to increase domestic biofuel production and import biofuels (raw materials or products) at the same time.

3-2) Oil Reduction (Energy Conservation) Potential

The LCS for the transportation sector of the PEP requires an oil reduction of 12.1 MTOE by the transportation sector by 2030. Estimates of the allocation of oil reduction measures of alternative fuels based on the LCS for the transportation sector, possible oil reduction by FE improvement of new vehicles, and the remaining portion are shown in Figure 2.2.3-12.

Figure 2.2.3-12. Evaluation of Oil Reduction Potential Based on the PEP Requirement in the Philippines



BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, EV = electric vehicle, FE = fuel economy, MTOE = million tonnes of oil equivalent, PEP = Philippine Energy Plan, VICS = vehicle information and communication system.
Note: Target is an assumption based on PEP 2012-30.
Source: Authors.

The PEP biofuel and CNG/LPG introduction targets could replace 1.5 MTOE and 3 MTOE of oil, respectively, and the FE improvement of new vehicles will reduce oil consumption by 1.5 MTOE. We do not take electricity for EVs into consideration, as its realisation is not foreseen and its contribution is negligible. To fulfil the oil reduction requirement, the remaining 6.1 MTOE of oil reduction has to be achieved through efficiency improvement of the traffic system, such as road infrastructure development and implementation of traffic flow management (electronic toll collection, vehicle information and communication system, etc.). As the required oil reduction compared to the total oil consumption scale is relatively large in the current PEP, an integrated approach of oil reduction measures, especially efficiency improvement of the traffic system, plays an important role for energy conservation in the transportation sector.

The CO_2 emissions reduction of road transportation is estimated to be 35.4 kt-CO_2 (sum of –38.6 kt-CO_2 through reduction of oil use and +3.2 kt-CO_2 through CNG use) under the condition of achieving the reduced energy consumption by the PEP by 2030.

3-3) Summary

Energy issues, today and in future (up to 2030)

1) Increasing import dependency of oil and lack of domestic refining capacity compared to demand

2) For fossil fuels, increasing diesel fuel consumption compared to that of gasoline is an issue; reducing diesel fuel must be considered.

3) For biofuels, ethanol production at a competitive cost is insufficient as the domestic supply of molasses is limited; the same can be said for biodiesel and securing biodiesel production is more difficult.

4) To cope with diesel fuel reduction and introduce higher blending of biodiesel, implementing HVO in addition to FAME is necessary to realise higher blending of biodiesel without any vehicle warranty issues.

Possible measures

1) To achieve the oil reduction target, an integrated approach of oil reduction measures is required through efficiency improvement of the traffic system, such as infrastructure development, traffic flow management, etc.

2) Use of gas might be limited to public transportation with minimum investment for CNG infrastructure.

3) To produce more biodiesel (for the diesel fuel blend), a wide variety of feedstock other than coconuts is necessary.

4) A system to support further biofuel implementation including trading (import raw materials or products) is required.

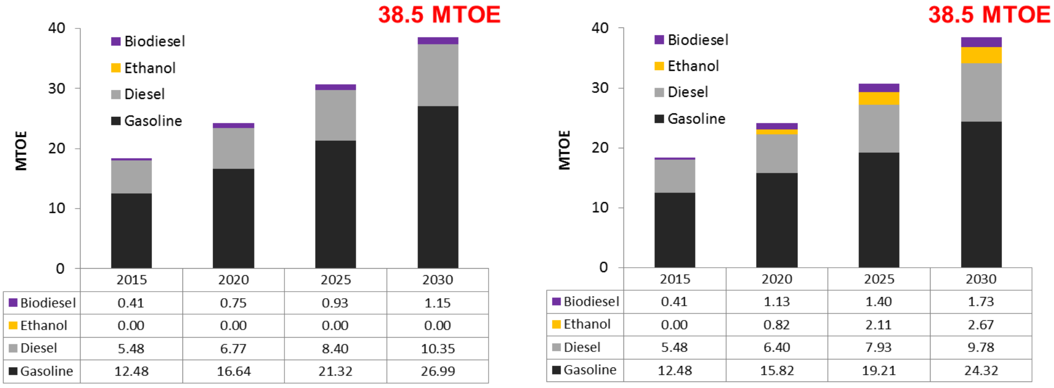
4) Malaysia

In Malaysia, under the National Automotive Policy (NAP 2014), the Energy Efficient Vehicle (EEV) Policy is being implemented by aiming to become an energy-efficient and advanced technology vehicle production hub in the Association of Southeast Asian Nations (ASEAN). The EEV Policy promotes EEV production by automotive manufactures that meet the investment and technology (e.g. fuel efficiency) criteria and provide incentives. According to the Ministry of International Trade and Industry, the 11th Malaysia Plan (2016–2020) encourages energy (oil) reduction by introducing EEVs, promoting use of biodiesel (B15) and CNG in the transportation sector. However, the government has not specified a clear reduction target of oil, and we tentatively set an oil reduction target of 35% compared to BAU for road transportation, which is equal to the government's CO_2 reduction commitment of the Paris Agreement in this study.

4-1) Oil Consumption and Biofuel Introduction Potential

The Energy Mix Model of Malaysia estimates the total energy consumption of road transportation up to 2030. The results of the simulation for both the BAU case and biofuels case are shown in Figure 2.2.3-13.

Figure 2.2.3-13. Total Energy Consumption of Road Transportation in Malaysia



a) Business as usual

	2015	2020	2025	2030
Biodiesel	0.41	0.75	0.93	1.15
Ethanol	0.00	0.00	0.00	0.00
Diesel	5.48	6.77	8.40	10.35
Gasoline	12.48	16.64	21.32	26.99

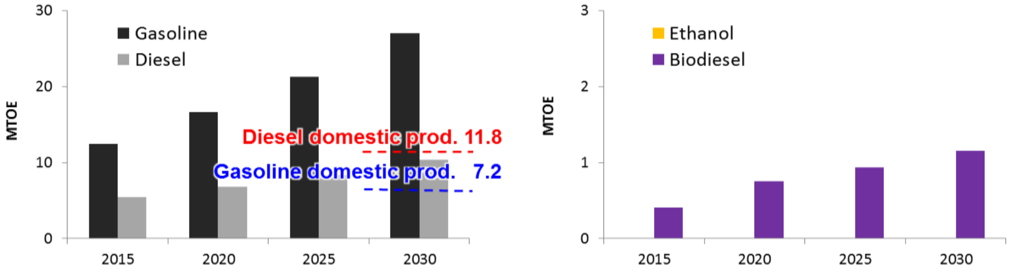
b) Biofuels case

	2015	2020	2025	2030
Biodiesel	0.41	1.13	1.40	1.73
Ethanol	0.00	0.82	2.11	2.67
Diesel	5.48	6.40	7.93	9.78
Gasoline	12.48	15.82	19.21	24.32

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-14 shows the gasoline/diesel fuel and biofuels consumption of the BAU case, and Figure 2.2.3-15 shows those of the biofuels case. The supply ability of each type of fuel is shown in the corresponding graphs.

Figure 2.2.3-14. Fuel Consumption of Business-as-Usual Case in Malaysia

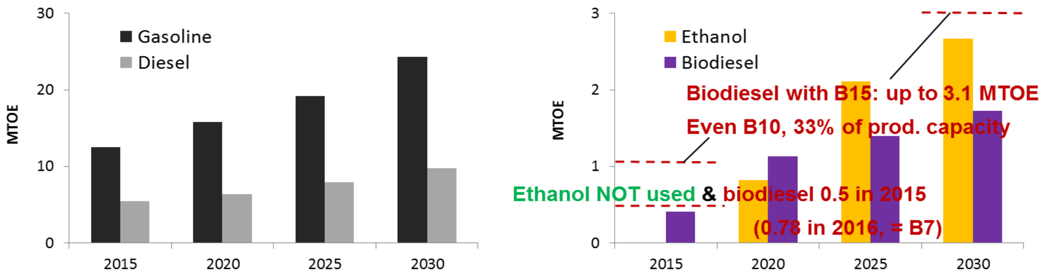


a) Gasoline/diesel fuel

b) Biofuels

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-15. Fuel Consumption of Biofuels Case in Malaysia



a) Gasoline/diesel fuel

b) Biofuels

MTOE = million tonnes of oil equivalent.

Source: Authors.

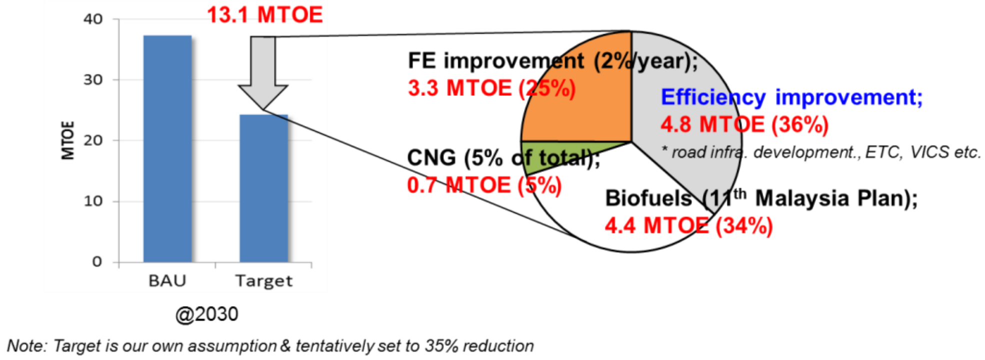
In Malaysia, as in Indonesia, gasoline consumption is higher than that of diesel fuel in the transportation sector. The imbalance between gasoline and diesel fuel consumption is one of the energy issues. If the difference in gasoline and diesel fuel consumption becomes too big, it will affect the healthy operations of oil refineries. The domestic refining capacity is about to meet the demand except for gasoline, and Malaysia relies on gasoline import (from Singapore) to some extent.

Ethanol is not currently used and therefore not considered in the BAU case (Figure 2.2.3-14). According to the government's biofuel plan, only biodiesel is promoted (B10) and utilisation of ethanol is not considered. However, if only biodiesel and increasing the blending ratio are promoted, the imbalance between gasoline and diesel fuel consumption will become worse. As shown in Figure 2.2.3-15, we consider both ethanol and biodiesel use in the biofuels case. The required volume of ethanol for the gasoline blend is larger than that of biodiesel for the diesel fuel blend. We believe that introducing both ethanol and biodiesel is necessary to mitigate the energy issues of road transportation, but securing sufficient ethanol domestically is quite difficult and the government needs to have a concrete plan of countermeasures. On the other hand, the biodiesel production ability projection shows that it is sufficient to meet the amount in the government's biofuel plan.

4-2) Oil Reduction (Energy Conservation) Potential

Based on our tentative target setting of 35% oil reduction for the transportation sector, the required oil reduction for road transportation by 2030 is 13.1 MTOE. Estimates of the allocation of oil reduction measures of alternative fuels, based on the 11th Malaysia Plan for biodiesel and oil replacement of 5% with CNG for the transportation sector, possible oil reduction by FE improvement of new vehicles, and the remaining portion are shown in Figure 2.2.3-16.

Figure 2.2.3-16. Evaluation of Oil Reduction Potential Based on Our Tentative Target Setting of 35% Reduction



BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, FE = fuel economy, MTOE = million tonnes of oil equivalent, VICS = vehicle information and communication system.
Note: Target is our own assumption and tentatively set to 35% reduction.
Source: Authors.

The introduction of biofuel and CNG can replace 4.4 MTOE and 0.7 MTOE of oil, respectively, and FE improvement of new vehicles will reduce 3.3 MTOE. In order to fulfil the oil reduction requirement, a further 4.8 MTOE oil reduction has to be achieved through efficiency improvement of the traffic system, such as road infrastructure development and implementation of traffic flow management (electronic toll collection, vehicle information and communication system, etc.). An integrated approach of oil reduction measures including efficiency improvement of the traffic system is required for the sake of energy conservation in the transportation sector.

The CO_2 emissions reduction of road transportation is estimated to be 39.9 kt-CO_2 (sum of –42.1 kt-CO_2 reduction through of oil use and +2.2 kt-CO_2 by CNG use) under the condition of 35% reduced energy consumption at 2030.

4-3) Summary

Energy issues, today and in future (up to 2030)

1) Increasing import dependency of oil
2) For fossil fuels, the imbalance between gasoline and diesel fuel consumption (gasoline consumption is much larger compared to that of diesel fuel) is an issue; reducing gasoline consumption should be prioritised.
3) For biofuels, the supply ability of biodiesel has potential, but securing ethanol (for gasoline blend) to realise a reduction of gasoline consumption is not foreseeable (no appropriate feedstock).
4) To introduce higher blending of biodiesel, implementation of HVO in addition to FAME is necessary to realise higher blending of biodiesel without any vehicle warranty issues.

Possible measures

1) To reduce oil consumption in the future, an integrated approach of oil reduction measures is required through efficiency improvement of the traffic system, such as infrastructure development and traffic flow management.
2) Increased use of domestic gas for public transportation including taxis
3) To reduce gasoline consumption, securing feedstock for ethanol is definitely required, and development of cellulosic ethanol will be an option.
4) Funding system to promote ethanol utilisation

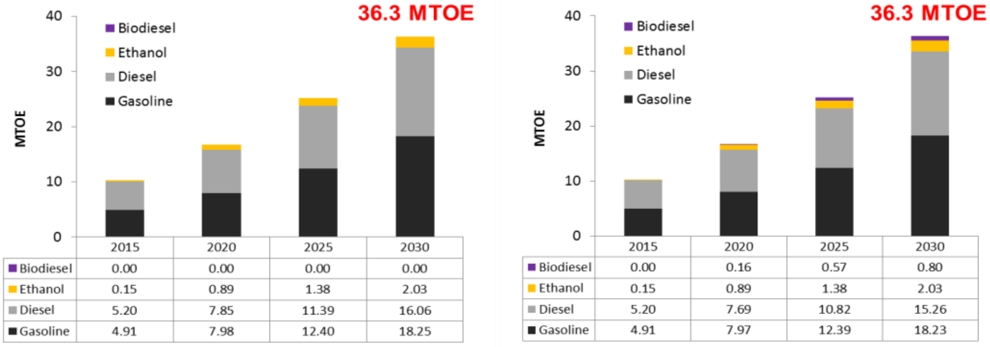
5) Viet Nam

The Government of Viet Nam is promoting better fuel economy vehicles by introducing the Energy Efficiency Labelling scheme since 2014 based on the Laws on Saving and Efficient Energy Use, 50/2010/QH12. For biofuel utilisation, the Biofuel Roadmap plans to implement both ethanol (E5 as of 2015 and up to E10 as of 2017) and biodiesel (B5 as of 2015), according to the Ministry of Industry and Trade and Ministry of Transportation. However, the government has not specified a clear reduction target of oil, and we tentatively set an oil reduction target of 20% compared to BAU for road transportation that is equal to the government's CO_2 reduction commitment of the Paris Agreement in this study.

5-1) Oil Consumption and Biofuel Introduction Potential

The Energy Mix Model of Viet Nam estimated the total energy consumption of road transportation up to 2030. The results of the simulation for both the BAU case and biofuels case are shown in Figure 2.2.3-17.

Figure 2.2.3-17. Total Energy Consumption of Road Transportation in Viet Nam



a) Business as usual

	2015	2020	2025	2030
■ Biodiesel	0.00	0.00	0.00	0.00
■ Ethanol	0.15	0.89	1.38	2.03
■ Diesel	5.20	7.85	11.39	16.06
■ Gasoline	4.91	7.98	12.40	18.25

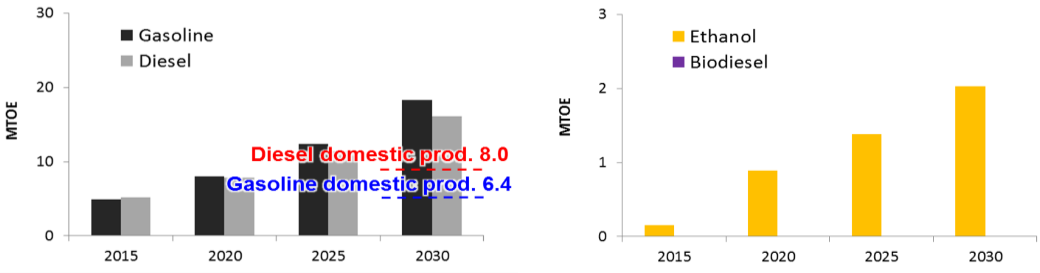
b) Biofuels case

	2015	2020	2025	2030
■ Biodiesel	0.00	0.16	0.57	0.80
■ Ethanol	0.15	0.89	1.38	2.03
■ Diesel	5.20	7.69	10.82	15.26
■ Gasoline	4.91	7.97	12.39	18.23

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-18 shows the gasoline/diesel fuel and biofuel consumption of the BAU case, and Figure 2.2.3-19 shows those of the biofuels case. The supply ability of each type of fuel is shown in the corresponding graphs.

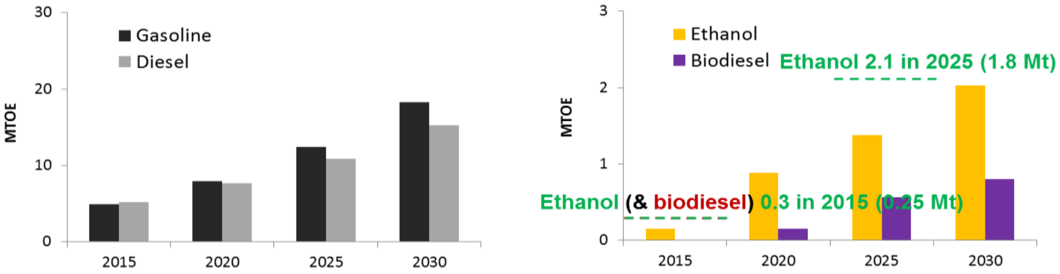
Figure 2.2.3-18. Fuel Consumption of Business-as-Usual Case in Viet Nam



a) Gasoline/diesel fuel **b) Biofuels**

MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.2.3-19. Fuel Consumption of Biofuels Case in Viet Nam



a) Gasoline/diesel fuel **b) Biofuels**

MTOE = million tonnes of oil equivalent.
Source: Authors.

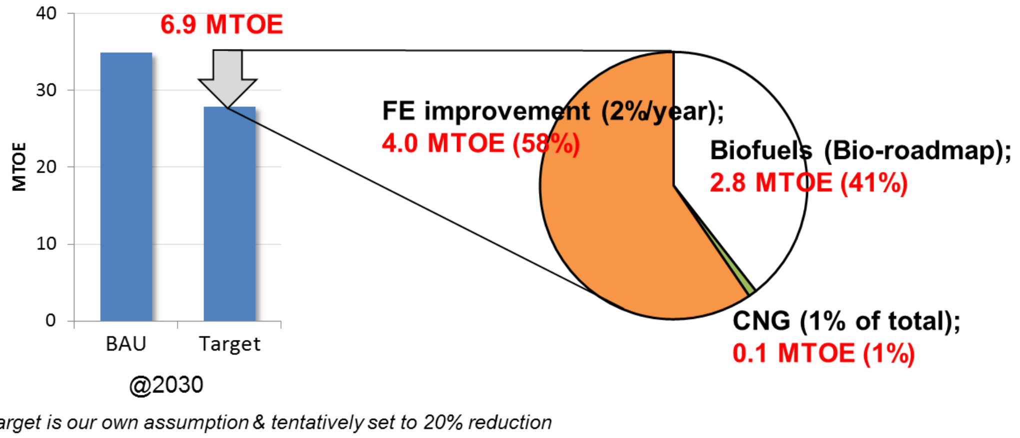
In Viet Nam, the current gasoline and diesel fuel consumption in the transportation sector are fairly balanced, but gasoline consumption is expected to be dominant in future as an increasing number of motorcycles will consume more gasoline. Domestic refining capacity is below demand as there is only one refinery and the country relies on petroleum products import.

Currently, ethanol-blended gasoline E5 is being introduced in some cities. Implementation is slightly behind the timeline set out in the Biofuel Roadmap because domestic ethanol production capacity is insufficient. Securing biodiesel production is difficult as the lack of raw material is a serious problem. Since it is not being implemented, it is not considered in the BAU case (Figure 2.2.3-18). However, we consider both ethanol and biodiesel use in the biofuels case, with slow implementation compared to the Biofuel Roadmap, as shown in Figure 2.2.3-19. Difficulty in achieving the biofuel introduction target is expected, as raw material production is limited, especially for biodiesel. The government needs to make a concrete plan to introduce biofuel with countermeasures to increase domestic biofuel production as much as possible, as well as import.

5-2) Oil Reduction (Energy Conservation) Potential

Based on our tentative target setting of 20% of oil reduction for the transportation sector, the required oil reduction for road transportation by 2030 is 6.9 MTOE. Estimates of the allocation of oil reduction measures of alternative fuels, based on the Biofuel Roadmap for biofuels and oil replacement of 1% with CNG for the transportation sector, and possible oil reduction by FE improvement of new vehicles are shown in Figure 2.2.3-20.

Figure 2.2.3-20. Evaluation of Oil Reduction Potential Based on Our Tentative Target Setting of 20% Reduction



BAU = business as usual, CNG = compressed natural gas, FE = fuel economy, MTOE = million tonnes of oil equivalent.
Note: Target is our own assumption and tentatively set to 20% reduction.
Source: Authors.

Introduction of biofuel and CNG can replace 2.8 MTOE and 0.1 MTOE of oil, respectively, and FE improvement of new vehicles will reduce 4.0 MTOE. As the required oil reduction compared to BAU oil consumption is relatively small in this study (as our tentative target for Viet Nam), no integrated approach of oil reduction measures including efficiency improvement of the traffic system is required, but alternative fuel introduction and FE improvement of new vehicles are sufficient for energy conservation in the transportation sector.

The CO_2 emissions reduction of road transportation is estimated to be 21.7 kt-CO_2 (sum of –22.0 kt-CO_2 through reduction of oil use and +0.3 kt-CO_2 through CNG use) under the condition of 20% reduced energy consumption by 2030.

5-3) Summary

Energy issues, today and in future (up to 2030)

1) Increasing import dependency of oil and lack of domestic refining capacity compared to demand
2) For fossil fuels, gasoline and diesel fuel consumption is balanced, but gasoline consumption may further increase because of the large number of motorcycles in the future.
3) For biofuels, insufficient biofuels feedstock supply ability and production capacity, especially for biodiesel.
4) Production of ethanol (from cassava) could possibly increase, but securing a sufficient amount of biodiesel domestically is difficult (no appropriate feedstock).

Possible measures

1) To reduce oil consumption in the future, an integrated approach of oil reduction measures is required through efficiency improvement of the traffic system, such as infrastructure development and traffic flow management.
2) Utilisation of domestic gas for public transportation including taxis
3) To reduce petroleum products consumption, introduction of both ethanol and biodiesel is required; securing feedstock or products, especially for biodiesel, is a key to achieving the Biofuel Roadmap.
4) For a system to support increased biofuel implementation, not only fiscal support but also trading (import raw materials or products) is required.

3. Policy Recommendation

3.1. Evaluation of the Current Energy Policies and Needs for Multinational Cooperation within ASEAN

The investigation of existing energy policies and possible measures to achieve policy targets by estimating energy consumption of road transportation up to 2030 has revealed the following concerns and limitations to solve energy issues within each country.

1) Thailand

For the AEDP, excess introduction of ethanol deteriorates the gasoline and diesel fuel consumption balance, and priority should be put on biodiesel as diesel fuel consumption is larger compared to that of gasoline in Thailand.

2) Indonesia

In accordance with KEN/RUEN direction, the key issues are to realise use of gas in the transportation sector and introduction of ethanol for the gasoline blend together with use of biodiesel. Gasoline consumption is higher than that of diesel fuel in Indonesia, and reduction of gasoline consumption should be prioritised. Institutional design and fiscal support for those must be considered as promoting measures.

3) Philippines

As far as the current PEP is concerned, there is a mismatch in the LCS projection of the transportation sector between the amount of energy to be reduced and that to be achieved by proposed measures. Validation is required and the energy conservation target needs to be revised. Achieving the biofuel introduction target is difficult as raw material production in the Philippines is limited.

4) Malaysia

Promotion of EEVs by setting a clear oil reduction target and efficiency improvement of the traffic system are required for energy conservation. Introduction of ethanol besides biodiesel must be considered given the imbalance between gasoline and diesel fuel consumption. However, lack of domestic ethanol production is an issue in Malaysia. Expansion of the use of domestic gas as an alternative fuel is necessary.

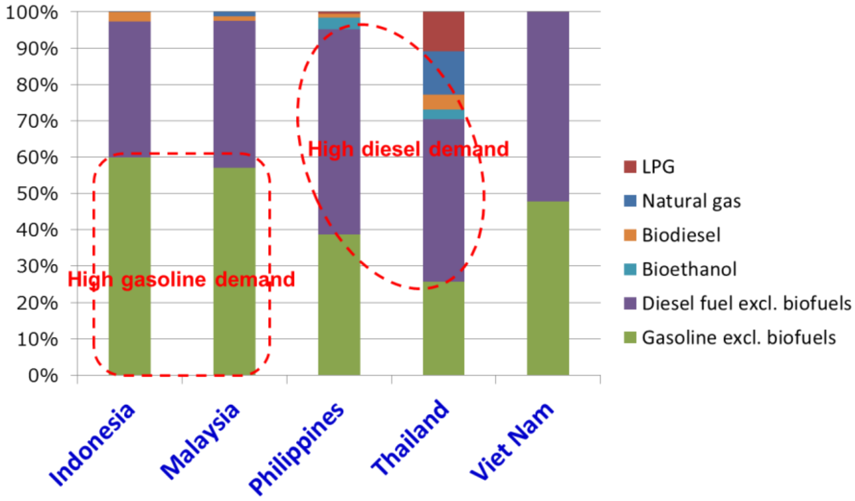
5) Viet Nam

For energy conservation, a clear oil reduction target and incentive scheme for better fuel economy vehicles along with energy efficiency labelling are needed. A concrete plan of biofuel introduction (moderate blending ratio is acceptable) with countermeasures to increase domestic raw material production is required, and import of biodiesel is definitely necessary as domestic production is quite difficult.

6) Discussion as ASEAN

Figure 2.3.1-1 shows the share of fuel types for road transportation in the five main study countries. In Indonesia and Malaysia, gasoline consumption is higher than that of diesel fuel, but in Thailand and the Philippines, diesel fuel consumption is higher than that of gasoline. In Viet Nam, both are fairly balanced at the moment.

Figure 2.3.1-1. Transportation Energy Share by Fuel Type in the Five Countries

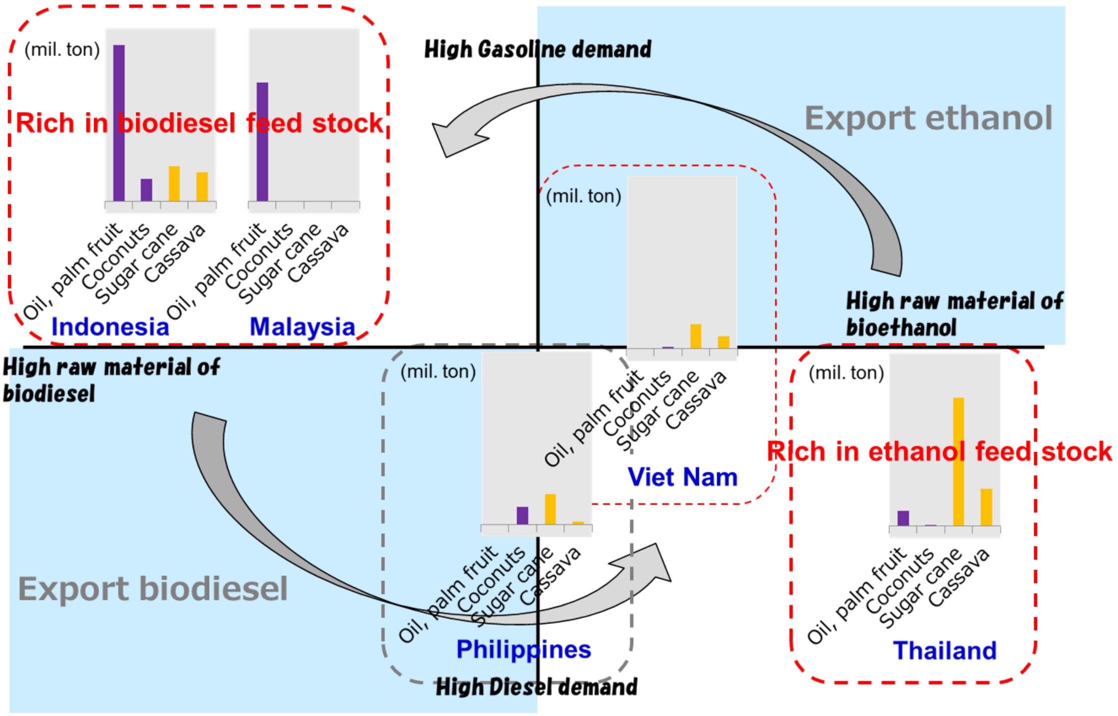


LPG = liquefied petroleum gas.
Source: International Energy Agency, World Energy Balances 2016.

To maintain healthy operations of oil refineries, the imbalance between gasoline and diesel fuel consumption must be small enough (below twofold if possible). To realise balanced consumption of gasoline and diesel fuel in terms of biofuels blending, the ideal relationship between petroleum products demand and biofuel supply ability is schematically illustrated in Figure 2.3.1-2.

As shown and made clear through our investigation and evaluation, unfortunately none of the countries in ASEAN meet this condition, and one of the concerns is insufficient raw materials for biofuels production in some countries. Then, multi-national cooperation amongst the ASEAN countries is worth considering for the sake of balanced biofuel supply and demand situation (biofuels security) in the region, together with appropriate biofuels utilisation target setting in each country.

Figure 2.3.1-2. Multinational Cooperation of Biofuel Supply in ASEAN



Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT) 2016.

3.2. Cost of Measures to Reduce Oil Consumption and Proposal of Alternative Combination of Measures to Achieve the Policy Requirement

In order to propose an appropriate combination of oil reduction measures, the cost of each oil reduction measure, such as better FE vehicle introduction, biofuels (ethanol and biodiesel), and natural gas utilisation, was evaluated. A case study has been carried out for Indonesia as an example.

The evaluation method is as follows. First, we used the Energy Mix Model to calculate and sum up all the related costs paid by the government as social cost and user cost such as increased vehicle/maintenance cost and fuel expenditure from 2015 to 2030.

Then, we compared the amount of oil reduced by each measure and total cost of implementation of each measure, and calculated the cost per unit energy (oil) reduction. Table 2.3.2-1 shows the conditions (fuel prices, increased cost of vehicle/maintenance, infrastructure cost, etc.) of calculation for the total implementation cost of each measure, and Table 2.3.2-2 summarises scenarios and their condition setting for the Energy Mix Model simulation.

Table 2.3.2-1. Conditions for Total Cost Calculation, 2015–2030

Item/Measure	Cost calculation data
Gasoline & Diesel fuel	MOPS price of December, 2015 Gasoline price; **5,820 Rp/L**, Diesel fuel price; **6,490 Rp/L**
Biofuels	MOPS price of December, 2015 Ethanol price; **7,560 Rp/L**, Biodiesel price; **8,000 Rp/L** Estimated more frequent fuel filter/engine oil change Diesel vehicle maintenance cost; **+500,000 Rp/year/unit vehicle**
FE improvement	Estimated 5,000 JPY (= 500,000 Rp) per 1.0% FE improvement, Vehicle cost-up for FE improvement; **+750,000 Rp/unit vehicle**
CNG use	CNG retail price in Jakarta CNG price; **3,100 Rp/L eq. gasoline** Estimated additional construction of CNG refueling SS CNG infrastructure cost; Mother SS, **80 billion Rp** / Daughter SS, **25 billion Rp**

CNG = compressed natural gas, FE = fuel economy, JPY = yen, L = litre, MOPS = mean of Plats Singapore, Rp = rupiah, SS = service station.
Source: Authors.

Table 2.3.2-2. Scenarios for Total Cost Calculation, 2015–2030, and Their Condition Setting for the Energy Mix Model Simulation

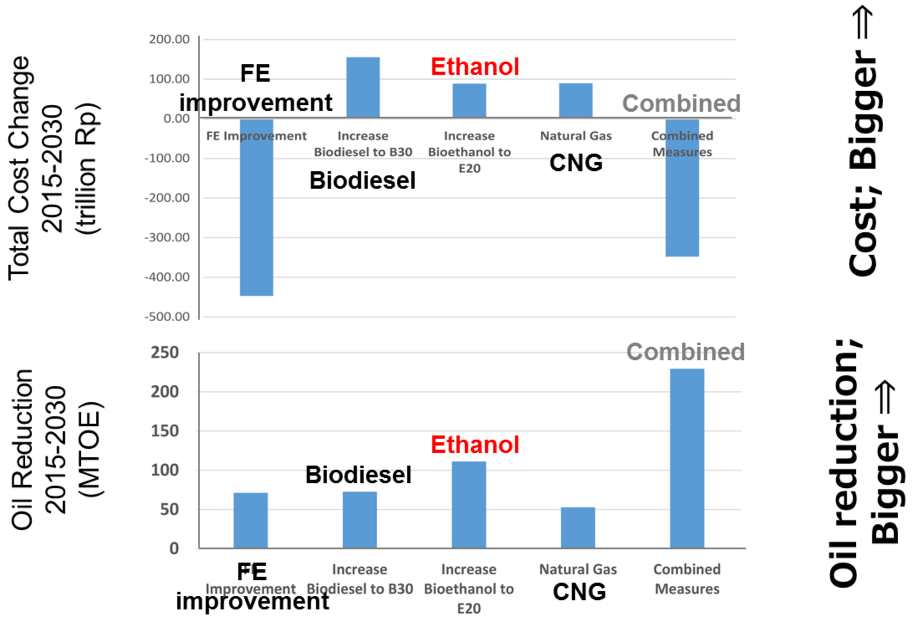
Scenario	FE improvement	Biofuels	CNG
Reference (BAU)	FE improvement, 0.5% a year	**B10**, No ethanol	No CNG vehicles
Increased FE improvement	FE improvement, **2.0% a year**	**B10**, No ethanol	No CNG vehicles
Increased biodiesel usage	FE improvement, 0.5% a year	**up to B30 in 2020** No ethanol	No CNG vehicles
Increased bioethanol usage	FE improvement, 0.5% a year	**B10**, **up to E20 in 2025**	No CNG vehicles
CNG vehicle introduction	FE improvement, 0.5% a year	**B10**, No ethanol	**Bus & Taxi in 5* cities**

* Jakarta, Surabaya, Palembang, Medan & Bandung

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

After the calculation with the Energy Mix Model, the total cost change compared to BAU, or the difference in total cost between each scenario and BAU during 2015–2030, and the amount of oil reduced during 2015–2030 were calculated and compared with each other (Figure 2.3.2-1). As the condition setting in each scenario specifically focuses on one of the oil reduction measures, other conditions are set to be same as BAU and the difference of total costs reveals introduction/implementation cost for the specified oil reduction measure.

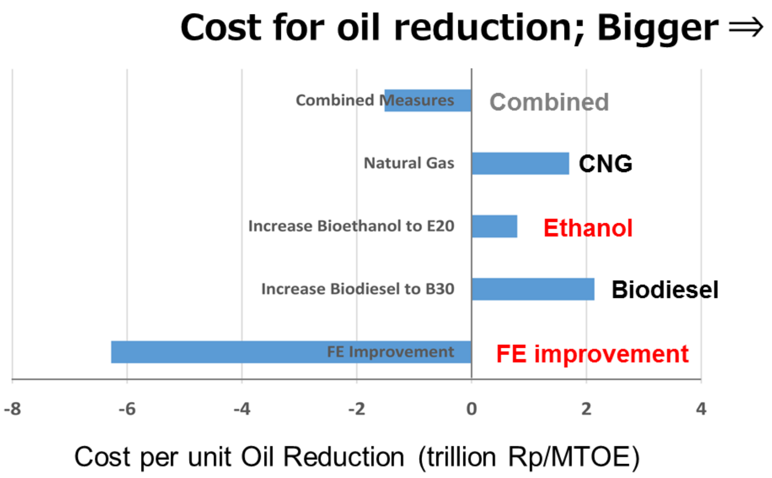
Figure 2.3.2-1. Total Cost Change and Amount of Oil Reduced during 2015–2030



CNG = compressed natural gas, FE = fuel economy, MTOE = million tonnes of oil equivalent, Rp = rupiah.
Source: Authors.

Finally, by using the data obtained, the required cost for reducing oil by means of each measure is calculated and shown in Figure 2.3.2-2. Amongst the alternative fuels for oil replacement, blending ethanol with gasoline can effectively reduce oil at minimum cost and using biodiesel has the highest cost. Generally speaking, the cost of biofuels is higher than that of gasoline/diesel fuel, which requires an increased cost for introduction. Normally, the price of CNG is lower than that of gasoline/diesel fuel and the cost of gas fuel utilisation is lower, whereas CNG refuelling infrastructure development requires additional costs. FE improvement of new vehicles reduces the total amount of fuels used compared to BAU with the limited price increase paid by users, leading to a negative cost of implementation.

Figure 2.3.2-2. Cost-effectiveness of Each Oil Reduction Measure



CNG = compressed natural gas, FE = fuel economy, MTOE = million tonnes of oil equivalent, Rp = rupiah.
Source: Authors.

This case study has been done for Indonesia in 2015, and some of the details may be different from other countries. Also, the fuel price data are past examples and do not reflect the exact current status. However, the indicative direction should be the same and the overall order of cost-effectiveness is still the same, and the results can be applied to other countries as well. Thus, we have calculated and evaluated the oil reduction cost in each country based on the Indonesian case study by changing the currency into US dollars (Table 2.3.2-3).

Table 2.3.2-3. Oil Reduction Cost Equivalents

Measure	**Cost in trillion Rp/MTOE**	**Cost in million US$/MTOE**
FE improvement	**-6.25**	**-46.8**
Biodiesel blending	**2.13**	**16.0**
Ethanol blending	**0.76**	**5.70**
CNG use	**1.69**	**12.7**

CNG = compressed natural gas, FE = fuel economy, MTOE = million tonnes of oil equivalent.
Note: Rp1 = US$0.00075 (July 2017).
Source: Authors.

1) Thailand

For Thailand, one of the concerns is deterioration of the gasoline and diesel fuel consumption balance through excess introduction of ethanol under the current policy due to the considerably larger diesel fuel consumption compared to that of gasoline. We have considered less ethanol blending as an alternative case, then kept the same level of biodiesel/CNG utilisation and FE improvement of new vehicles compared to those of the base case as summarised in Table 2.3.2-

4. The same oil reduction (–14.7 MTOE) can be achieved by increasing the allocation to efficiency improvement of the traffic system by 2030. As a result, the total oil reduction cost of the alternative case is calculated as US$3.4 million less than the base case. The figures inserted in the biofuels cells are the required amounts of ethanol/biodiesel in terms of volume in million litres.

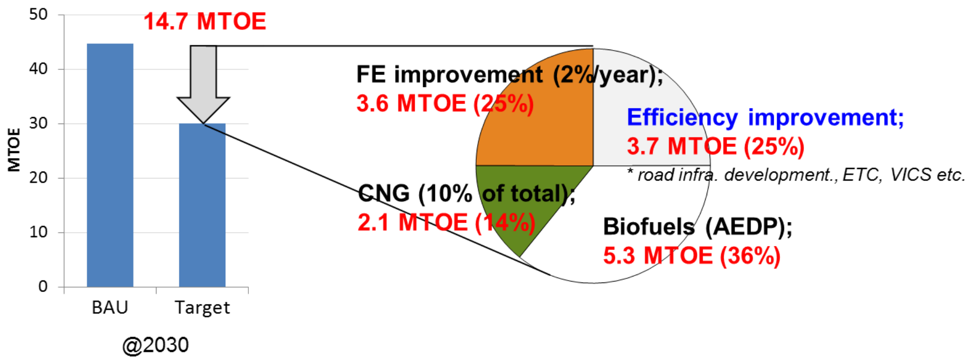
Table 2.3.2-4. Proposal of Alternative Combination of Oil Reduction Measures (Alternative Case) and Cost Comparison with Existing Policy (Base Case)

		Oil reduction (MTOE)		Difference (MTOE)	Cost change (mill. US$)
		Base Case	Alternative Case		
Biofuels	Ethanol	3.1 (21%) : **4,136 ML**	2.5 (17%) : **3,340 ML**	**-0.6**	**-3.4**
	B.diesel	2.8 (19%) : **3,812 ML**	2.8 (19%) : **3,813 ML**	-	-
CNG		2.1 (14%)	2.1 (14%)	-	-
FE improvement		3.6 (25%)	3.6 (25%)	-	-
Traffic system		3.1 (21%)	3.7 (25%)	**+0.6**	
Total		**▲14.7 @2030**		**±0**	**-3.4**

CNG = compressed natural gas, FE = fuel economy, ML = megalitre, MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.3.2-3 shows the oil reduction potential of the alternative case. The total biofuel consumption will decrease by 5.3 MTOE, CNG can replace 2.1 MTOE of oil, and FE improvement of new vehicles will reduce 3.6 MTOE. A further 3.7 MTOE of oil reduction has to be achieved through efficiency improvement of the traffic system to reduce the same amount of oil by 2030.

Figure 2.3.2-3. Oil Reduction Potential of the Alternative Case for Thailand



Note: Target is an assumption based on EEP 2015-36

AEDP = Alternative Energy Development Plan, BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, FE = fuel economy, MTOE = million tonnes of oil equivalent, VICS = vehicle information and communication system.
Note: Target is an assumption based on EEP 2015-36.
Source: Authors.

CO_2 emissions reduction of road transportation is estimated to be 37.1 kt-CO_2 (sum of –43.3 kt-CO_2 through reduction of oil use and +6.2 kt-CO_2 through CNG use) by 2030, and the CO_2 reduction potential is equal to the base case.

2) Indonesia

In Indonesia, one of the key issues is the introduction of ethanol for the gasoline blend together with use of biodiesel. Gasoline consumption is higher than that of diesel fuel, and reduction of gasoline consumption must be considered. We have considered ethanol blending and reduced the biodiesel introduction amount instead as the alternative case. The level of CNG utilisation has also been reduced as the planned CNG introduction amount in the RUEN is too big, We set it to be same as the current CNG utilisation ratio in Thailand – that is, 10% of the current road transportation energy total consumption. Lastly, FE improvement of new vehicles and efficiency improvement of the traffic system have been kept same as the base case, as summarised in Table 2.3.2-5. The same oil reduction (–40.2 MTOE) can be achieved by 2030, with the total cost reduced at the same time by US$75.4 million compared to the base case. The figures inserted in the biofuels cells are the required amounts of ethanol/biodiesel in million litres.

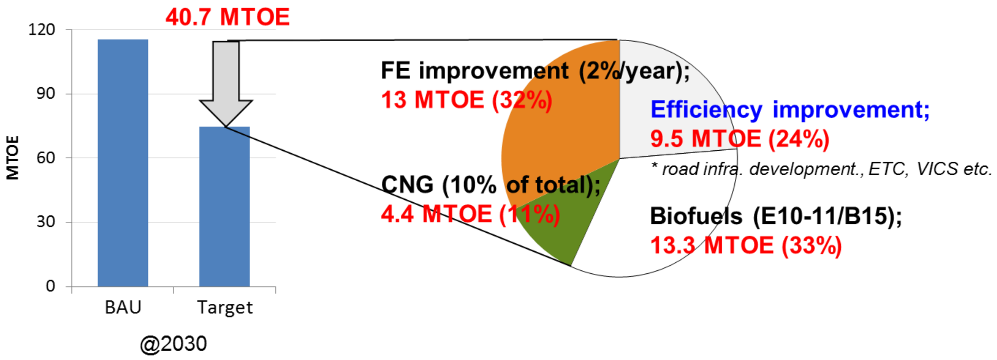
Table 2.3.2-5. Proposal of Alternative Combination of Oil Reduction Measures (Alternative Case) and Cost Comparison with Existing Policy (Base Case)

		Oil reduction (MTOE)		Difference (MTOE)	Cost change (mill. US$)
		Base Case	**Alternative Case**		
Biofuels	**Ethanol**	0 (0%) : **0 ML**	8.6 (21%) : **11,666 ML**	**+8.6**	**+49.0**
	B.diesel	9.3 (23%) : **12,568 ML**	4.7 (12%) : **6,284 ML**	**-4.6**	**-73.6**
CNG		8.4 (21%)	4.4 (11%)	**-4.0**	**-50.8**
FE improvement		13.0 (32%)	13.0 (32%)	-	-
Traffic system		9.5 (24%)	9.5 (24%)	-	
Total		**▲40.2 @2030**		**±0**	**-75.4**

CNG = compressed natural gas, FE = fuel economy, ML = megalitre, MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.3.2-4 shows the oil reduction potential of the alternative case. Biofuels, a combination of E10-11/B15 introduction, and CNG utilisation at 10% of the current total energy consumption can replace 13.3 MTOE and 4.4 MTOE of oil, respectively, and FE improvement of new vehicles will reduce oil consumption by 13 MTOE. In order to reduce same amount of oil by 2030, the remaining 9.5 MTOE of oil reduction has to be achieved through efficiency improvement of the traffic system.

Figure 2.3.2-4. Oil Reduction Potential of the Alternative Case for Indonesia



BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, FE = fuel economy, MTOE = million tonnes of oil equivalent, VICS = vehicle information and communication system.
Note: reduction by each measure are assumption based on RUEN transport sector.
Source: Authors.

The CO_2 emissions reduction of road transportation is estimated to be 114.2 kt-CO_2 (sum of –128.2 kt-CO_2 through reduction of oil use and +14.0 kt-CO_2 through CNG use) by 2030, and the CO_2 reduction potential is bigger (potential reduction of additional 12.8 kt-CO_2) than the base case.

3) Philippines

As far as the current PEP is concerned, the energy conservation target seems to be unrealistic and necessary to be revised as the energy reduction required by the LCS for the transportation sector of the PEP is too large compared to the total energy consumption scale. Also, securing a sufficient amount of biofuels to meet the target is difficult as raw material production in the Philippines is limited.

We set the revised target of oil reduction for the Philippines to be 35%, as in Malaysia (35% is the largest reduction target amongst the five countries investigated in this study). The required amount of oil to be reduced will be 6.5 MTOE by 2030, instead of 12.1 MTOE of the base case. We considered the same level of ethanol blending and increased biodiesel introduction amount as the revised target case. The CNG utilisation level has also been reduced as the planned CNG introduction amount in the PEP is too large and set to be the same as the current CNG utilisation ratio in Thailand (i.e. 10% of current road transportation energy total consumption). FE improvement of new vehicles has been kept the same as the base case, as summarised in Table 2.3.2-6. The oil reduction allocated to efficiency improvement of the traffic system is not too large to achieve the revised target. The total cost is reduced by US$18.6 million compared to the base case. The figures inserted in the biofuels cells are the required amounts of ethanol/biodiesel in million litres.

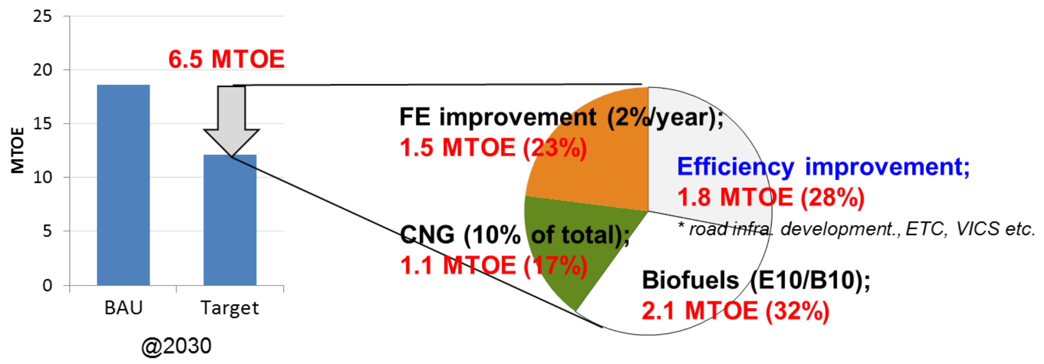
Table 2.3.2-6. Proposal of Alternative Combination of Oil Reduction Measures (Revised Target Case) and Cost Comparison with Existing Policy (Base Case)

		Oil reduction (MTOE)		Difference (MTOE)	Cost change (mill. US$)
		Base Case	Revised Target Case		
Biofuels	Ethanol	0.9 (12%) : **1,178 ML**	0.8 (12%) : **1,013 ML**	**-1.0**	**-5.7**
	B.diesel	0.6 (21%) : **848 ML**	1.3 (20%) : **1,698 ML**	**+0.7**	**+11.2**
CNG		3.0 (25%)	1.1 (17%)	**-1.9**	**-24.1**
FE improvement		1.5 (12%)	1.5 (23%)	-	-
Traffic system		6.1 (30%)	1.8 (28%)	**-4.3**	
Total		**▲12.1 ⇒ ▲6.5 @2030**		**-5.6**	**-18.6**

CNG = compressed natural gas, FE = fuel economy, ML = megalitre, MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.3.2-5 shows the oil reduction potential of the revised target case with the revised target. Biofuels, a combination of E10/B10 introduction, and CNG utilisation of 10% of the current total energy consumption can replace 2.1 MTOE and 1.1 MTOE of oil, respectively. FE improvement of new vehicles will reduce oil consumption by 1.5 MTOE, and the remaining 1.8 MTOE of oil reduction has to be achieved through efficiency improvement of the traffic system.

Figure 2.3.2-5. Oil Reduction Potential of the Revised Target Case for the Philippines



BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, FE = fuel economy, MTOE = million tonnes of oil equivalent, VICS = vehicle information and communication system.
Note: Target is our own assumption and tentatively set to 35% reduction.
Source: Authors.

The CO_2 emissions reduction of road transportation is estimated to be 19.5 kt-CO_2 (sum of –20.7 kt-CO_2 through reduction of oil use and +1.2 kt-CO_2 through CNG use) by 2030, and the CO_2 reduction potential is smaller (emission increases 15.9 kt-CO_2) than the base case due to the revised target setting (amount of oil reduced is smaller by 5.6 MTOE).

4) Malaysia

For Malaysia, introduction of ethanol besides biodiesel must be considered, given the imbalance between gasoline and diesel fuel consumption. Gasoline consumption is higher than that of diesel fuel, and reduction of gasoline consumption must be considered as in Indonesia. We have considered ethanol blending and a reduced biodiesel introduction amount instead as the alternative case. The level of CNG utilisation has been kept the same. Lastly, FE improvement of new vehicles and efficiency improvement of the traffic system have also been kept the same as the base case, as summarised in Table 2.3.2-7. The same oil reduction amount (–13.2 MTOE) can be achieved by 2030, with the total cost reduced at the same time by US$16.0 million compared to the base case. The figures inserted in the biofuels cells are the required amounts of ethanol/biodiesel in million litres.

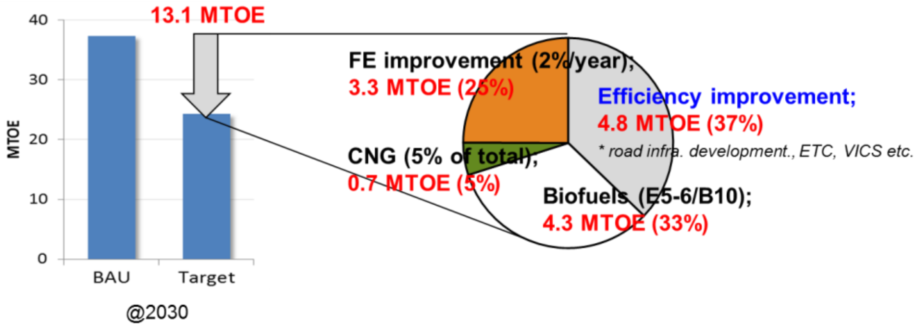
Table 2.3.2-7. Proposal of Alternative Combination of Oil Reduction Measures (Alternative Case) and Cost Comparison with Existing Policy (Base Case)

		Oil reduction (MTOE)		Difference (MTOE)	Cost change (mill. US$)
		Base Case	**Alternative Case**		
Biofuels	**Ethanol**	0 (0%) : **0 ML**	1.4 (11%) : **1,847 ML**	**+1.4**	**+8.0**
	B.diesel	4.3 (33%) : **5,946 ML**	2.9 (22%) : **3,964 ML**	**-1.4**	**-24.0**
CNG		0.7 (5%)	0.7 (5%)	-	-
FE improvement		3.3 (25%)	3.3 (25%)	-	-
Traffic system		4.8 (37%)	4.8 (37%)	-	
Total		**▲13.1 @2030**		**±0**	**-16.0**

CNG = compressed natural gas, FE = fuel economy, ML = megalitre, MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.3.2-6 shows the oil reduction potential of the alternative case. Biofuels, a combination of E5-6/B10 introduction, and CNG utilisation of 5% of the current total energy consumption can replace 4.3 MTOE and 0.7 MTOE of oil, respectively, and FE improvement of new vehicles will reduce oil consumption by 3.3 MTOE. In order to reduce same amount of oil by 2030, the remaining 4.8 MTOE of oil reduction has to be achieved through efficiency improvement of the traffic system.

Figure 2.3.2-6. Oil Reduction Potential of the Alternative Case for Malaysia



Note: Target is our own assumption & tentatively set to 35% reduction

BAU = business as usual, CNG = compressed natural gas, ETC = electronic toll collection, FE = fuel economy, MTOE = million tonnes of oil equivalent, VICS = vehicle information and communication system.
Note: Target is our own assumption and tentatively set to 35% reduction.
Source: Authors.

The CO_2 emissions reduction of road transportation is estimated to be 39.9 kt-CO_2 (sum of –42.1 kt-CO_2 through reduction of oil use and +2.2 kt-CO_2 through CNG use) by 2030, and the CO_2 reduction potential is equal to the base case.

5) Viet Nam

In Viet Nam, gasoline and diesel fuel consumption are fairly balanced, but as far as biofuels are concerned, one concern is the insufficient biofuels feedstock supply ability, especially for biodiesel. We have considered less ethanol blending as the alternative case and kept the same biodiesel utilisation level. The CNG utilisation level has been increased by considering domestically produced natural gas resources in Viet Nam, and set at 5% of the current road transportation energy total consumption (as in Malaysia). Finally, FE improvement of new vehicles and efficiency improvement of traffic system have also been kept the same as the base case, as summarised in Table 2.3.2-8. The same oil reduction amount (–6.9 MTOE) can be achieved by 2030, with the total cost slightly increased by US$2.8 million compared to the base case. The figures inserted in the biofuels cells are the required amounts of ethanol/biodiesel in million litres.

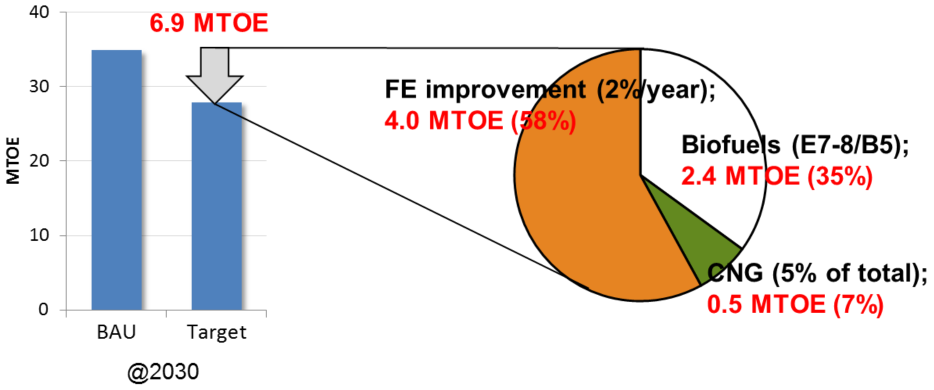
Table 2.3.2-8. Proposal of Alternative Combination of Oil Reduction Measures (Alternative Case) and Cost Comparison with Existing Policy (Base Case)

		Oil reduction (MTOE)		Difference (MTOE)	Cost change (mill. US$)
		Base Case	**Alternative Case**		
Biofuels	**Ethanol**	2.0 (29%) : **2,740 ML**	1.6 (23%) : **2,158 ML**	**-0.4**	**-2.3**
	B.diesel	0.8 (12%) : **1,085 ML**	0.8 (12%) : **1,085 ML**	-	-
CNG		0.1 (1%)	0.5 (7%)	**+0.4**	**+5.1**
FE improvement		4.0 (58%)	4.0 (58%)	-	-
Traffic system		0 (0%)	0 (0%)	-	
Total		**▲6.9 @2030**		**±0**	**+2.8**

CNG = compressed natural gas, FE = fuel economy, ML = megalitre, MTOE = million tonnes of oil equivalent.
Source: Authors.

Figure 2.3.2-7 shows the oil reduction potential of the alternative case. Biofuels, a combination of E7-8/B5 introduction, and CNG utilisation of 5% of the current total energy consumption can replace 2.4 MTOE and 0.5 MTOE of oil, respectively, and FE improvement of new vehicles will reduce oil consumption by 4.0 MTOE. As our tentative target setting of a 20% oil reduction by 2030 for Viet Nam is not large, an integrated approach of oil reduction measures including efficiency improvement of the traffic system is not required.

Figure 2.3.2-7. Oil Reduction Potential of the Alternative Case for Viet Nam



BAU = business as usual, CNG = compressed natural gas, FE = fuel economy, MTOE = million tonnes of oil equivalent.
Note: Target is our own assumption and tentatively set to 20% reduction.
Source: Authors.

The CO_2 emissions reduction of road transportation is estimated to be 20.5 kt-CO_2 (sum of –22.0 kt-CO_2 through reduction of oil use and +1.5 kt-CO_2 through CNG use) by 2030, and the CO_2 reduction potential is slightly smaller (emission increases of 1.2 kt-CO_2) than the base case due to increased use of CNG.

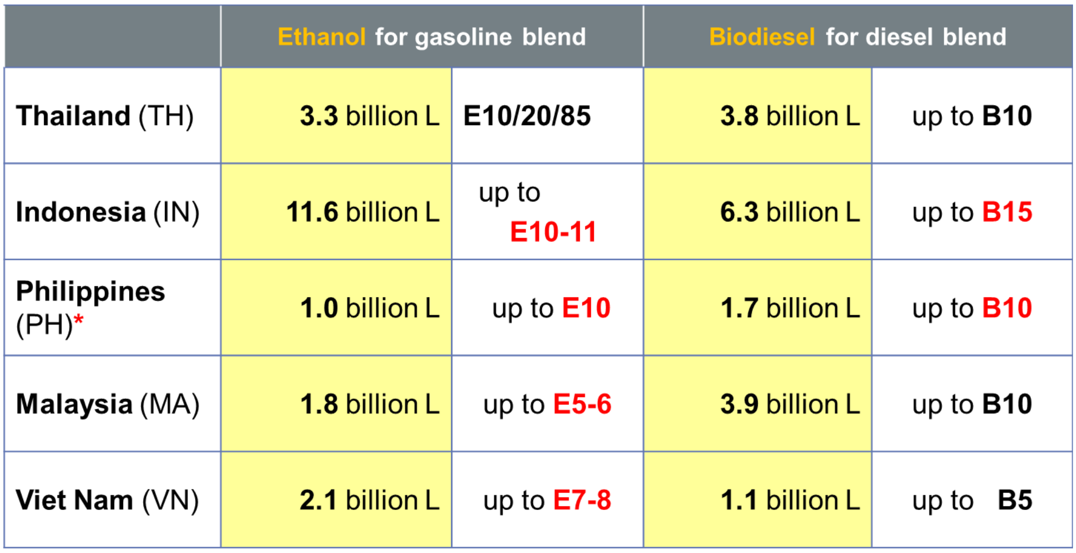
3.3. Proposal of Biofuels Balancing Concept in ASEAN

Existing energy policies as well as gasoline/diesel fuel supply and demand status issues of road transportation, including alternative fuels (natural gas and biofuels), were studied for the five main countries in ASEAN. The priority was on discussing measures for mitigating energy issues in each country by achieving the policy targets, but concerns and limitations of solving energy issues within each country have been made clear. In order to minimise the concerns and limitations, we also proposed an appropriate combination of oil reduction measures as the alternative case.

1) Biofuel supply/demand status in each country

Under the condition of a more cost-effective combination of oil reduction measures to achieve the policy target, together with adequate biofuel utilisation for replacing gasoline/diesel fuel, the required amounts of ethanol/biodiesel in each country by 2030 are summarised in Table 2.3.3-1 (the figures inserted in the biofuels cells of Table 2.3.2-3 to Table 2.3.2-7 are the required amounts of ethanol/biodiesel in units of million litres).

Table 2.3.3-1. Required Amount of Ethanol and Biodiesel in Each Country by 2030 for the Alternative Case



	Ethanol for gasoline blend		Biodiesel for diesel blend	
Thailand (TH)	**3.3** billion L	**E10/20/85**	**3.8** billion L	up to **B10**
Indonesia (IN)	**11.6** billion L	up to **E10-11**	**6.3** billion L	up to **B15**
Philippines (PH)*	**1.0** billion L	up to **E10**	**1.7** billion L	up to **B10**
Malaysia (MA)	**1.8** billion L	up to **E5-6**	**3.9** billion L	up to **B10**
Viet Nam (VN)	**2.1** billion L	up to **E7-8**	**1.1** billion L	up to **B5**

* Oil reduction target for Philippines is a Tentative target of ▲35% (revised target)

Source: Authors.

Next, we examined the supply ability or potential of ethanol/biodiesel in each country up to 2030 to fulfil demand. Each country conducted a survey, based on their own projection/estimation, and the possible supply potentials of ethanol/biodiesel up to 2030 are shown in Table 2.3.3-2 to Table 2.3.3-6, respectively.

Table 2.3.3-2. Ethanol and Biodiesel Supply Potentials up to 2030 in Thailand

Ethanol	unit	2015	2020	2025	2030	notes
Sugar cane	mil.t	4.03	5.96	6.80	7.38	
Cassava	mil.t	2.00	3.22	5.19	8.36	
Feedstock total	mil.t	**6.03**	**9.18**	**11.99**	**15.74**	
Nr. of plants	-	22	26			Currently 26 (capacity; 5.79 ML/d, registered license; 6.35 ML/d), and 2 more with registered license of 0.71 ML/d
Capacity	bil.L	1.64	5.79			
Ethanol total	bil.L	**1.21**	**4.42**	**6.08**	**8.33**	
Biodiesel	**unit**	**2015**	**2020**	**2025**	**2030**	**notes**
Palm	mil.t	0.82	1.1	1.56	1.67	
Coconuts	mil.t	-	-	-	-	Not planed to be used for biodiesel
Feedstock total	mil.t	**0.82**	**1.10**	**1.56**	**1.67**	
Nr. of plants	-	11	13			Currently 13 (capacity; 6.62 ML/d)
Capacity	bil.L	1.62	6.62			
Biodiesel total	bil.L	**1.24**	**3.50**	**4.91**	**5.26**	

Source: Authors.

Table 2.3.3-3. Ethanol and Biodiesel Supply Potentials up to 2030 in Indonesia

Ethanol	unit	2015	2020	2025	2030	notes
Sugar cane	mil.t	28 (1.2)	31 (1.8)	35 (2.1)	40 (2.4)	50 sugarcane mills, (available molasses for ethanol feedstock)
Cassava	mil.t	24	26	28	30	Even imported from VN to fulfill t starch prod.
Feedstock total	mil.t	**52**	**57**	**63**	**70**	
Nr. of plants	-	3	6	6	6	Total 14 plants, only 3 are capable of producing ethanol for fuel grade
Capacity	bil.L	0.1	0.4	0.6	0.8	
Ethanol total	bil.L	**0.1**	**0.4**	**0.6**	**0.8**	
Biodiesel	**unit**	**2015**	**2020**	**2025**	**2030**	**notes**
Palm	mil.t	30	40	50	60	
Coconuts	mil.t	0.9	1.2	1.5	1.8	Govt. is pushing to increase production
Feedstock total	mil.t	**33.9**	**41.2**	**51.5**	**61.8**	
Nr. of plants	-	15	25	30	40	Capacity is underutilized, need to secure sufficient CPO to maintain prod.
Capacity	bil.L	4.5	12	20	24	
Biodiesel total	bil.L	**4.5**	**12**	**20**	**24**	

Source: Authors.

Table 2.3.3-4. Ethanol and Biodiesel Supply Potentials up to 2030 in the Philippines

Ethanol	unit	2015	2020	2025	2030	notes
Sugar cane	mil.t	0.51 (0.47)	3.37 (0.80)	3.71 (1.00)	4.08 (1.10)	(available molasses for ethanol feedstock)
Cassava	mil.t	-	-	-	-	No plan
Feedstock total	mil.t	**0.47**	**0.80**	**1.00**	**1.10**	
Nr. of plants	-	10	14	38	52	Estimated number with annual production capacity of 30 million L/year to be added
Capacity	bil.L	0.28	0.41	1.13	1.55	
Ethanol total	bil.L	**0.28**	**0.85**	**1.13**	**1.55**	Maintain E10 mandate until 2020
Biodiesel	**unit**	**2015**	**2020**	**2025**	**2030**	**notes**
Palm	mil.t	-	-	-	-	No plan
Coconuts	mil.t	0.76	1.03	1.66	2.67	CNO equivalent
Feedstock total	mil.t	**0.76**	**1.038**	**1.66**	**2.67**	
Nr. of plants	-	11	13	13	15	
Capacity	bil.L	0.58	0.74	0.74	0.79	
Biodiesel total	bil.L	**0.20**	**0.22**	**0.66**	**0.79**	Maintain B2 until 2020, B5 beginning 2021

Source: Authors.

Table 2.3.3-5. Ethanol and Biodiesel Supply Potentials up to 2030 in Malaysia

No ethanol production

Ethanol	unit	2015	2020	2025	2030	notes
Sugar cane	mil.t	-	-	-	-	
Cassava	mil.t	-	-	-	-	
Feedstock total	mil.t	-	[illegible]	-	-	
Nr. of plants	-	-	-	-	-	No new plants being constructed within next 5 years
Capacity	bil.L	-	-	-	-	
Ethanol total	bil.L	-	-	-	-	
Biodiesel	**unit**	**2015**	**2020**	**2025**	**2030**	**notes**
Palm	mil.t	0.36	0.67	1.11	2.92	Huge potential for palm
Coconuts	mil.t	-	-	-	-	No plan
Jatropha	mil.t	-	-	-	-	Plans of introducing Jatropha as feedstock
Feedstock total	mil.t	**0.36**	**0.67**	**1.11**	**2.92**	
Nr. of plants	-	31	31	31	31	22 plants in operation, 9 plants are idling (2017)
Capacity	bil.L	3.4	3.4	3.4	3.4	
Biodiesel total	bil.L	**0.67**	**1.5**	**2.5**	**3.4**	Projected incl. export

Source: Authors.

Table 2.3.3-6. Ethanol and Biodiesel Supply Potentials up to 2030 in Viet Nam

Ethanol	unit	2015	2020	2025	2030	notes
Sugar cane	mil.t	18.0	25.5			Mainly for sugar industry
Cassava	mil.t	11.0 (fresh	12.7 (fresh)	-	16.5 (fresh)	Cassava is mainly used for starch production and export, only a part is used for ethanol prod.
Corn	mil.t	18.0	25.5			Mainly for food & animal
Feedstock total	mil.t		**1.6** (dried)	-	**1.8** (dried)	Feedstock for ethanol prod., dried cassava is for ethanol production
Nr. of plants	-	2	7		7	4 plants (total capacity, 400kL/y) produce E100; 2 plants (total capacity, 126kL/y) are upgraded to produce E100; 1 plant (capacity, 100kL/y) is under construction
Capacity	bil.L	0.17	0.62		0.62	
Ethanol total	bil.L	**0.17**	**0.52**		**0.62**	
Biodiesel	**unit**	**2015**	**2020**	**2025**	**2030**	**notes**
Palm	mil.t	-	-	-	-	
Coconuts	mil.t	-	-	-	-	
Fish oil	mil.t	-	-		-	Plans to use as feedstock
Feedstock total	mil.t	-		-	-	
Nr. of plants	-		-	-	-	
Capacity	bil.L	-	-	-	-	
Biodiesel total	bil.L	-	-	-	-	

No biodiesel production

CNO = coconut oil, CPO = crude palm oil, kL/y = kilolitre per year, L = litre, ML/d = million litres per day, t = tonne, VN = Viet Nam.
Source: Authors.

Based on the provided information on the future biofuel supply potential from each country, the estimated domestic supply potentials of ethanol/biodiesel in each country by 2030 are summarised in Table 2.3.3-7, together with the information on the main feedstock/raw materials for biofuels production. Further, the biofuel supply/demand status for the five main countries in ASEAN by 2030 are finally summarised in Table 2.3.3-8, based on the information shown in Table 2.3.3-1 and Table 2.3.3-7.

The evaluation criteria are as follows. If estimated supply volume, for example, of ethanol exceeds demand in a country, the country has the potential for export ethanol. If the estimated supply volume, for example, of biodiesel is less than demand in another country, the country does not have the potential to meet demand by itself and needs to import biodiesel (in this case, figures in the excess/deficit cells are indicated as negative).

Table 2.3.3-7. Estimated Domestic Supply Potential of Ethanol and Biodiesel in Each Country by 2030

	Ethanol for gasoline blend		Biodiesel for diesel blend	
Thailand (TH)	**8.3** billion L	from **Sugar cane** and **Cassava**	**5.2** billion L	from **Palm**
Indonesia (IN)	**0.8** billion L	from **Sugar cane**	**24** billion L	from **Palm**
Philippines (PH)	**1.5** billion L	from **Sugar cane**	**0.8** billion L	from **Coconuts**
Malaysia (MA)	No production	-	**3.4** billion L	from **Palm**
Viet Nam (VN)	**0.6** billion L	mainly from **Cassava**	No production	-

Source: Authors.

Table 2.3.3-8. Biofuel Supply/Demand Status Summary for the Five Countries by 2030

	Ethanol for gasoline blend			Biodiesel for diesel blend		
	Supply (billion L)	Demand (billion L)	Excess/ Deficit	Supply (billion L)	Demand (billion L)	Excess/ Deficit
Thailand (TH)	**8.3**	**3.3**	**5.0** billion L	**5.2**	**3.8**	**1.4** billion L
Indonesia (IN)	**0.8**	**11.6**	**▲10.8** billion L	**24**	**6.3**	**17.7** billion L
Philippines (PH)	**1.5**	**1.0**	**0.5** billion L	**0.8**	**1.7**	**▲0.9** billion L
Malaysia (MA)	**-**	**1.8**	**▲1.8** billion L	**3.4**	**3.9**	**▲0.5** billion L
Viet Nam (VN)	**0.6**	**2.1**	**▲1.5** billion L	**-**	**1.1**	**▲1.1** billion L

* **Blue deficit**; shall be covered by the country's own effort first,
Red deficit; can be fulfilled by means of regional cooperation through trading of biofuels

Source: Authors.

2) Discussions and possibility for multinational cooperation of biofuel supply

Taking into account the estimated biofuel supply potentials in each country by 2030, there are deficits of ethanol supply in Indonesia (–10.8 billion L), Malaysia (–1.8 billion L), and Viet Nam (–1.5 billion L) to fulfil demand, as well as deficits of biodiesel supply in the Philippines (–0.9 billion L), Malaysia (–0.5 billion L), and Viet Nam (–1.1 billion L) to meet the respective demand as shown in Table 2.3.3-8. However, as far as the deficit of ethanol in Viet Nam is concerned, Viet Nam has a large cassava production potential and only a part is currently used for ethanol production as mentioned in Table 2.3.3-6. The same can be said for the biodiesel deficit in Malaysia as a huge volume of CPO is produced in Malaysia, including applications other than biodiesel production (Table 2.3.3-5). Thus, we see possibilities for Viet Nam and Malaysia, respectively, to solve their ethanol and biodiesel deficits through domestic efforts to increase either raw material or biofuel production by themselves.

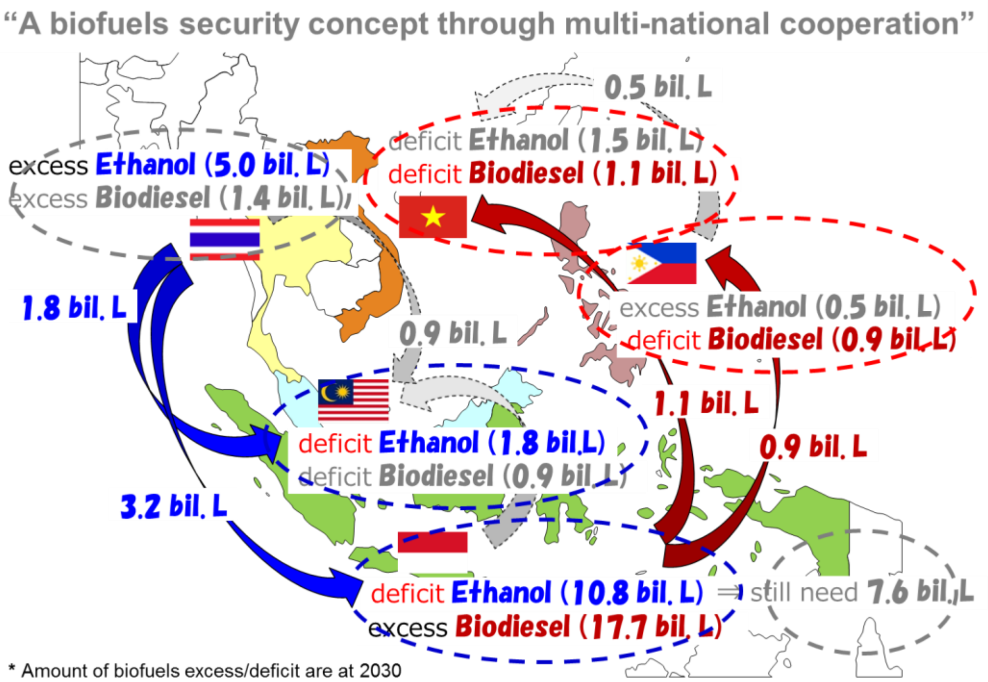
As excess supply of biofuels is concerned, Thailand has an excess volume of ethanol of 5.0 billion litres and the same for the Philippines of 0.5 billion litres. Indonesia has an excess of biodiesel of 17.7 billion litres and the same for Thailand of 1.4 billion litres, as shown in Table 2.3.3-8. The excess ethanol supply in Thailand (and also that in the Philippines) can be exported to Malaysia and Indonesia to fulfil demand as their domestic ethanol production is not sufficient, and the excess biodiesel supply in Indonesia (and that in Thailand as well) can be exported to the Philippines and Viet Nam as their domestic biodiesel is in short supply.

As an overall result, we see possibilities to supplement each other’s biofuels within the ASEAN region, acting as a form of biofuel security within the ASEAN region. Multinational cooperation in export/import of biofuels between the neighbouring countries will be able to help achieve the policy requirements in each country. However, the issue of insufficient total ethanol production volume in ASEAN as a whole remains to support the huge demand in Indonesia and cannot be fully supplemented within the ASEAN region. Finally, there are request for additional ethanol to be imported from outside ASEAN (e.g. from Brazil or the United States).

3) Proposal of ‘Biofuels Balancing Concept in ASEAN’

As discussed above, multinational cooperation of biofuel supply can be a measure for biofuel security within the ASEAN region except for ethanol to fulfil the huge demand in Indonesia, and ethanol is required to be imported from outside ASEAN additionally as the total ethanol production in ASEAN is not sufficient. We have named this biofuel security concept the ‘Biofuels Balancing Concept in ASEAN’, which schematically shown in Figure 2.3.3-1 with the volume of ethanol and/or biodiesel to be exported/imported by 2030. We consider the excess amount of ethanol in the Philippines and biodiesel in Thailand to be used for supporting Viet Nam and Malaysia in making their own respective effort to cover their ethanol or biodiesel deficit by themselves. The required amount of ethanol to be imported from outside ASEAN by 2030 will be around 7.6 billion litres.

Figure 2.3.3-1. Proposal of the Biofuel Supplementation Scheme within the ASEAN Region: Biofuels Balancing Concept in ASEAN



* Amount of biofuels excess/deficit are at 2030

Source: Authors.

In order to realise this biofuel security concept through multinational cooperation in practice, taking measures to get rid of barriers to prevent trading of biofuels between the neighbouring countries is the key to success.

Examples of necessary measures

1) Harmonisation of biofuel quality standards amongst the ASEAN Member States
2) NOT to specify feedstock for biofuel production only for domestic resources (e.g. coconuts for biodiesel production in the Philippines), performance-based and feedstock-neutral specifications are required.

The automotive industry globally (under the collaboration amongst the European Automobile Manufacturers Association, Alliance of Automobile Manufacturers in the United States, Engine Manufacturers Association in the United States, and Japan Automobile Manufacturers Association) has conducted the above-mentioned activities to promote high-quality fuels and harmonise fuel standards to ensure proper engine and vehicle operations and thus to benefit consumers. Proposed examples of recommendations by the automotive industry include the 'World-wide Fuel Charter Ethanol Guidelines' and 'Biodiesel Guidelines'. The 'EAS–ERIA Biodiesel Fuel Standard: 2013' proposed by the ERIA Energy Project Working Group through its activity as the benchmarking standard for biodiesel (FAME) in ASEAN and East Asia is another example.

The recommendation to the governments of ASEAN Member States are as follows: the key is to consider the opinions of all related stakeholders such as vehicle manufactures, fuel suppliers including biofuel producers, consumers, and policy makers, especially to follow the requirements and proposals initiated by the automotive industry for vehicle and fuel users to accept the increased biofuel utilisation and for all related stakeholders to discuss in each country for the sake of aligning opinions on how to realise biofuel security within the ASEAN region.

The Philippines is currently importing ethanol from Brazil and/or the United States, and even from Thailand in some cases. This could compel us to study more in detail the practices already being applied in the Philippines, how they are managing to import ethanol from outside the country to fulfil demand given the deficit in domestic production by giving priority to using domestically produced ethanol.

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Chapter 3

Next-Generation Biofuels: Technology and Economy

1 Introduction

First-generation biofuels such as ethanol made from sugarcane and cassava, as well as biodiesel made from palm oil and coconut oil are widely used in East Asia Summit countries. To promote the introduction of biofuels, high-concentration use of biofuels is planned in the transportation sector in each country (Chapter 2). With an increase in biofuel consumption, oil crop plantations will expand in a disorderly manner and the expansion will cause serious environmental destruction such as disorderly felling in wildwoods and problems of haze. Utilisation of nonconventional biomass such as non-edible crops and farm wastes should be considered for the sustainable introduction of biofuels.

On the other hand, automobile manufacturers have requested the introduction of next-generation biofuels such as synthetic hydrocarbons made from biomass (Koyama et al., 2007). Synthetic hydrocarbons are more compatible as transportation fuels because they are similar to conventional petroleum fuels. Another merit of next-generation biofuels is that they can be produced from any kind of biomass.

Biofuels are gradually being introduced as alternative aviation fuels. The International Air Transport Association (IATA) has decided its Sustainable Alternative Aviation Fuels Strategy. According to the simulation of greenhouse gas (GHG) reduction in the aviation sector, the introduction of biofuel is effective for reducing GHGs. Alternative aviation fuel made from biomass is limited to synthetic paraffinic kerosene because aviation fuel is used in low temperature. The process for producing alternative aviation fuel is similar to that of synthetic hydrocarbons for automobiles.

To solve these problems using nonconventional resources, development of economic production of next-generation biofuels made from nonconventional resources will be needed. However, information on non-edible feedstocks such as availability is limited and the technical problems concerning production of biofuels are not clear. Therefore, economic production technology of the next-generation biofuel has not been established.

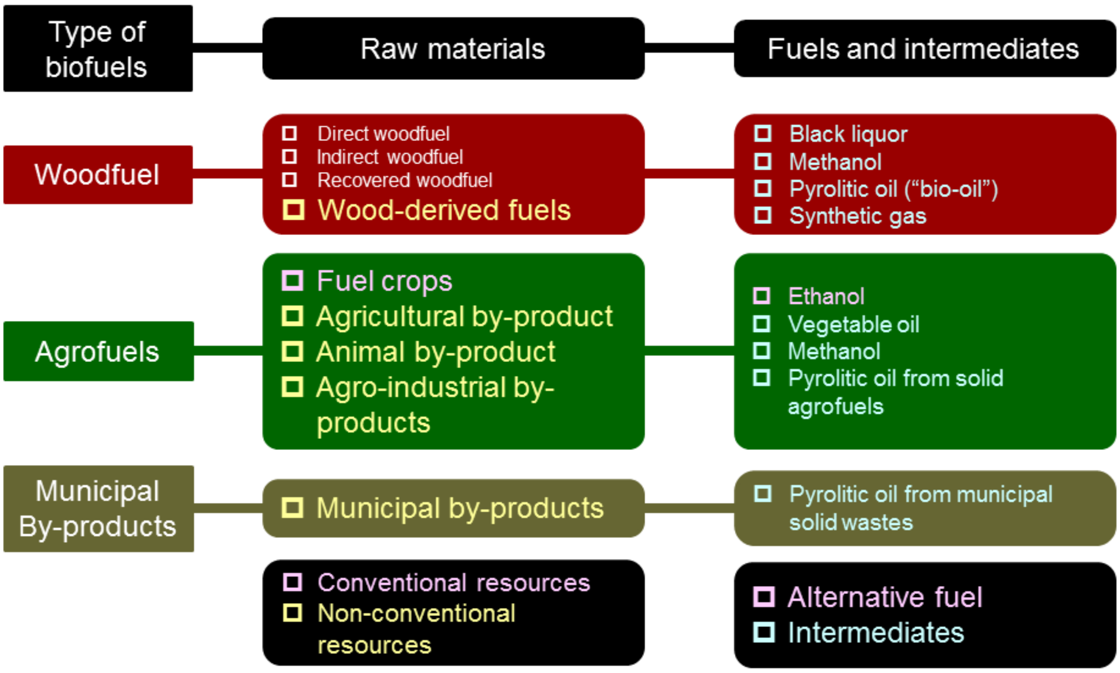
In this study, we consider three subjects: utilisation of nonconventional resources, production technology of next-generation biofuels and their quality, and cost performance improvement of next-generation biofuel production.

2 Utilisation of nonconventional resources

First-generation biofuels have been made from fuel crops. The production of fuel crops is limited and their utilisation as a biofuel resource also influences the food supply. To minimise the influence on the food supply and GHG emissions, the utilisation of waste biomass and agricultural by-products is desirable. Various processes give us intermediates from wood and farm waste (Figure 3.2-1). They can be converted into transportation fuels by catalyst technologies such as hydrotreating, transesterification, and Fischer-Trøpsch (FT) synthesis.

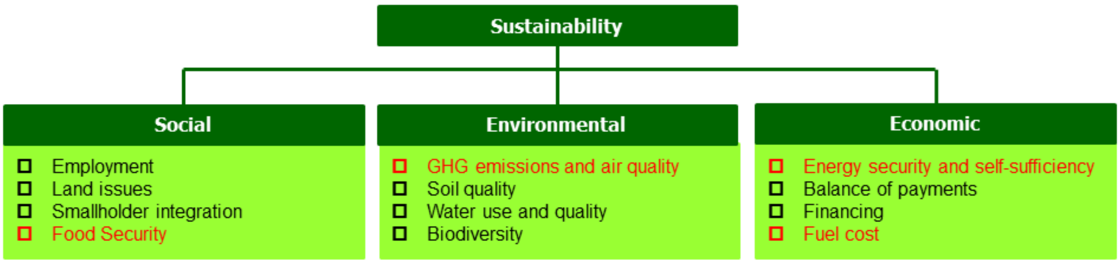
Of recent, the sustainability of biofuels is being considered when making policy to introduce biofuels. Sustainable production of next-generation biofuels includes three pillars of impacts: social, environmental, and economic (Figure 3.2-2). Social impacts include employment (job and income), land issues, food security, smallholder integration, and health problems. Environmental impacts include GHG balances, impact on soil, water and biodiversity, and direct and indirect land use changes. Apart from GHG balance, these factors mainly influence biomass production. Economic impacts include various factors in the security of biomass supply, the cost of fuel production, transportation cost, benefit of fuel supply, and the subsidy for the biofuel production.

Figure 3.2-1. Biofuel Classification



Source: FAO (2009).

Figure 3.2-2. Environmental, Social, and Economic Aspects of Biofuel and Bioenergy Production

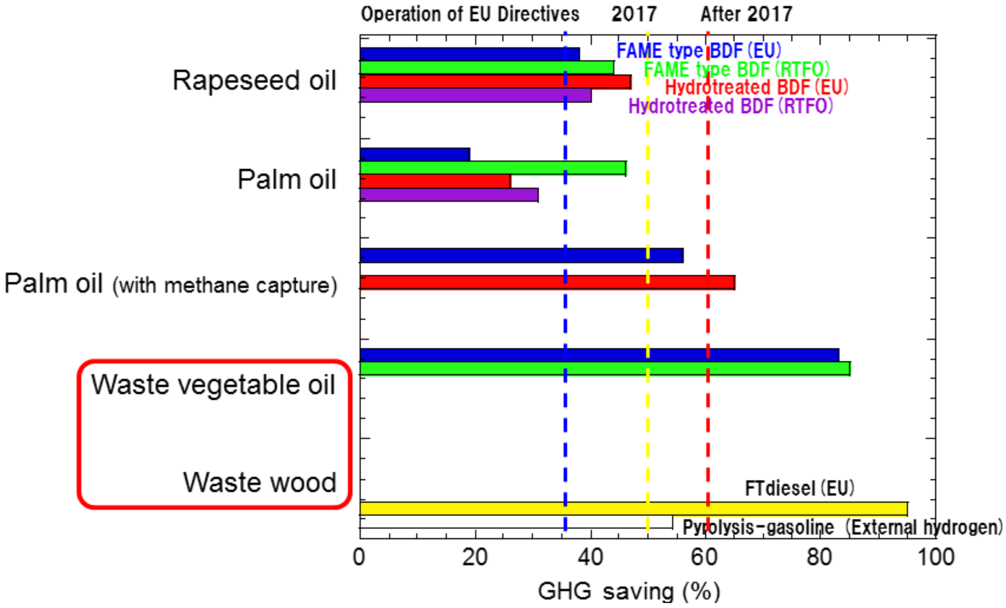


Note: Items in red font are considered in this chapter.
Sources: IEA (2010; 2011).

From the viewpoint of diversification of resources, the utilisation of nonconventional resources can satisfy food security (social problem) and energy security (economy).

Figure 3.2-3 shows GHG savings of diesel-substituted biofuel production. First- and next-generation biodiesel fuels made from farm products such as palm oil and rapeseed oil showed low GHG savings and are unable to meet EU directives. In case of facilities equipped with GHG traps (e.g. for methane capture), the rate of GHG savings in the reduction rate increases. The utilisation of waste materials is very effective for GHG reduction and increases sustainability in biofuel production.

Figure 3.2-3. Greenhouse Gas Savings of Diesel-Substituted Biofuel Production

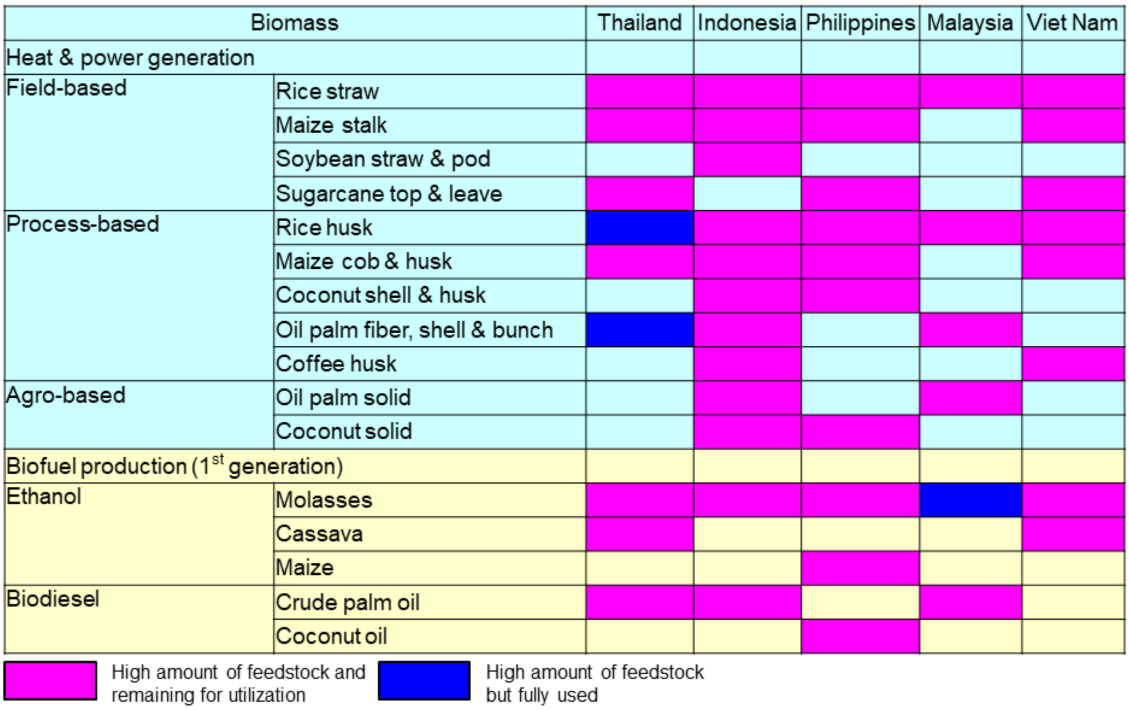


BDF = biodiesel fuel, EU = European Union, RTFO = Renewable Transport Fuel Obligation.
Sources: Argonne National Laboratory (2011); EU (2009); Renewable Fuels Agency (UK) (2012).

These results suggest that it is important to consider the selection of raw material and fuel production technology for sustainable introduction of biofuels.

ASEAN Member States produce various types of biomass. The availability of farm waste in the five ASEAN Member States is shown in Figure 3.2-4. Liquid biomass is mainly used as feedstocks of first-generation biofuels and solid biomass is mainly used for heat power and generation.

Figure 3.2-4. Biomass Potential Status in Major ASEAN Member States



Biomass		Thailand	Indonesia	Philippines	Malaysia	Viet Nam
Heat & power generation						
Field-based	Rice straw	🟪	🟪	🟪	🟪	🟪
	Maize stalk	🟪	🟪	🟪		🟪
	Soybean straw & pod		🟪			
	Sugarcane top & leave	🟪		🟪		🟪
Process-based	Rice husk	🟦	🟪	🟪	🟪	🟪
	Maize cob & husk	🟪	🟪	🟪		🟪
	Coconut shell & husk		🟪	🟪		
	Oil palm fiber, shell & bunch	🟦	🟪		🟪	
	Coffee husk		🟪			🟪
Agro-based	Oil palm solid		🟪		🟪	
	Coconut solid		🟪	🟪		
Biofuel production (1st generation)						
Ethanol	Molasses	🟪	🟪	🟪	🟦	🟪
	Cassava	🟪				🟪
	Maize			🟪		
Biodiesel	Crude palm oil	🟪	🟪		🟪	
	Coconut oil			🟪		

🟪 High amount of feedstock and remaining for utilization

🟦 High amount of feedstock but fully used

Sources: National Science Technology and Innovation Policy Office (Thailand); Joint Graduate School of Energy and Environment (2014).

The species and amounts of agricultural by-products depend on the farm products. For example, rice is grown in most ASEAN Member States. By-products of rice production such as rice straw and rice husk are available as energy resources in these countries. On the other hand, by-products from the palm industry are only available in Indonesia, Malaysia, and Thailand. Some agricultural wastes are fully used in conventional industry. When we use the biomass as a resource of fuel production, we must consider the amount of resources, availability considering conventional use, and locality.

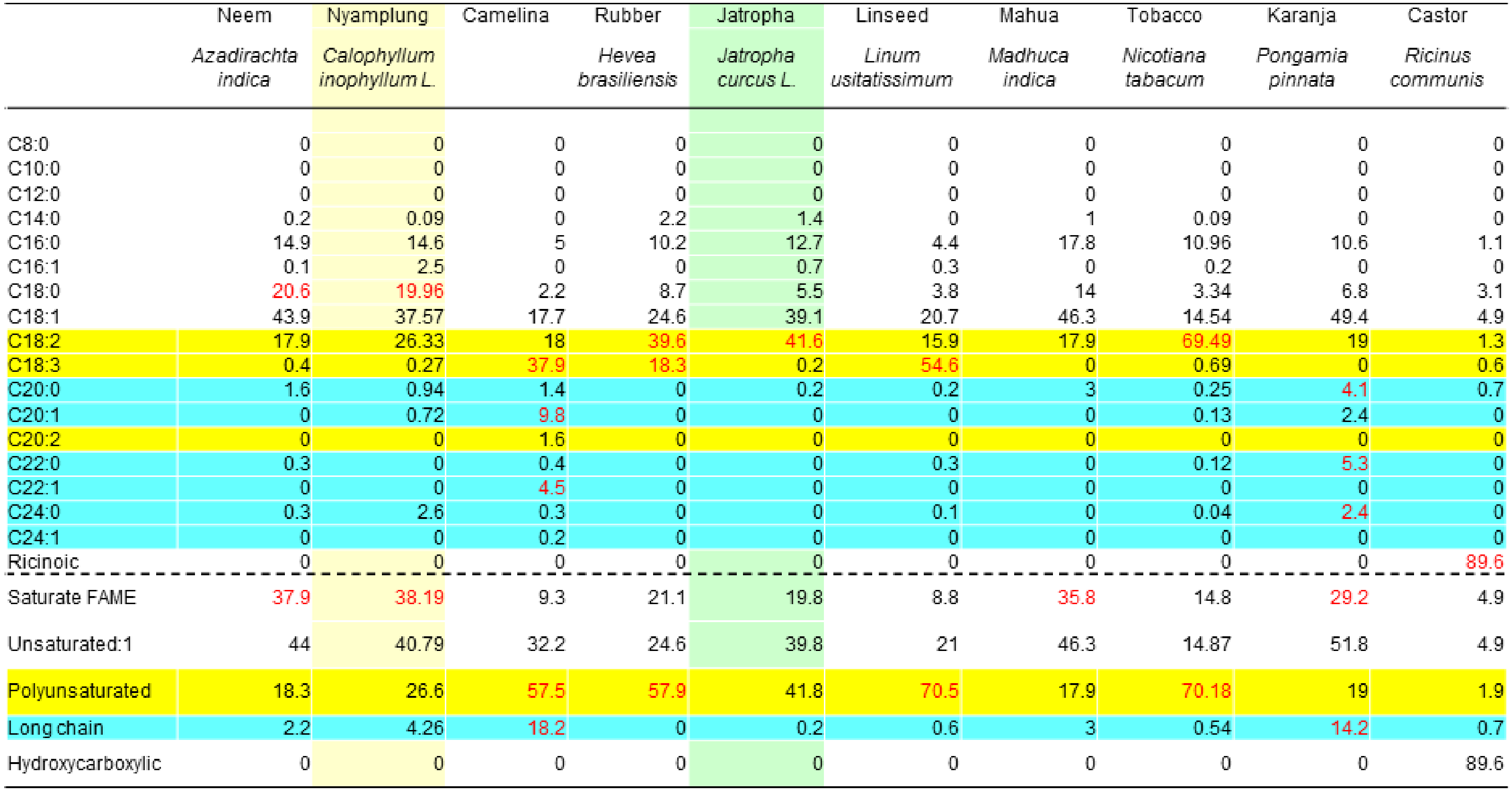
3. Production Technology of Next-Generation Biofuels and Their Quality

There are two ways of biofuel production from nonconventional resources. One is a method to produce biofuels using a conventional procedure. Sometimes, fuels obtained by this method are also called next-generation biofuels. Strictly, these fuels should be classified as first-generation biofuels. Typical fuels in this category are biodiesel fuels produced from non-edible biomass. The other method is a process using petroleum refinery facilities to produce hydrocarbon-type biofuels, which is described later.

When nonconventional resources are used for biofuel production, their properties influence the fuel quality and the difficulty of fuel production. Table 3.3-1 shows oil productivity and acid value of non-edible feedstocks. Some oils show high acid value derived from free fatty acids. Free fatty acids and homogeneous alkaline catalyst (KOH, NaOH) used in the conventional process form soap. To prevent soap formation, pretreatment (esterification, etc.) of free fatty acids is needed. The low-grade resources are inexpensive, but we should consider that they may cause a rise in the production cost.

The quality of ethanol made from biomass is almost constant because it is a pure chemical.

Table 3.3.-1 Yield, Oil Content, and Acid Value of Various Non-edible Oils



	Neem	Nyamplung	Camelina	Rubber	Jatropha	Linseed	Mahua	Tobacco	Karanja	Castor
	Azadirachta indica	*Calophyllum inophyllum L.*		*Hevea brasiliensis*	*Jatropha curcus L.*	*Linum usitatissimum*	*Madhuca indica*	*Nicotiana tabacum*	*Pongamia pinnata*	*Ricinus communis*
C8:0	0	0	0	0	0	0	0	0	0	0
C10:0	0	0	0	0	0	0	0	0	0	0
C12:0	0	0	0	0	0	0	0	0	0	0
C14:0	0.2	0.09	0	2.2	1.4	0	1	0.09	0	0
C16:0	14.9	14.6	5	10.2	12.7	4.4	17.8	10.96	10.6	1.1
C16:1	0.1	2.5	0	0	0.7	0.3	0	0.2	0	0
C18:0	20.6	19.96	2.2	8.7	5.5	3.8	14	3.34	6.8	3.1
C18:1	43.9	37.57	17.7	24.6	39.1	20.7	46.3	14.54	49.4	4.9
C18:2	17.9	26.33	18	39.6	41.6	15.9	17.9	69.49	19	1.3
C18:3	0.4	0.27	37.9	18.3	0.2	54.6	0	0.69	0	0.6
C20:0	1.6	0.94	1.4	0	0.2	0.2	3	0.25	4.1	0.7
C20:1	0	0.72	9.8	0	0	0	0	0.13	2.4	0
C20:2	0	0	1.6	0	0	0	0	0	0	0
C22:0	0.3	0	0.4	0	0	0.3	0	0.12	5.3	0
C22:1	0	0	4.5	0	0	0	0	0	0	0
C24:0	0.3	2.6	0.3	0	0	0.1	0	0.04	2.4	0
C24:1	0	0	0.2	0	0	0	0	0	0	0
Ricinoic	0	0	0	0	0	0	0	0	0	89.6
Saturate FAME	37.9	38.19	9.3	21.1	19.8	8.8	35.8	14.8	29.2	4.9
Unsaturated:1	44	40.79	32.2	24.6	39.8	21	46.3	14.87	51.8	4.9
Polyunsaturated	18.3	26.6	57.5	57.9	41.8	70.5	17.9	70.18	19	1.9
Long chain	2.2	4.26	18.2	0	0.2	0.6	3	0.54	14.2	0.7
Hydroxycarboxylic	0	0	0	0	0	0	0	0	0	89.6

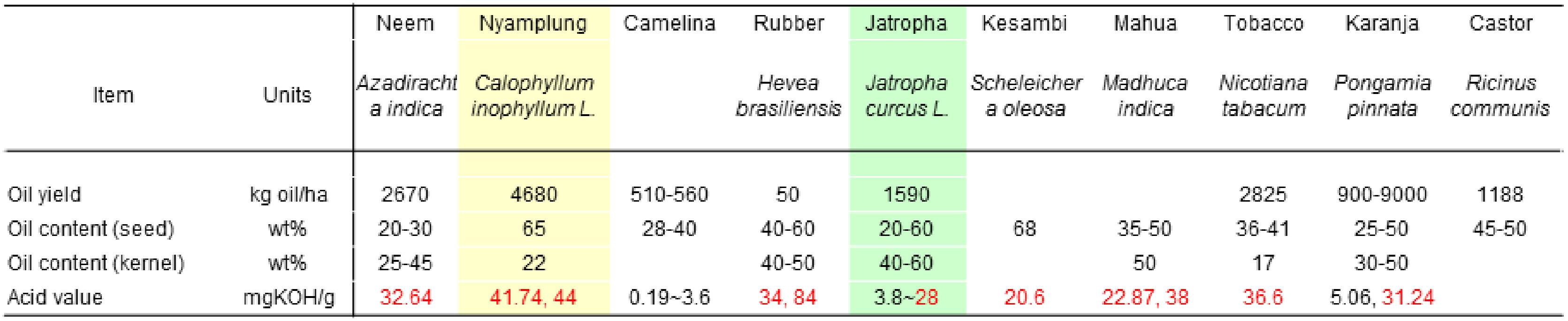
Sources: Bankovic-Ilic et al. (2012); Borugadda et al. (2012); Atabani et al. (2013); Silitonga et al. (2015); Wakil et al. (2015); Khayoon et al. (2012); Ahmad et al. (2014).

On the other hand, the quality of biodiesel fuel is not constant because it is a mixture of various fatty acid methyl esters (FAME). Therefore, the fatty acid composition of oil has a large influence on fuel property. Table 3.3-2 shows the fatty acid composition of biodiesel fuel produced from non-edible oil. Neem (scientific name: *Azadirachta indica*) and nyamplung (scientific name: *Calophyllum inophyllum L.*) biodiesel fuels contain high concentrations of saturated FAME such as methyl stearate, and their cloud points are relatively higher than other biodiesel fuels (see Table 3.3-3). Biodiesel fuels produced from rubber seed and tobacco oil contain 57.9% and 70.2% of polyunsaturated FAME, respectively (Table 3.3-2). Both fuels show low oxidation stability. If we use these feedstocks as biodiesel fuel production, improvement of quality is needed.

To use transportation fuels safely, the quality guarantee by the fuel standard is important. The fuel standard of first-generation fuels (ethanol and FAME-type biodiesel fuel) has already been introduced to control the quality of commercial biofuels. The proposed EAS–ERIA Biodiesel Fuel Standard (EEBS2013) is based on resources used in East Asia Summit countries and experimental data. The EEBS value has been adopted as the national standard of some countries (ERIA, 2015).

The limits of oxidation stability, monoglyceride content, and phosphorus content are getting strict in the recent revision of the biodiesel fuel quality standard. To meet the standard, biodiesel fuel must be upgraded through physical and chemical treatment (Table 3.3-4). For example, the oxidation stability of biodiesel can be improved by partial hydrogenation technology developed under the Science and Technology Research Partnership for Sustainable Development (SATREPS) project in collaboration with Japanese (National Institute of Advanced Industrial Science and Technology) and Thai (Thailand Institute of Scientific and Technological Research, National Science and Technology Development Agency/National Metal and Materials Technology Center) research institutes (Table 3.3-5). This technology enables the reduction of polyunsaturated FAME, which are easily oxidised by air. The upgraded biodiesel was named H-FAME. Development of H-FAME technology for commercialisation has already started under a new alternative energy development plan of the Thai government (Alternative Energy Development Plan 2015).

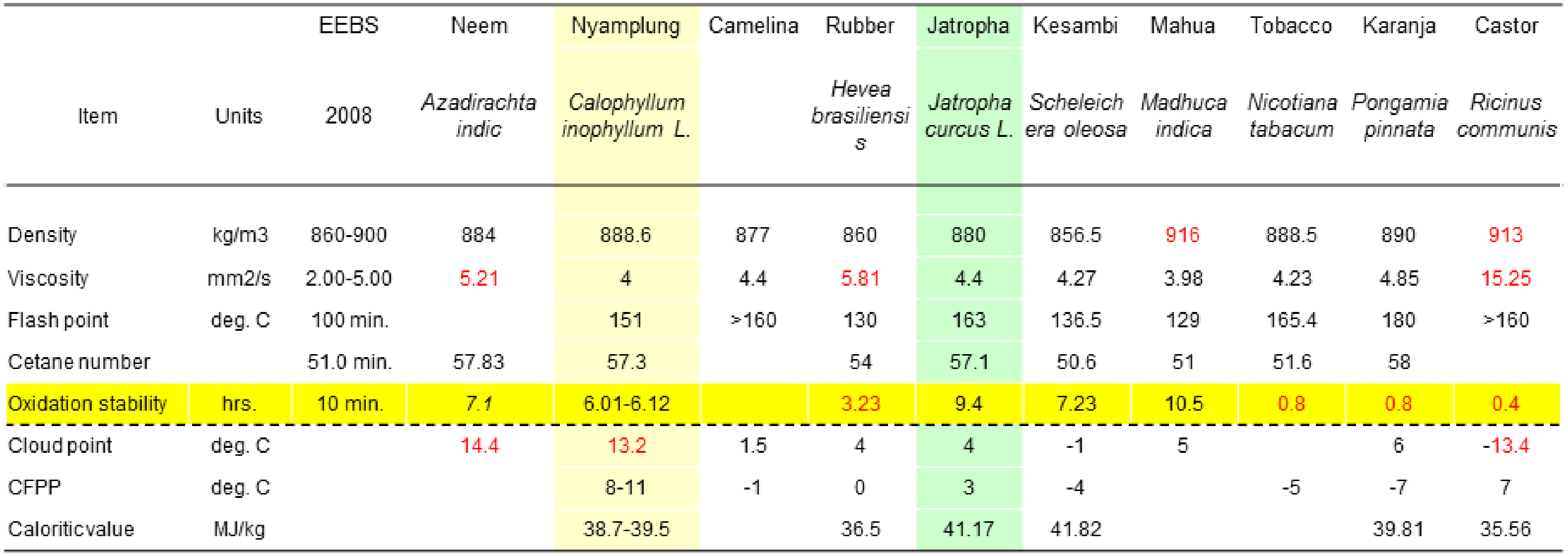
Table 3.3-2. Fatty Acid Composition of Various Non-edible Oils



Item	Units	Neem	Nyamplung	Camelina	Rubber	Jatropha	Kesambi	Mahua	Tobacco	Karanja	Castor
		Azadirachta indica	*Calophyllum inophyllum L.*		*Hevea brasiliensis*	*Jatropha curcus L.*	*Scheleichera oleosa*	*Madhuca indica*	*Nicotiana tabacum*	*Pongamia pinnata*	*Ricinus communis*
Oil yield	kg oil/ha	2670	4680	510-560	50	1590			2825	900-9000	1188
Oil content (seed)	wt%	20-30	65	28-40	40-60	20-60	68	35-50	36-41	25-50	45-50
Oil content (kernel)	wt%	25-45	22		40-50	40-60		50	17	30-50	
Acid value	mgKOH/g	32.64	41.74, 44	0.19~3.6	34, 84	3.8~28	20.6	22.87, 38	36.6	5.06, 31.24	

Source: Atabani et al. (2013).

Table 3.3-3. Properties of Fatty Acid Methyl Ester Produced from Various Non-edible Oils



Item	Units	EEBS	Neem	Nyamplung	Camelina	Rubber	Jatropha	Kesambi	Mahua	Tobacco	Karanja	Castor
		2008	*Azadirachta indic*	*Calophyllum inophyllum L.*		*Hevea brasiliensis*	*Jatropha curcus L.*	*Scheleichera oleosa*	*Madhuca indica*	*Nicotiana tabacum*	*Pongamia pinnata*	*Ricinus communis*
Density	kg/m3	860-900	884	888.6	877	860	880	856.5	916	888.5	890	913
Viscosity	mm2/s	2.00-5.00	5.21	4	4.4	5.81	4.4	4.27	3.98	4.23	4.85	15.25
Flash point	deg. C	100 min.		151	>160	130	163	136.5	129	165.4	180	>160
Cetane number		51.0 min.	57.83	57.3		54	57.1	50.6	51	51.6	58	
Oxidation stability	hrs.	10 min.	*7.1*	6.01-6.12		3.23	9.4	7.23	10.5	0.8	0.8	0.4
Cloud point	deg. C		14.4	13.2	1.5	4	4	-1	5		6	-13.4
CFPP	deg. C			8-11	-1	0	3	-4		-5	-7	7
Caloritic value	MJ/kg			38.7-39.5		36.5	41.17	41.82			39.81	35.56

Sources: Bankovic-Ilic et al. (2012); Atabani et al. (2013); Silitonga et al. (2015); Khayoon et al. (2012); Ahmad et al. (2014); Atabani et al. (2014); Ong et al. (2013).

The conclusions regarding the utilisation of nonconventional biomass as feedstocks of conventional biofuel are the following: (1) we should consider not only productivity of fruit/seed, but also composition and physical properties in case of raw material selection, (2) a pretreatment process is sometimes needed to improve fuel quality when low-grade non-edible oils are used as raw materials, and (3) fuel properties such as oxidation stability can be improved by reforming and refining technologies.

Table 3.3-4. EAS–ERIA Biodiesel Fuel standard and Improvement of Oxidation Stability, Monoglyceride Content, and Phosphorus Content

	EEBS2013	Upgrading method
Oxidation stability	10 h minimum	Antioxidant addition Partial hydrogenation
Monoglyceride	0.7 mass % maximum	Wintering + filtration Partial hydrogenation + filtration/adsorption
Phosphorus	4.0 mass % maximum	Water washing

ASEAN = Association of Southeast Asian Nations, EAS = East Asia Summit, ERIA = Economic Research Institute for ASEAN and East Asia, h = hour.
Source: ERIA (2015).

Table 3.3-5 Oxidation Stability of Various Biodiesels and Partial Hydrogenated Biodiesels Measured by Rancimat (EN14112)

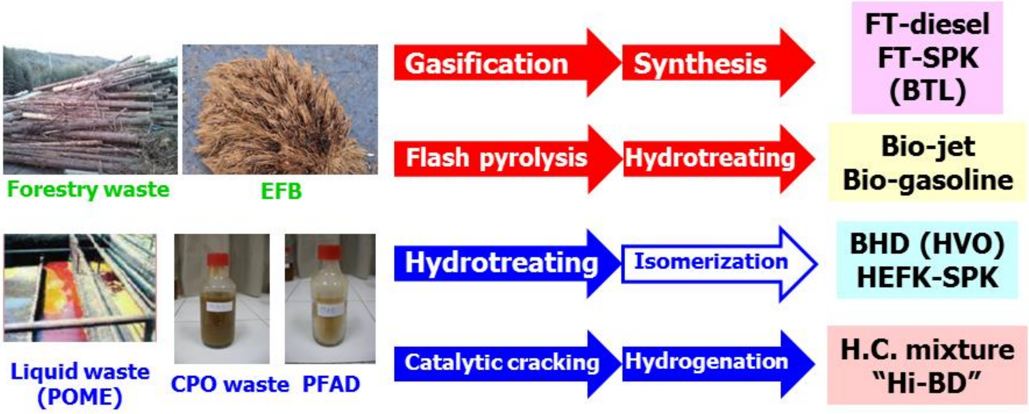
	Feed (h)	Hydrogenated (h)
Rapeseed ME	6.75	71.36
Soybean ME	1.54	87.19
Palm ME	5.72	100.21
Jatropha ME	0.58	11.91

ME = Methyl Ester.
Source: PCT/JP2011/053473, PCT/JP2014.077636, TH Pat. 54699.

Hydrocarbon-type next-generation biofuels produced by refinery systems are welcomed by automobile manufacturers because their qualities are similar to conventional petroleum transportation fuel. Another advantage of next-generation biofuels is the utilisation of solid resources and low-grade waste materials. Many processes to produce next-generation biofuels have been proposed (Figure 3.3-1). Those processes consist of various new technologies such as gasification, flash pyrolysis, hydrotreating, cracking, and FT synthesis. The property of the product and results of the cost calculation are reported in some articles. In the current state, it is not sufficient to accept these technologies as economic methods for biofuel production.

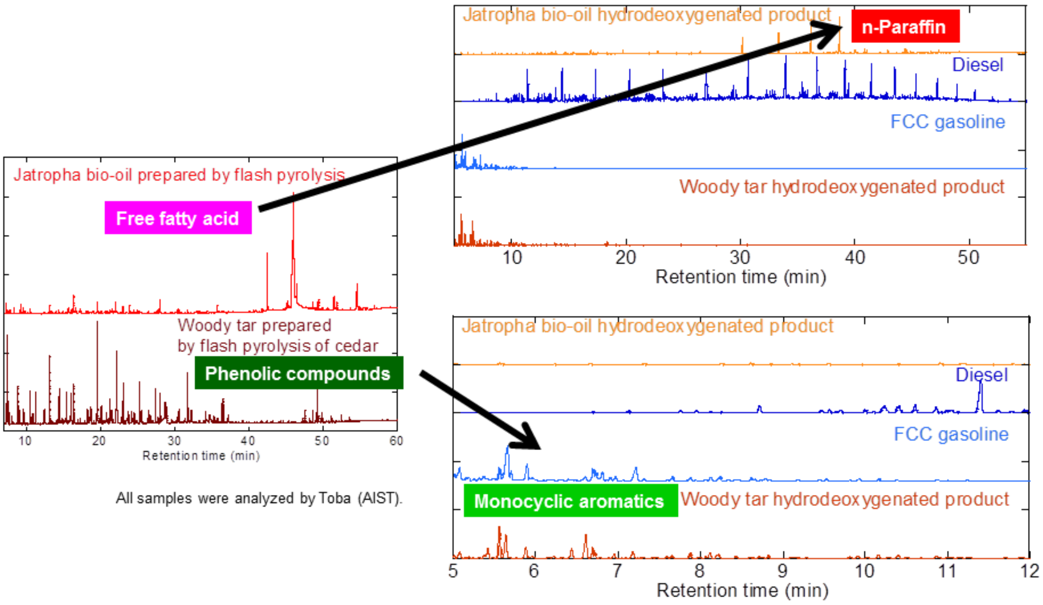
The end use of the product depends on the property of the raw material. Figure 3.3-2 shows gas chromatograms of bio-oils produced by flash pyrolysis of solid biomass and final products. Compared with conventional petroleum gasoline and diesel, a final product obtained from Jatropha bio-oil is similar to diesel. A final product obtained from woody tar is similar to fluid catalytic cracked (FCC) gasoline.

Figure 3.3-1. Production of Hydrocarbon-Type Next-Generation Biofuels



BHD = bio-hydrogenated diesel, BTL = biomass to liquid, CPO = crude palm oil, EFB = empty fruit bunch, FT = Fischer–Tropsch, H.C. = hydrocarbon, HEFA-SPK = hydroprocessed esters and fatty acids-synthetic paraffinic kerosene, HVO = hydrotreated vegetable oil, PFAD = palm fatty acid distillate, POME = palm oil mill effluent.
Source: Authors.

Figure 3.3-2. Gas Chromatograms of Bio-oils and Final Products Made by Flash Pyrolysis and Upgrading Reaction

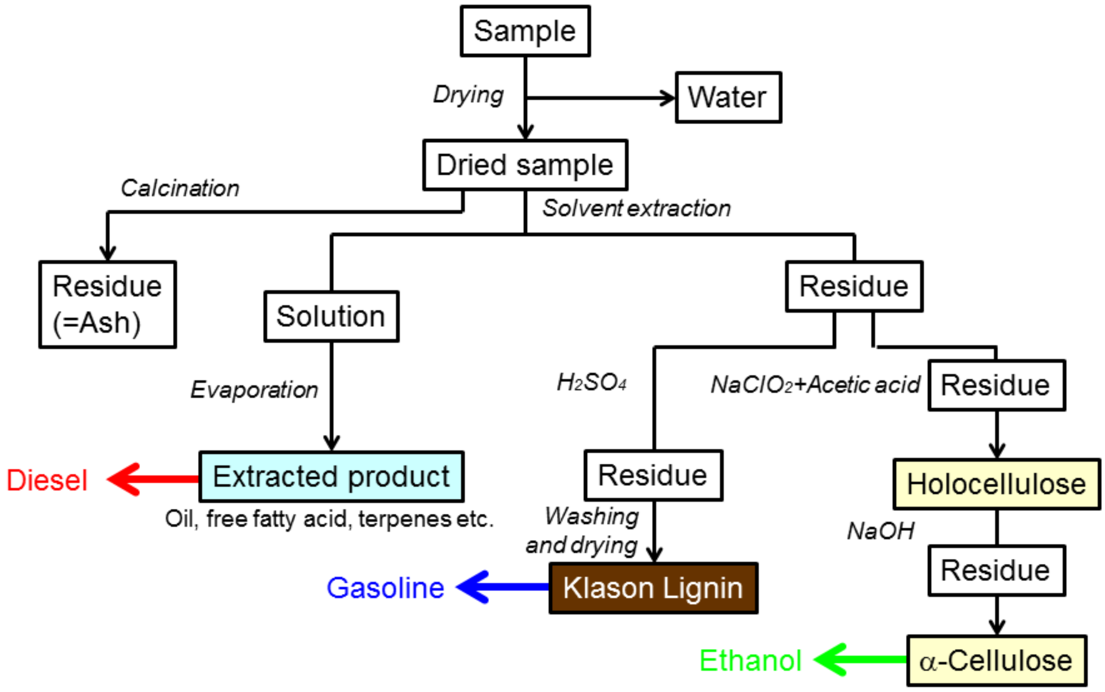


FCC = Fluid Catalytic Cracking.
Source: Authors.

These results show that we have to choose the raw material and a manufacturing process appropriately, according to the final product. Therefore, analysis of the biomass composition is very important before using it. In the case of biomass gasification, this factor is not important because the intermediate of gasification of any biomass is synthetic gas.

Except gasification, quantification of biomass components is very important to decide the final products. The main components of biomass are usually cellulose, hemicellulose, lignin, and triglycerides. Cellulose and hemicellulose are easily decomposed into small molecules such as furan compounds, cyclic ketones, and short chain carboxylic acids under high temperature treatment. These compounds are more suitable for intermediates of fine chemicals producing. For transportation fuel, cellulose and hemicellulose should be converted into ethanol. Basic structures of lignin and triglycerides are stable under thermochemical conversion. Useful intermediates for producing alternative fuels are obtained from lignin and triglycerides by thermal or catalytic conversion. The typical quantification method of biomass components is shown in Figure 3.3-3. We can estimate the fuel potential of each biomass using a simple analysis.

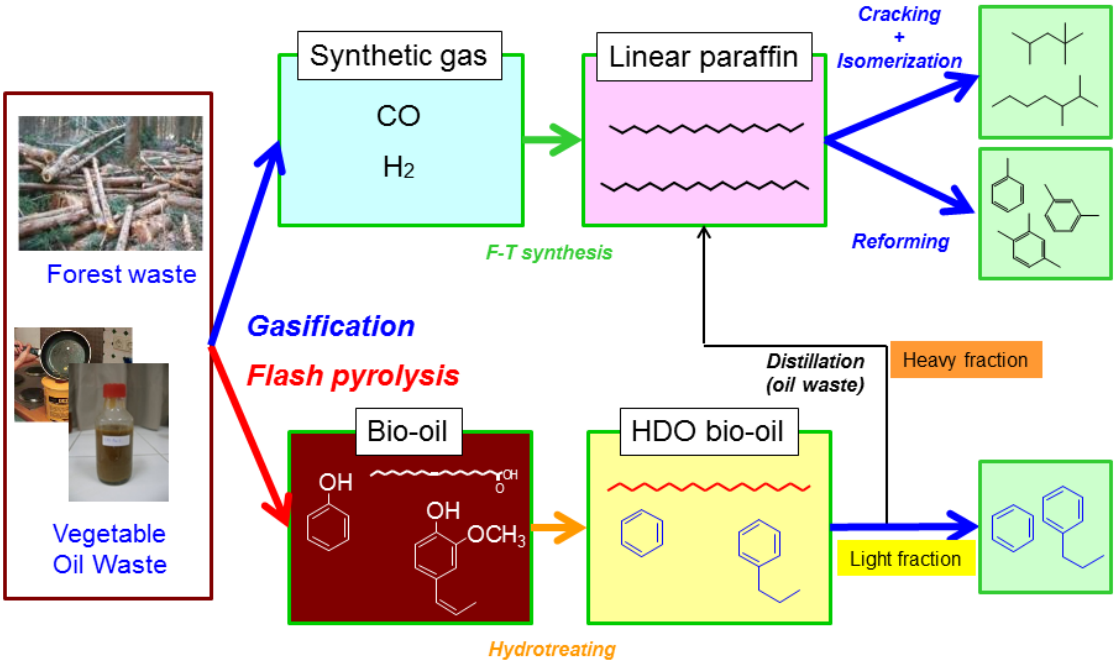
Figure 3.3-3. Systematic Quantitative Analysis of Biomass Components



Source: Authors.

Two ways of producing alternative hydrocarbon gasoline from biomass are considered (Figure 3.3-4). In the case of biomass gasification, synthetic gas is obtained as an intermediate. Synthetic gas is converted into linear paraffins by FT synthesis. Finally, iso-paraffinic hydrocarbons are obtained by catalytic cracking and isomerisation, and aromatic hydrocarbons are obtained by reforming. On the other hand, flash pyrolysis of the biomass gives us bio-oil containing oxygen compounds such as phenolic compounds, free fatty acids, and cyclic ketones. The components contained in bio-oil are converted into hydrocarbons by deoxygenation. Aromatic hydrocarbons (high-octane compounds) derived from phenolic compounds are contained in the fraction of low boiling point. Linear paraffins derived from fatty acids are contained in the heavy fraction. These components can be divided by distillation.

Figure 3.3-4. Alternative Gasoline Production from Waste Biomass

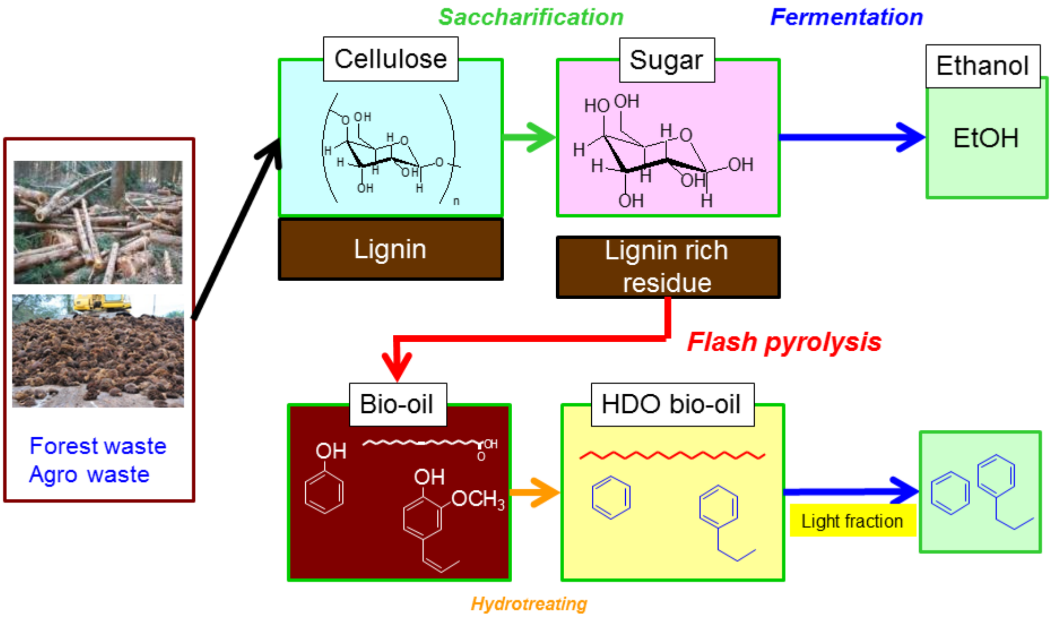


HDO = heavy duty oil.
Source: Authors.

It is difficult to produce transportation fuel properly with the components derived from cellulose and hemicellulose by usual flash pyrolysis. In this case, saccharification and fermentation for producing ethanol are carried out in the first step. Then, lignin-rich residue obtained from the saccharification process is converted into bio-oil by flash pyrolysis (Figure 3.3-5). Figure 3.3-6 shows gas chromatograph of bio-oils obtained from willow and saccharised residue of willow. Saccharised residue still contains lignin, and it can give phenolic compounds as intermediates of the production of aromatic gasoline.

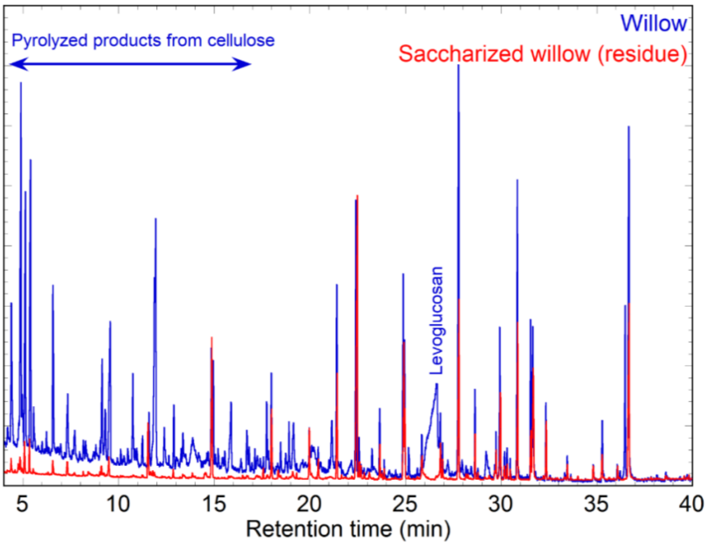
In the case of alternative diesel production by biomass gasification (Figure 3.3-7), linear paraffins are obtained by FT synthesis. The intermediates can easily be converted into products by isomerisation (and cracking). Synthetic gas is converted into linear paraffins by FT synthesis.

Figure 3.3-5. Combined Ethanol and Alternative Gasoline Production from Waste Biomass



Source: Authors.

Figure 3.3-6. Gas Chromatograms of Bio-oils Obtained from Willow and Its Saccharised Residue



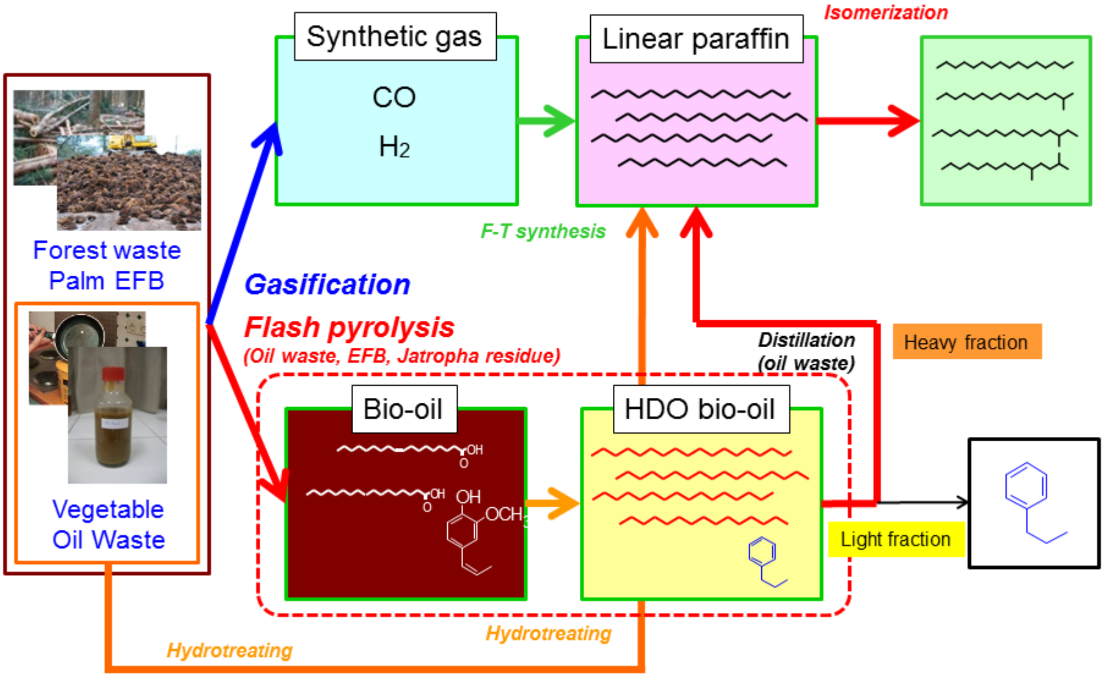
Source: Authors.

Glycerides and fatty acid contained in oil waste can be converted into linear paraffins by catalytic hydrodeoxygenation. These compounds form linear paraffins through flash pyrolysis. Alternative diesel can be obtained from usual woody biomass only through gasification.

The target fuel and production process depends on the composition of key compounds in the biomass resources. Analysis of raw materials is important for evaluating the potential of fuel productivity.

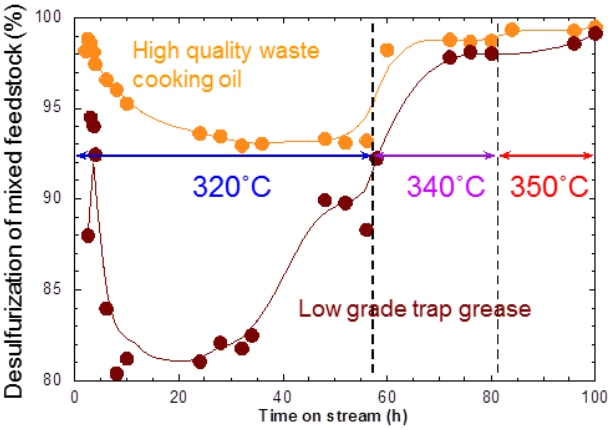
When low-grade materials or new resources are used as the feedstock of fuel production, their quality sometimes influences the activity and life of the catalyst. Such technical information is scarce, though these factors are important in the simulation of production cost (prediction of catalyst life). Figure 3.3-8 shows the effect of feedstock on hydrotreating of 10 weight% waste cooking oil or trap grease/straight-run diesel mixture based on our experimental data. Trap grease, a waste material from sewage, contains a high concentration of free fatty acids and its acid value is much higher than that of waste cooking oil. Catalytic activity was seriously damaged in the hydrodesulfurisation of trap grease/straight-run diesel mixture. To produce high-quality diesel like sulfur-free diesel, the reaction must be carried out under a more severe condition and the catalyst life may shorten.

Figure 3.3-7. Alternative Diesel Production from Waste Biomass



Source: Authors.

Figure 3.3-8. Hydrotreating of Waste Cooking Oil or Trap Grease/Straight-Run Diesel Mixture



Source: Ministry of the Environment, Japan (2012).

Recently, the standard of hydrocarbon biofuel as a blendstock of diesel fuel has been established (EN15940:2016). The quality of some alternative diesel fuels is shown in Table 3.3-6.

Some blendstocks do not meet with the conventional petroleum diesel fuel standard (EN590) and have a high cetane number and cloud point compared with petrodiesel. However, the properties of most these blendstocks meet with the new standard. In the future, it will be necessary to discuss the standard of the next-generation biofuel, which is produced from the biomass obtained in East Asia Summit countries.

The conclusions in this section are the following:

(1) The advantage of next-generation fuel is to be able to use inexpensive raw materials such as waste materials from the viewpoint of production. It also contributes to reduction of GHG emissions.

(2) There are various processes such as gasification, pyrolysis, and hydrotreating for producing next-generation biofuels. The final product and its productivity depend on the manufacturing process.

(3) The analysis of the biomass composition is indispensable to decide the use of the final product.

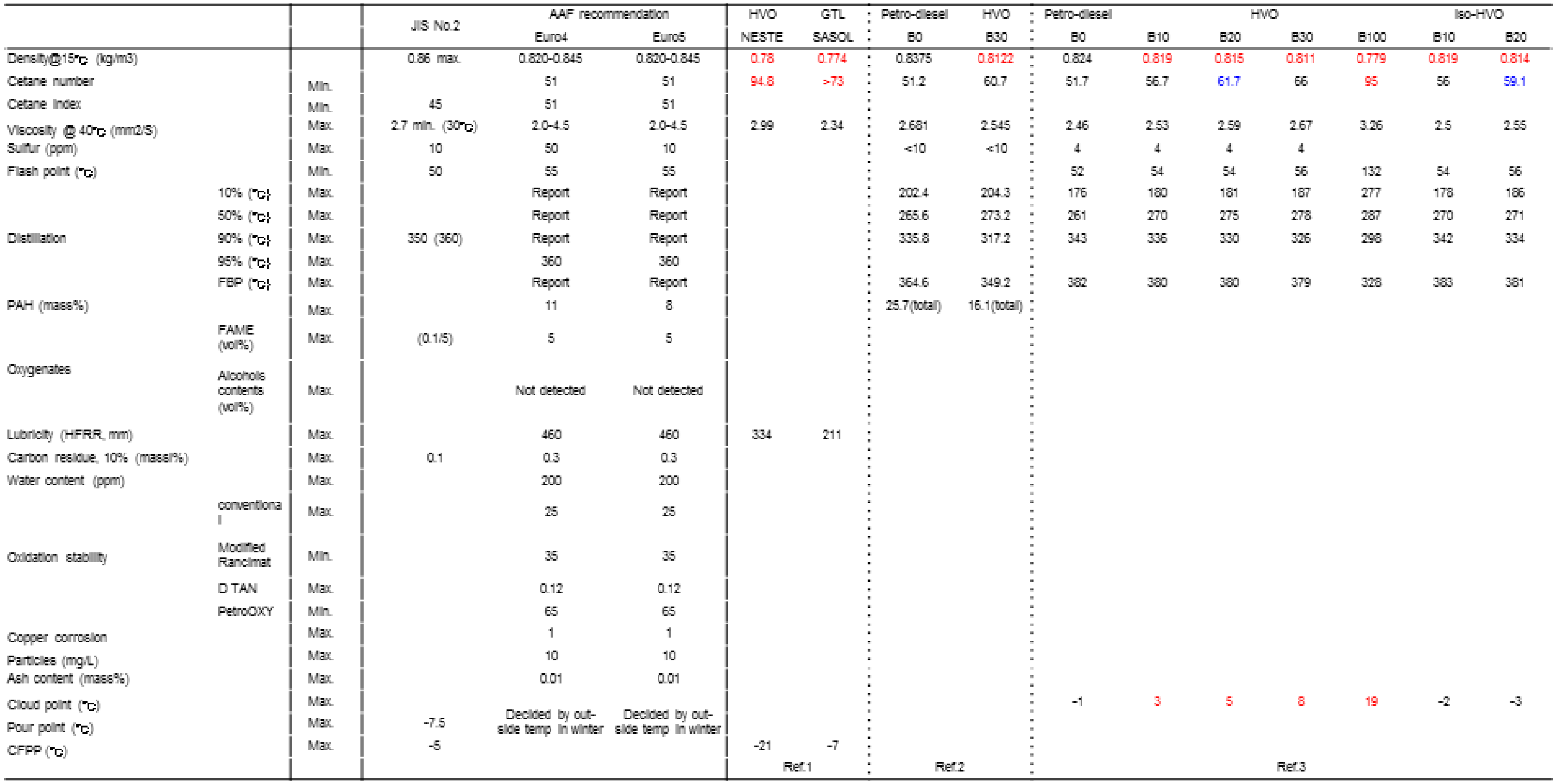
(4) When low-grade material is used as a feedstock, its quality influences catalytic activity. In this case, a durable catalyst must be developed. It is necessary to clarify technological problems through experimental works.

(5) Fuel blended with hydrocarbon biofuel not always meets the conventional fuel standard. The quality of blendstock should be defined by the standard specification.

3.4 Cost Performance Improvement of Next-Generation Biofuel Production

Generally, the prices of current biofuels are higher than those of conventional petroleum fuels. To promote biofuel, funding system has been introduced.

Table 3.3-6. Properties of Various Alternative Diesel Fuel (HVO, FT-Diesel)



			JIS No.2	AAF recommendation		HVO	GTL	Petro-diesel	HVO	Petro-diesel	HVO				Iso-HVO	
				Euro4	Euro5	NESTE	SASOL	B0	B30	B0	B10	B20	B30	B100	B10	B20
Density@15℃ (kg/m3)			0.86 max.	0.820-0.845	0.820-0.845	0.78	0.774	0.8375	0.8122	0.824	0.819	0.815	0.811	0.779	0.819	0.814
Cetane number		Min.		51	51	94.8	>73	51.2	60.7	51.7	56.7	61.7	66	95	56	59.1
Cetane index		Min.	45	51	51											
Viscosity @ 40℃ (mm2/S)		Max.	2.7 min. (30℃)	2.0-4.5	2.0-4.5	2.99	2.34	2.681	2.545	2.46	2.53	2.59	2.67	3.26	2.5	2.55
Sulfur (ppm)		Max.	10	50	10			<10	<10	4	4	4	4			
Flash point (℃)		Min.	50	55	55					52	54	54	56	132	54	56
	10% (℃)	Max.		Report	Report			202.4	204.3	176	180	181	187	277	178	186
	50% (℃)	Max.		Report	Report			265.6	273.2	261	270	275	278	287	270	271
Distillation	90% (℃)	Max.	350 (360)	Report	Report			335.8	317.2	343	336	330	326	298	342	334
	95% (℃)	Max.		360	360											
	FBP (℃)	Max.		Report	Report			364.6	349.2	382	380	380	379	328	383	381
PAH (mass%)		Max.		11	8			25.7(total)	16.1(total)							
	FAME (vol%)	Max.	(0.1/5)	5	5											
Oxygenates	Alcohols contents (vol%)	Max.		Not detected	Not detected											
Lubricity (HFRR, mm)		Max.		460	460	334	211									
Carbon residue, 10% (mass%)		Max.	0.1	0.3	0.3											
Water content (ppm)		Max.		200	200											
	conventional	Max.		25	25											
Oxidation stability	Modified Rancimat	Min.		35	35											
	D TAN	Max.		0.12	0.12											
	PetroOXY	Min.		65	65											
Copper corrosion		Max.		1	1											
Particles (mg/L)		Max.		10	10											
Ash content (mass%)		Max.		0.01	0.01											
Cloud point (℃)		Max.								-1	3	5	8	19	-2	-3
Pour point (℃)		Max.	-7.5	Decided by out-side temp in winter	Decided by out-side temp in winter											
CFPP (℃)		Max.	-5			-21	-7									
						Ref.1		Ref.2		Ref.3						

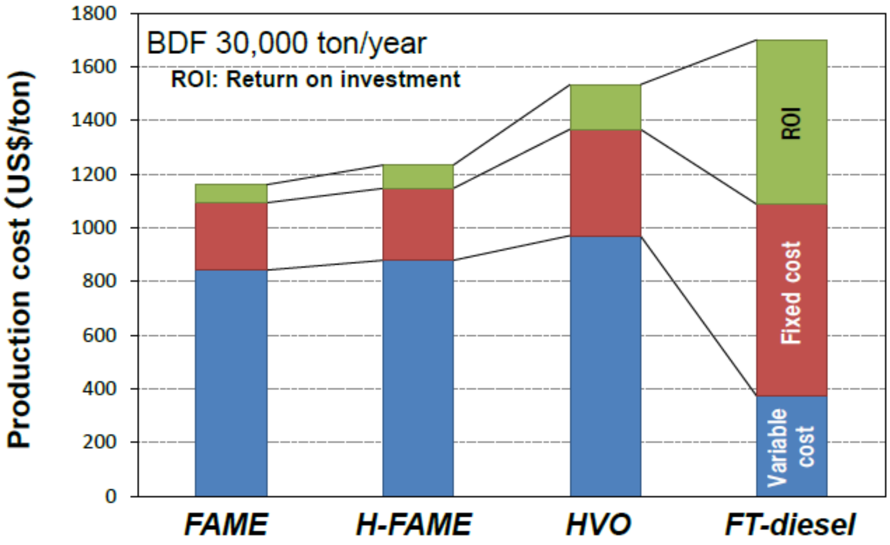
FT = Fischer-Trøpsch, HVO = hydrotreated vegetable oil.
Source: Authors.

However, it is predicted that the next-generation biofuels will be more expensive. In this section, the factors to reduce the price of next-generation biofuel are clarified.

Raw Material Cost

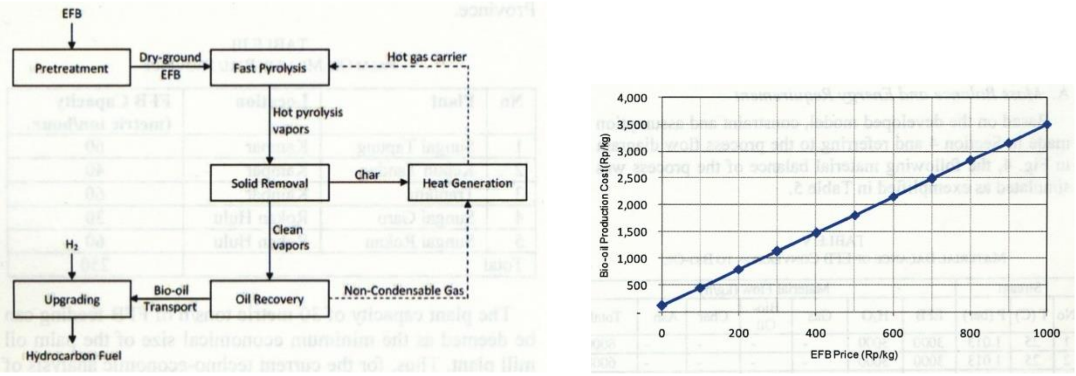
Currently, edible feedstocks are mainly used as biofuel resources. For biodiesel production, more than 95% of biodiesel is produced from edible oils. The use of edible feedstocks in biofuel production has a large influence on food demand and supply. In addition, the price of transportation biofuel is usually higher than that of corresponding fossil fuel. To accelerate biofuel introduction, the fuel price must be reduced. According to feasibility studies of biofuel production, the biofuel price depends mainly on the cost of feedstock. Figure 3.4-1 shows production costs of conventional and next-generation biodiesel (Waseda University, 2011). FAME, H-FAME, and hydrogenated vegetable oil (HVO) are produced from palm oil. Of the total biodiesel cost, 64%–73% is the cost of feedstock. Baroi et al. (2015) showed that the raw material cost in total biodiesel manufacturing costs is 66.6%. Poddar et al. (2015) showed that the raw material cost in total biodiesel manufacturing costs is 83.6%. These results suggest that the cost reduction of feedstock is effective for improvement of the economy of biodiesel production.

Figure 3.4-1. Feasibility Study of Biodiesel Production from Palm Oil (FAME, H-FAME, and HVO) and Woody Biomass (FT-Diesel)



BDF = biodiesel fuel, FAME = fatty acid methyl esters, FT = Fischer-Trøpsch, H-FAME = hydrogenated FAME, HVO = hydrotreated vegetable oil.
Source: Waseda University (2011).

Figure 3.4-2 Fuel Production Scheme from Empty Fruit Bunch and Bio-oil Production Cost



Source: Peryoga et al. (2014).

Figure 3.4-2 shows the scheme of transportation fuel production from empty fruit bunch (EFB) of palm by pyrolysis and upgrading, and the results of bio-oil production cost analysis (Peryoga et al., 2014). The bio-oil production cost is proportional to the EFB price.

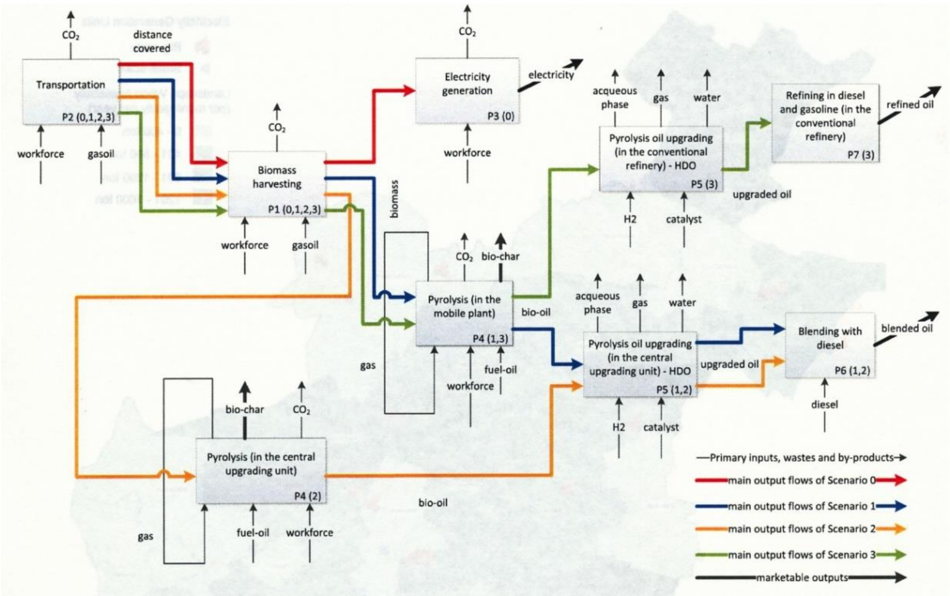
These results suggest that the cost reduction of feedstock is important for improvement of the economy of biodiesel production. The utilisation of cheap feedstocks such as non-edible feedstocks including waste materials contributes to the reduction of the biofuel price.

Process Selection

Utilisation of non-conventional resources contributes to reduction of feedstock cost. However, operation and management cost is usually more expensive than conventional biofuel production. In future, optimal process R&D is needed to reduce operation and management cost. In this section, we would like to show some examples of process selection to reduce cost of biofuel production.

Transportation fuel is usually produced via several steps. Each step has some possibilities to produce intermediates and products. Figure 3.4-3 shows a flow diagram of fuel production. Three scenarios were proposed for producing fuel (Scenarios 1–3). The diagram consists of three main steps: pyrolysis, upgrading (hydrodeoxygenation: HDO), and co-processing/blending. Pyrolysis is carried out using a mobile plant (S1, S3) or central unit (S2). Pyrolysis oil upgrading is carried out using a central unit (S1, S2) or conventional refinery (S3). Produced oil from the upgrading process is refined with crude petroleum fraction (co-processing: S3) or blended with refined petroleum fraction (S1, S2).

Figure 3.4-3. Supply Chain Flow Diagram of Fuel Production via Pyrolysis and Upgrading

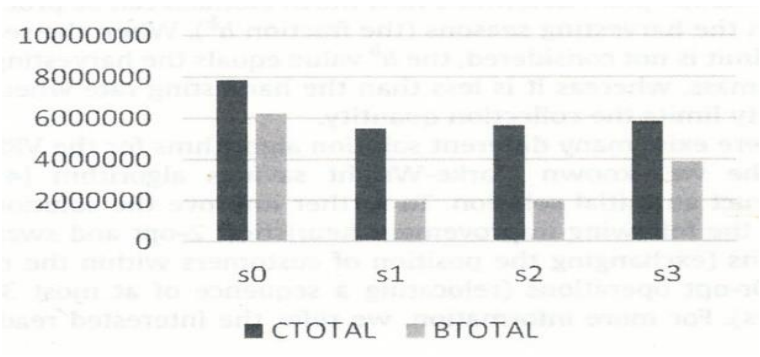


Source: Yazan et al. (2016).

The result of the cost calculation (in euro) of each scenario is shown in Figure 3.4-4. Compared with scenarios 1–3, the fuel production cost is almost equal. However, the benefit of scenario 3 is higher than that of scenarios 1 and 2. These results indicate that upgrading (HDO) and co-processing processes have more benefits than the pyrolysis process. In this case, we should choose scenario 3 to produce transportation fuel, economically.

Recently, various alternative jet fuels are proposed: GTJ – gas to jet, OTJ – oil to jet, ATJ – alcohol to jet, and STJ – sugar to jet. From solid waste, GTJ and OTJ processes are suitable for alternative jet fuel production. A comparison of intermediate production cost is shown in Table 3.4-1 (Wang et al., 2016). Pyrolysis can create an intermediate more cheaply more than FT synthesis. The final jet fuel cost depends on the cost of upgrading.

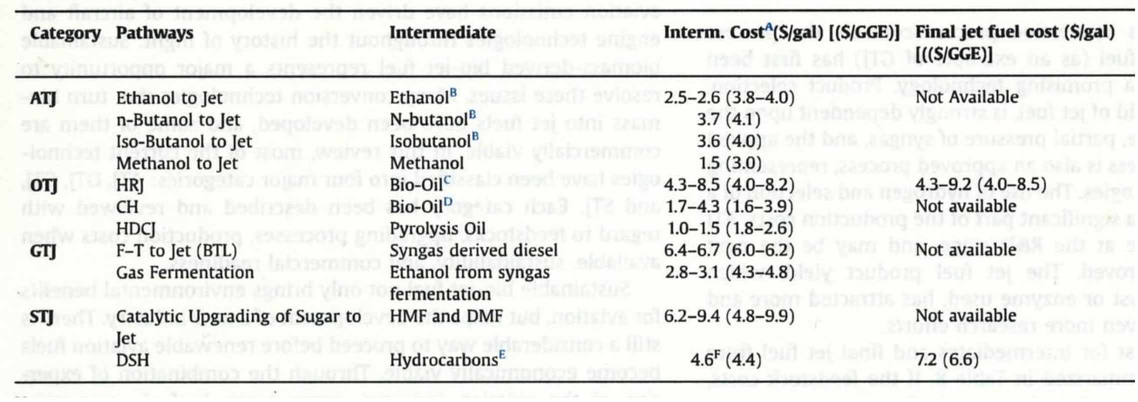
Figure 3.4-4. Total Production Cost and Benefit of Fuel Production



Source: Yazan et al. (2016).

Utilisation of by-products, or simultaneous production of valuable chemicals, contributes to cost reduction of fuel production. Table 3.4-2 shows the cost effect of fuel production using FT synthesis with/without the methanol to gas (MTG) process (Baliban et al., 2013). In the D-1 process, fuel is produced by FT synthesis using the Ir catalyst and methanol to gas process. On the other hand, fuel is produced by only FT synthesis using the Co catalyst in the K-1 process. While fuel can be produced for US$100.86 per barrel (bbl) in D-1, it costs US$110.96/bbl in K-1.

Table 3.4-1 Production Costs of Alternative Jet Fuel from Various Pathways

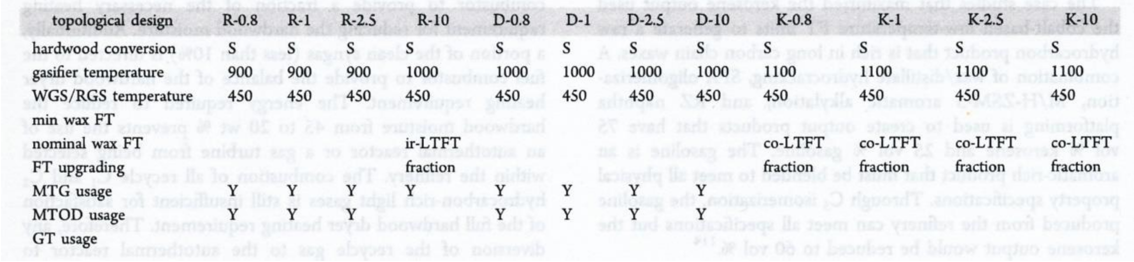


Category	Pathways	Intermediate	Interm. Cost[A]($/gal) [($/GGE)]	Final jet fuel cost ($/gal) [(($/GGE)]
ATJ	Ethanol to Jet	Ethanol[B]	2.5–2.6 (3.8–4.0)	Not Available
	n-Butanol to Jet	N-butanol[B]	3.7 (4.1)	
	Iso-Butanol to Jet	Isobutanol[B]	3.6 (4.0)	
	Methanol to Jet	Methanol	1.5 (3.0)	
OTJ	HRJ	Bio-Oil[C]	4.3–8.5 (4.0–8.2)	4.3–9.2 (4.0–8.5)
	CH	Bio-Oil[D]	1.7–4.3 (1.6–3.9)	Not available
	HDCJ	Pyrolysis Oil	1.0–1.5 (1.8–2.6)	
GTJ	F–T to Jet (BTL)	Syngas derived diesel	6.4–6.7 (6.0–6.2)	Not available
	Gas Fermentation	Ethanol from syngas fermentation	2.8–3.1 (4.3–4.8)	
STJ	Catalytic Upgrading of Sugar to Jet	HMF and DMF	6.2–9.4 (4.8–9.9)	Not available
	DSH	Hydrocarbons[E]	4.6[F] (4.4)	7.2 (6.6)

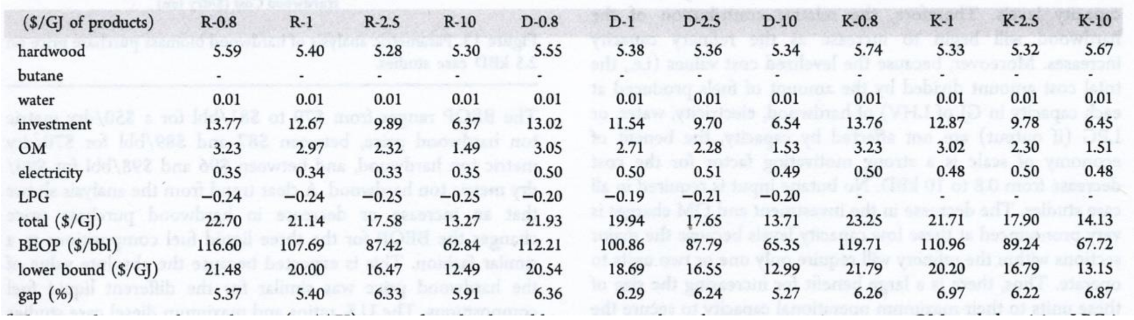
Source: Wang et al. (2016).

From the viewpoint of energy consumption, energy savings may contribute to cost reduction of fuel production. Figure 3.4-5 shows the simulation result of energy input for producing biofuel via a fast pyrolysis-upgrading process from solid biomass (Wong et al., 2016). Energy consumption of hydroprocessing (hydrotreating and hydrocracking) is much higher than other processes (harvesting, transportation, and pyrolysis). This result indicates that improvement of hydroprocessing may reduce energy consumption and contribute to cost cutting.

Table 3.4-2. Cost Effect of Fuel Production Using FT Synthesis with/without Methanol to Gas Process



topological design	R-0.8	R-1	R-2.5	R-10	D-0.8	D-1	D-2.5	D-10	K-0.8	K-1	K-2.5	K-10
hardwood conversion	S	S	S	S	S	S	S	S	S	S	S	S
gasifier temperature	900	900	900	1000	1000	1000	1000	1000	1100	1100	1100	1100
WGS/RGS temperature	450	450	450	450	450	450	450	450	450	450	450	450
min wax FT												
nominal wax FT				ir-LTFT fraction					co-LTFT fraction	co-LTFT fraction	co-LTFT fraction	co-LTFT fraction
FT upgrading												
MTG usage	Y	Y	Y	Y	Y	Y	Y	Y				
MTOD usage	Y	Y	Y		Y	Y	Y	Y				
GT usage												

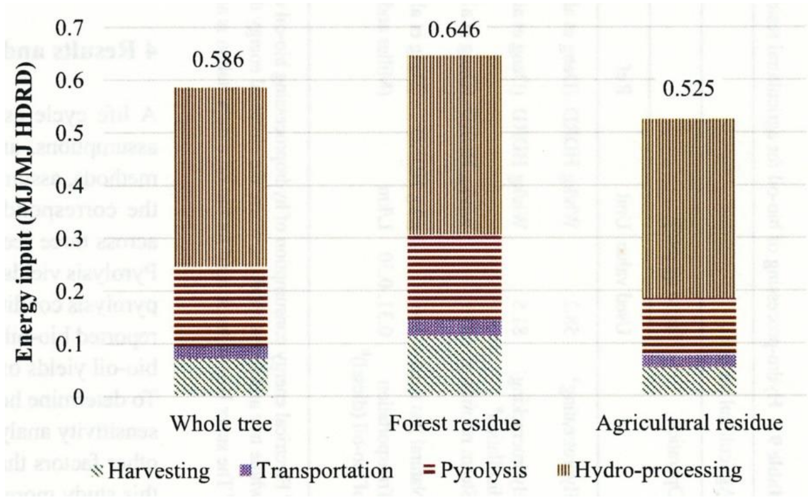


($/GJ of products)	R-0.8	R-1	R-2.5	R-10	D-0.8	D-1	D-2.5	D-10	K-0.8	K-1	K-2.5	K-10
hardwood	5.59	5.40	5.28	5.30	5.55	5.38	5.36	5.34	5.74	5.33	5.32	5.67
butane	-	-	-	-	-	-	-	-	-	-	-	-
water	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
investment	13.77	12.67	9.89	6.37	13.02	11.54	9.70	6.54	13.76	12.87	9.78	6.45
OM	3.23	2.97	2.32	1.49	3.05	2.71	2.28	1.53	3.23	3.02	2.30	1.51
electricity	0.35	0.34	0.33	0.35	0.50	0.50	0.51	0.49	0.50	0.48	0.50	0.48
LPG	−0.24	−0.24	−0.25	−0.25	−0.20	−0.19	−0.21	−0.20	-	-	-	-
total ($/GJ)	22.70	21.14	17.58	13.27	21.93	19.94	17.65	13.71	23.25	21.71	17.90	14.13
BEOP ($/bbl)	116.60	107.69	87.42	62.84	112.21	100.86	87.79	65.35	119.71	110.96	89.24	67.72
lower bound ($/GJ)	21.48	20.00	16.47	12.49	20.54	18.69	16.55	12.99	21.79	20.20	16.79	13.15
gap (%)	5.37	5.40	6.33	5.91	6.36	6.29	6.24	5.27	6.26	6.97	6.22	6.87

Source: Baliban et al. (2013).

To reduce hydroprocessing costs, upgrading of pyrolysis vapour using a supported metal catalyst with fixed bed flow rector is proposed (Area200 in Figure 3.4-6) (Dutta et al., 2016). In this process, partially upgraded (deoxygenated) products are obtained. In the hydrodeoxygenation of partially upgraded products, hydrogen consumption and catalyst life seem to be improved compared with those of hydroprocessing of usual bio-oil. Therefore, the cost of hydroprocessing and separation is very low (Area400) compared with the result of Figure 3.4-5.

Figure 3.4-5. Simulation Result of Energy Input for Producing Biofuel

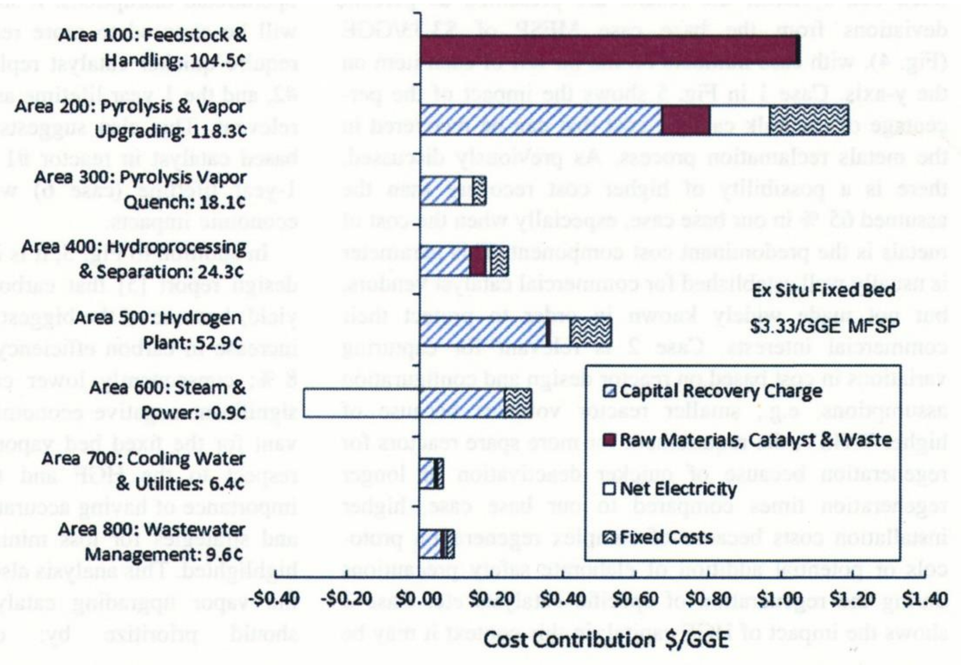


Source: Wong et al. (2016).

It is important to simulate sensitivity of each factor for producing biofuel. In the case of jet fuel production from Jatropha oil and residue, more than half of the direct capital cost is oil upgrading (Figure 3.4-7) (Wang, 2016).

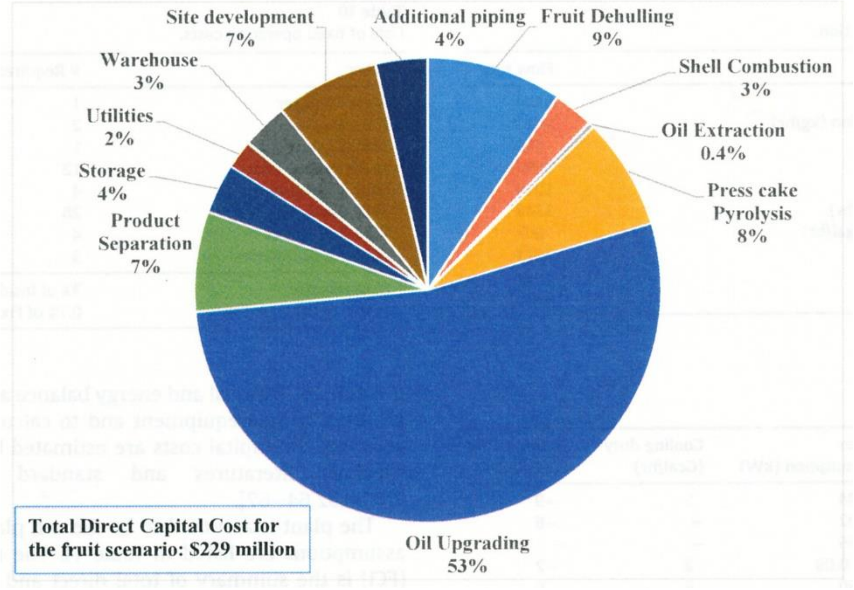
According to the simulation of cost sensitivity (Figure 3.4-8), the hydrotreating catalyst cost has a large influence on product price (MJSP or minimum jet fuel selling price). It can be concluded that the reduction of the catalyst price gives the largest effect to supply cheap fuel (Tijmensen et al., 2002).

Figure 3.4-6. Cost Contribution by Each Process



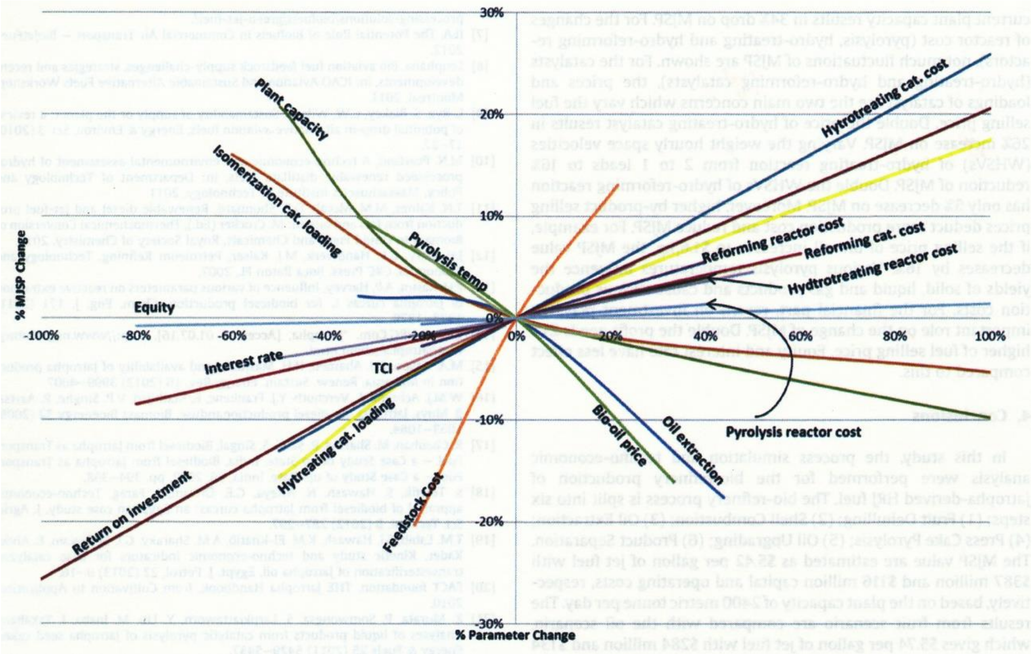
Source: Dutta et al. (2016).

Figure 3.4-7. Distribution of Total Direct Capital Cost



Source: Wang (2016).

Figure 3.4-8. Cost Sensitivity Analysis of Jet Fuel Production from Jatropha



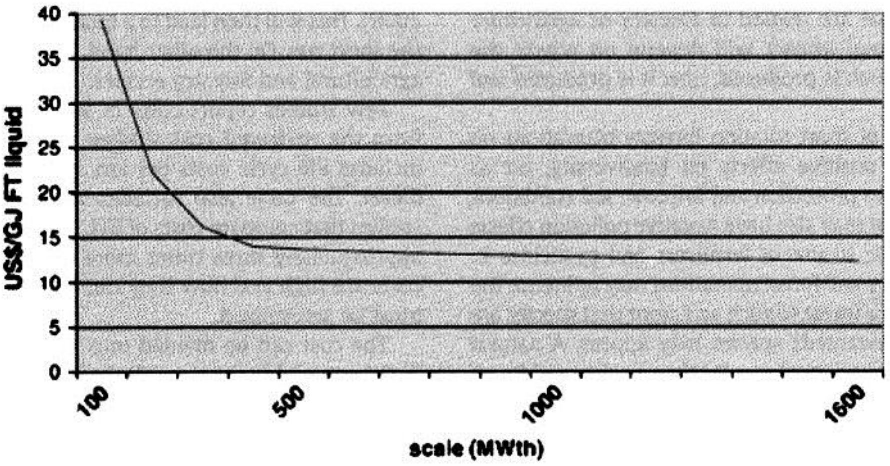
Source: Wang (2016).

Plant Scale

The scale of the biofuel manufacturing plant also has an influence on fuel price. An example of a biomass-to-liquids (BTL) process is indicated in Figure 3.4-9 (Tijmensen et al., 2002). The fuel price produced in a small-scale plant is high. The price decreases with increasing plant scale. However, the scale merit is sometimes denied by various factors such as transportation cost and productivity of raw materials when the scale becomes too large. Therefore, there is an optimal range in economical plant scale. If a cheaper raw material can be used, the cost performance of a small-scale plant may be improved.

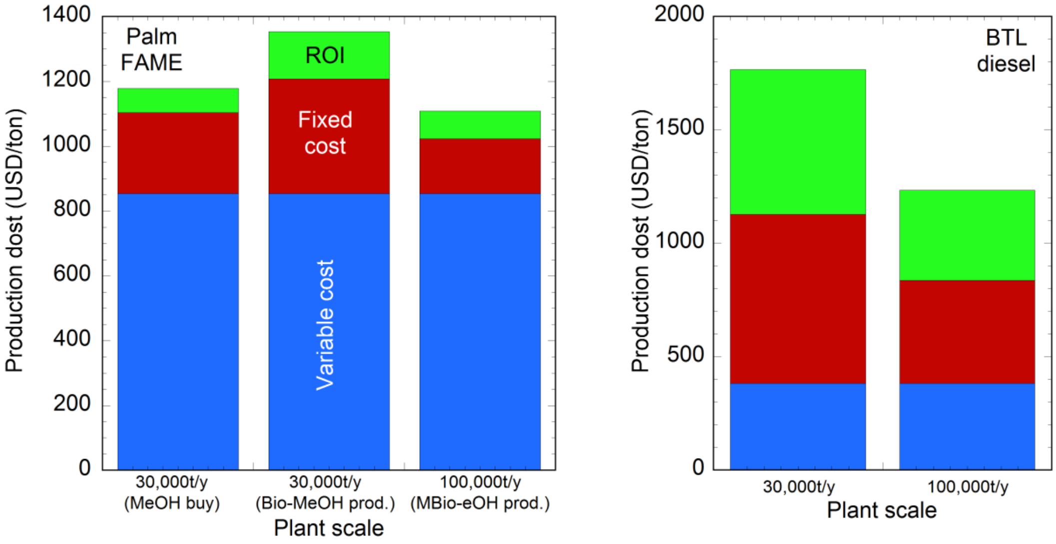
The production cost consists roughly of variable cost, fixed cost, and return on investment. The influence of the plant scale on these factors is shown in Figure 3.4-10. In the case of biodiesel (FAME) production, the variable cost per product weight is the same in all cases. The FAME production cost using methanol produced from biomass in the plant is higher than that using commercial methanol. This is mainly caused by an increase of fixed cost to construct a methanol plant. When the plant scale becomes larger, fixed cost per product weight decreases. A similar effect is observed in the manufacturing of BTL diesel fuel. Expansion of the fuel production scale is effective for reducing the fixed cost of fuel production.

Figure 3.4-9. Economy of Scale Effects for Biomass-to-Liquids Production from Poplar



Source: Tijmensen et al. (2002).

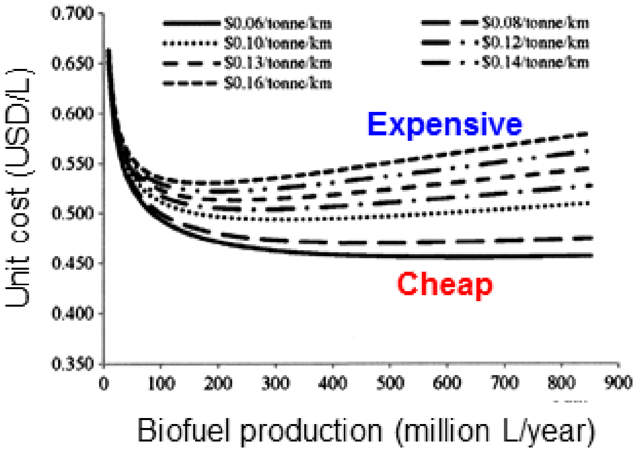
Figure 3.4-10. Feasibility Study of Alternative Diesel Production



Source: Waseda University (2011).

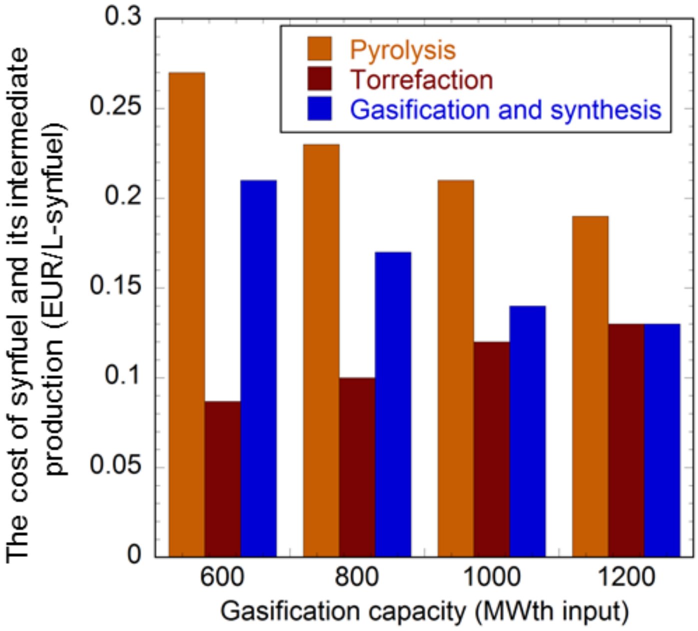
Scale merit is influenced by various factors. Jenkins et al. (2014) simulated the influence of the transportation cost rate of raw materials and intermediates on the relationship between plant capacity and ethanol production cost (Figure 3.4-11). The transportation cost usually depends on the distance from the place of raw material supply to the factory of intermediate and fuel production, as well as the shape and amount of the transported materials. If the transportation cost is too high, the scale merit is denied. The costs of the intermediate production and fuel synthesis by the BTL process are shown in Figure 3.4-12. The cost of synfuel production (gasification and synthesis) decreases with increasing gasification capacity. The cost of pyrolysis intermediate supply also decreases with increasing gasification capacity. On the contrary, the cost of torrefaction intermediate supply increases with increasing gasification capacity. The difference between pyrolysis and torrefaction causes transportation fee. The products of pyrolysis and torrefaction are liquid (tar) and solid, respectively. Liquid materials are less bulky and easier to carry to the fuel production factory by land transportation, ship and pipe line. This is an example of the shape effect of the transported materials on transportation fee.

Figure 3.4-11. Unit Cost as a Function of Biofuel Production for Various Delivery Rate Cost



Source: Jenkins et al. (2014).

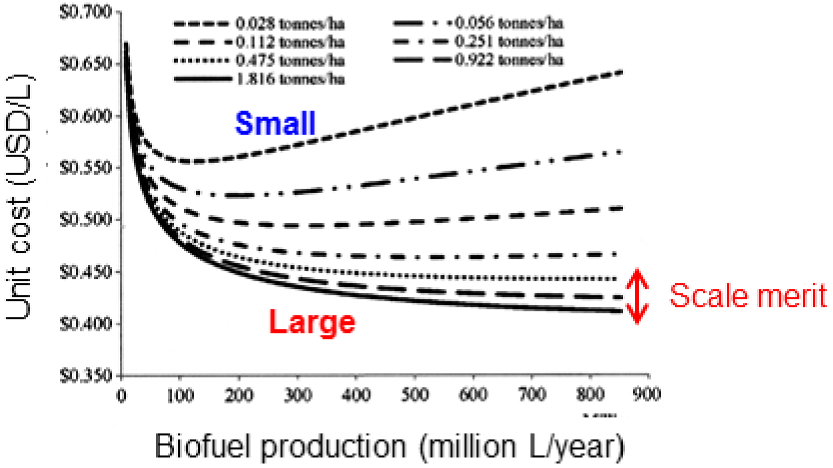
Figure 3.4-12. Synfuel Production Costs for Different Gasification Capacity



Source: Zimmer et al. (2017).

The productivity of the biomass also influences the scale merit. In the case of transportation of raw materials from farms with low productivity to a big factory, it is necessary to transport the materials multiple times. Consequently, an increase in total transport distance causes a cost increase and the scale merit to the fuel cost almost disappears (Figure 3.4-13).

Figure 3.4-13. Unit Cost as a Function of Biofuel Production for Various Equivalent Yields

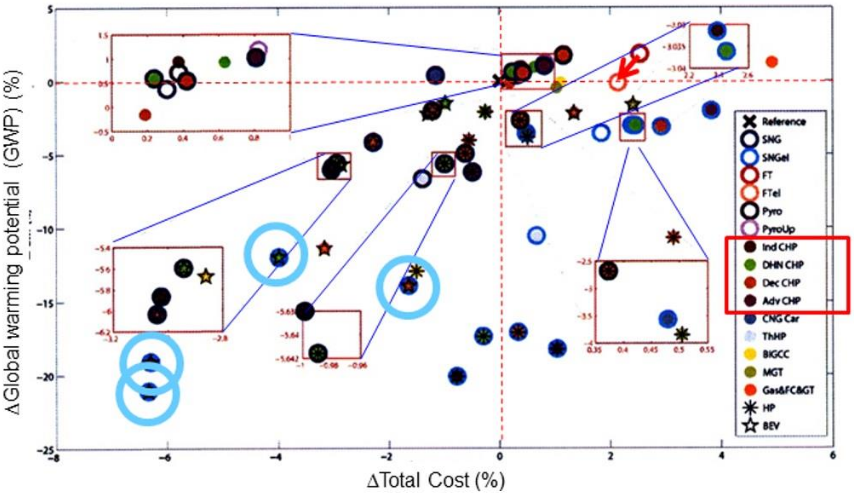


Source: Jenkins et al. (2014).

Energy Supply System

To reduce the influence on the cost and global warming, we have to consider measures based on a combination of the fuel manufacturing process, energy supply, and energy consumption by vehicles. Improvement of fuel efficiency of vehicles has been implemented by electrification. In addition, selection of an energy supply system is also an important factor that influences the cost and global warming. Figure 3.4-14 shows the annual global warming potential (GWP) impact and total cost relative values for various scenarios compared to the reference scenario. Light-blue plots indicate the influence of an energy supply system on the increase of GWP impact and total cost. In these cases, electricity is generated by substituted natural gas (SNG) produced with an electrolyser from biomass and the electricity was consumed by battery electric vehicles. The reduction of total cost depends on the combined heat and power supply systems. This result indicates that the optimum energy supply can contribute to the reduction of total cost and global warming.

Figure 3.4-14. Annual Global Warming Potential Impact and Total Cost Relative Values for the 56 Scenarios Compared to the Reference Scenario

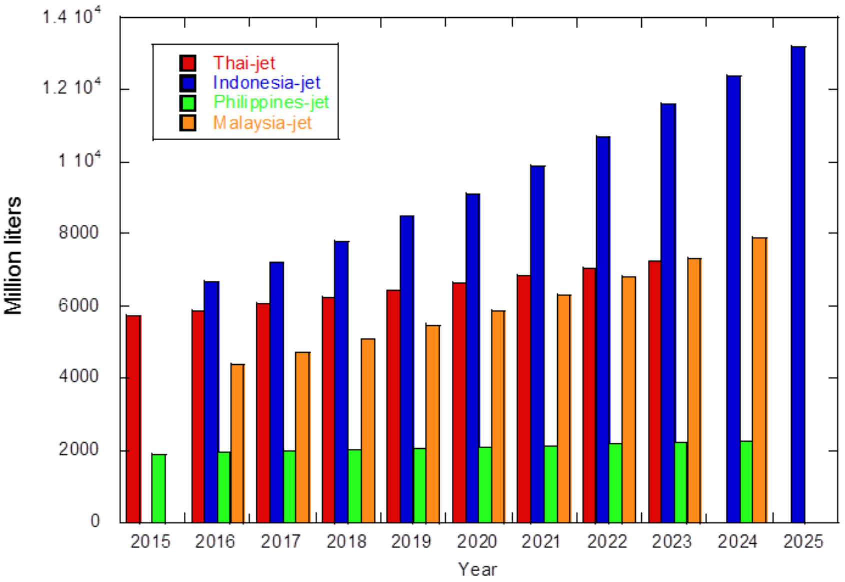


Source: Gironès et al. (2017).

5. Next-Generation Biofuel as Sustainable Aviation Fuel

Global demand for aviation fuel expands year by year. In particular, the demand for aviation fuel in developing countries will dramatically expand. In ASEAN, the demand in Indonesia and Malaysia will expand (Figure 3.5-1).

Figure 3.5-1. Aviation Fuel Demand Outlook in ASEAN-4 Countries



Sources: United States Department of Agriculture (2014; 2015).

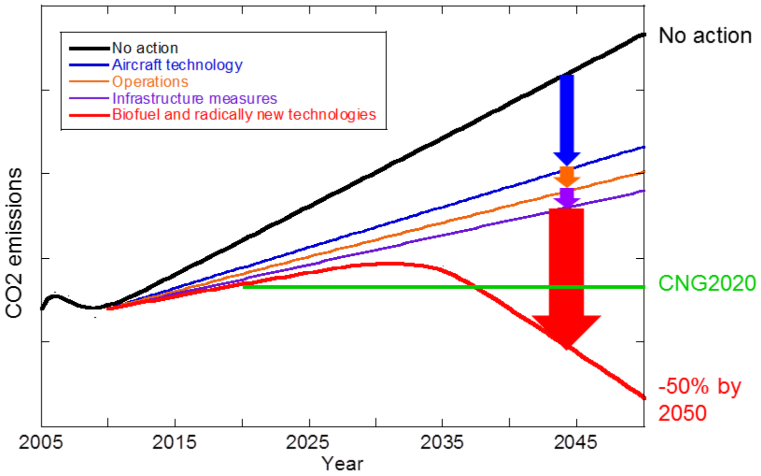
To correspond to the increase of aviation fuel and the reduction of fossil fuel consumption and GHG emissions, IATA decided the Sustainable Alternative Aviation Fuels Strategy. This strategy mentions three targets: (1) 1.5% fuel efficiency improvement from 2009 until 2020, (2) carbon-neutral growth from 2020, and (3) 50% reduction in carbon emissions by 2050 relative to a 2005 baseline. Automobile fuels are mainly used in domestic transportation. Each government can decide independently the policy such as quality and introduction of biofuel. However, aviation fuel is used for international transportation. Therefore, international decision applies to all countries.

It is predicted that international aviation net CO_2 emissions will increase 4.5 times from 2010 to 2040. Reducing GHG emissions involves several measures. Amongst them, the introduction of alternative aviation fuel is most effective (Figure 3.5-2).

Currently, there are only a few factories in the world that produce alternative aviation fuels and the products are used tentatively. According to the IATA outlook, the production of sustainable aviation fuel (SAF) will increase from around 2030. In the future, introducing alternative aviation fuel in earnest will require development and improvement of manufacturing processes of the fuel and the policy which promote the introduction.

In this study, we investigate manufacturing processes and product quality of alternative aviation fuels and clarify technological problems.

Figure 3.5-2. Greenhouse Gas Reduction in the Aviation Sector

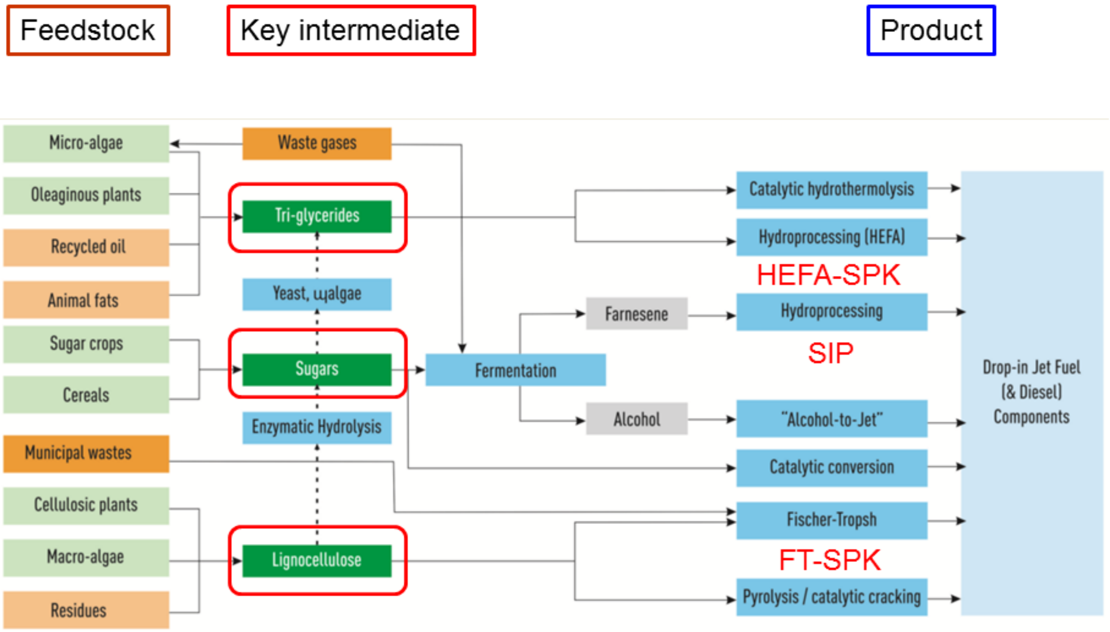


Source: IATA (2015).

Figure 3.5-3 gives a simplified view of pathways for alternative aviation fuel production (Novelli, 2014). Hydroprocessed ester and fatty acid synthetic paraffinic kerosene (HEFA-SPK), and FT synthetic paraffinic kerosene (FT-SPK) are the main alternative aviation fuels, which are produced by hydroprocessing (hydrodeoxygenation and isomerisation) and FT synthesis, respectively. Recently, a synthesised iso-paraffinic (SIP) fuel produced by a fermentation process was introduced. From the viewpoint of the diversification of resources, FT-SPK is more desirable because many kinds of resources such as solid biomass and waste materials can be used as resources.

The properties of HEFA-SPK and FT-SPK are close to those of HVO and FT-diesel, respectively. It is possible to produce alternative aviation and diesel fuels with the same raw materials and process. For example, FT-WAX, a product of FT synthesis is converted into FT-SPK by cracking and isomerisation, and FT-diesel by isomerisation and mild cracking. The key technology which enables each fuel to be produced selectively is catalyst technology. An example obtained in our laboratory is shown in Figure 3.5-4.

Figure 3.5-3. Pathways for Alternative Aviation Fuel Production

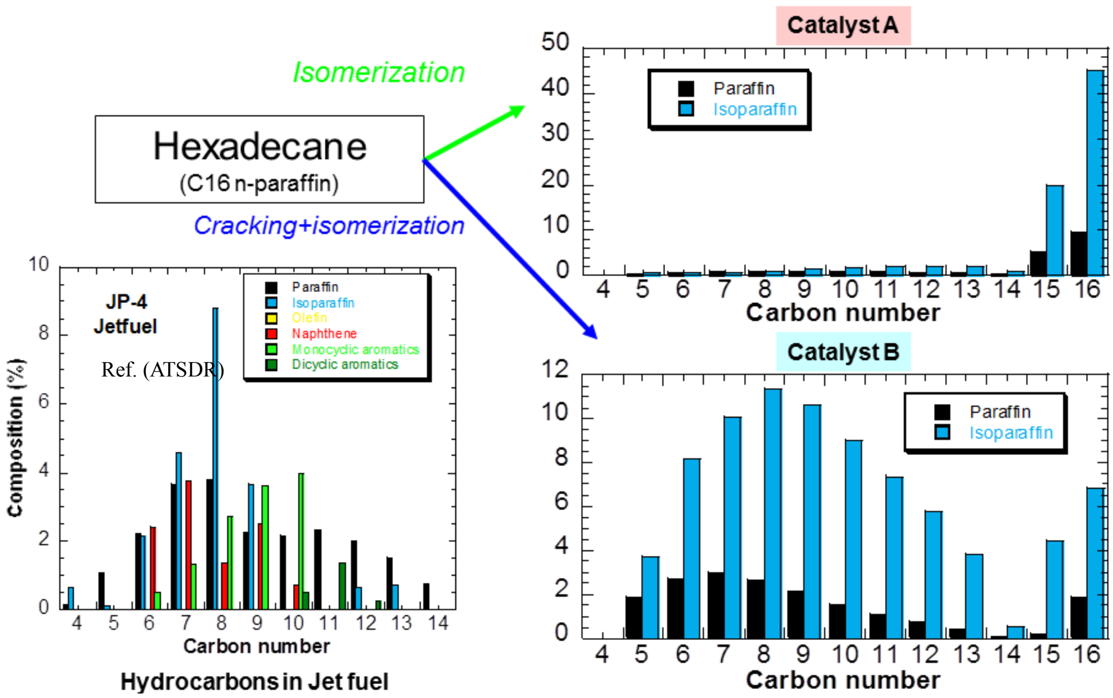


Source: Novelli (2014).

An alternative jet fuel standard has been established by the American Society for Testing and Materials ASTM D7566. The specifications are determined by mainly cold flow property and material compatibility. The remarkable item is aromatic hydrocarbon content. Because of fuel system material problems (sealing, etc.), aromatic hydrocarbons are required. HEFA-SPK and FT-SPK are usually a mixture of paraffinic hydrocarbons and they do not contain aromatic hydrocarbons (see Figure 3.5-5). Addition of aromatic hydrocarbons that are derived from petroleum fraction or produced by reforming paraffinic hydrocarbons is needed to meet the fuel standard.

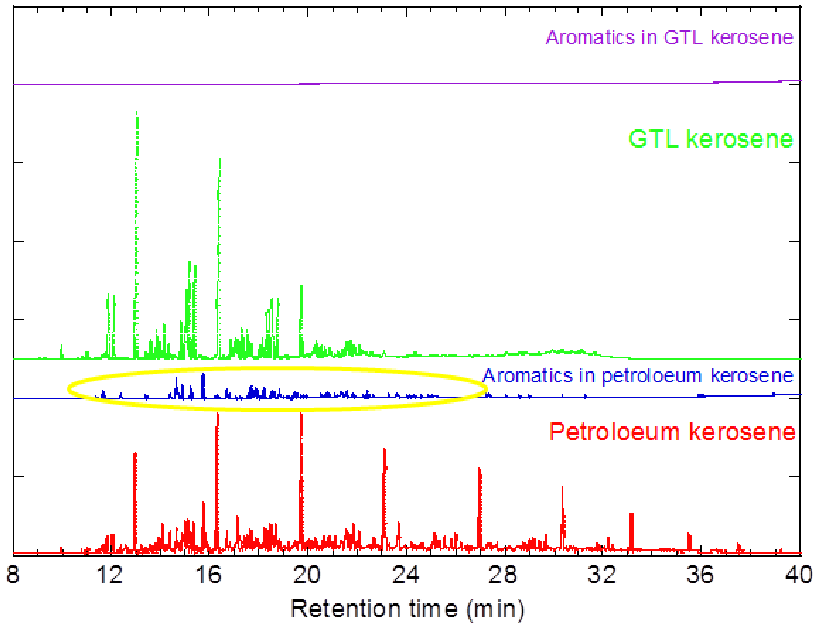
Recently, countries in East Asia have passed policies to introduce alternative aviation fuel. In Japan, a committee was established for the study of a process leading to the introduction of biojet fuel for the 2020 Summer Olympic Games and Paralympic Games in Tokyo. The Ministry of Land, Infrastructure, Transport and Tourism announced that use of biojet fuel (30 September 2015). Initiatives for Next Generation Aviation Fuels (INAF) plans a roadmap towards using nationally sourced aviation biofuels by 2020 (INAF, 2015). In Indonesia, the Directorate General of Civil Aviation has announced the Indonesian Alternative Fuels and Renewable Energy Initiatives for the reduction of GHG emissions (ICAO, 2017). In Malaysia, the Sustainable Fuel Centre of Excellence has been established by Airbus and key Malaysian partners to assess local solutions for sustainable biomass production (Airbus, 2014). The aim is to determine the most suitable feedstock to ensure any future jet fuel production.

Figure 3.5-4. Effect of Catalyst Species on Product Distribution in Hydrotreating of Hexadecane



Source: Authors.

Figure 3.5-5. Gas Chromatograms of Petroleum Kerosene and Gas-to-Liquids Kerosene



GTL = Gas-to-Liquids
Source: Authors.

The conclusions from this section are as follows:

(1) The demand for aviation fuel in developing countries will expand. In ASEAN, the demand in Indonesia and Malaysia will expand particularly.

(2) It is predicted that international aviation net CO_2 emissions will increase. The introduction of biofuel is effective for reducing GHGs. ASEAN Member States should consider the introduction of alternative aviation fuel produced from their own resources.

(3) FT-SPK and HEFA-SPK are the main alternative aviation fuels. They are produced by biomass gasification-FT synthesis and hydrodeoxygenation-cracking/isomerisation of oil and fat, respectively. Catalyst technology enables the production of both alternative aviation fuel and alternative diesel fuel for automobiles, selectively.

(4) The quality of petroleum-alternative mixed jet fuel and each blendstock should be controlled by standard specification (ASTM D7566).

(5) To introduce alternative aviation fuel, the decision of a national policy is needed. It is also necessary to consider cooperation between countries based on the resources.

6. Conclusions

Next-generation biofuels are expected to be sustainable transportation fuels, which contribute to energy security because they can be produced from various nonconventional resources such as woody biomass and waste materials. Various technologies have been developed such as the fuel manufacturing process from nonconventional raw materials. To choose an appropriate fuel production process, it is important to know the chemical and physical properties of the raw material sufficiently.

At present, some commercial plants are under operation. However, the price of the supplied next-generation biofuel is relatively high. Therefore, cost reduction is very important for accelerating next-generation biofuel introduction. Securing cheap resources, improving raw material productivity, and reducing the transportation cost are effective for variable cost reduction. The location of the manufacturing plant should be considered to reduce the supply cost of raw materials. On the other hand, selection of the fuel manufacturing process and its scale are also important factors for reducing the manufacturing cost. Cost reduction in the manufacturing process also depends on the measures of energy supply. In the future, it will be possible to supply next-generation biofuel more economically by optimising the combination of such factors as well as developing higher-performance manufacturing technology.

The electrification of small vehicles has been progressing, mainly in advanced countries. However, the electrification of buses, trucks, and airplanes has been difficult. The next-generation biofuel produced from sustainable raw materials will contribute to reduction of global warming in the transportation sector.

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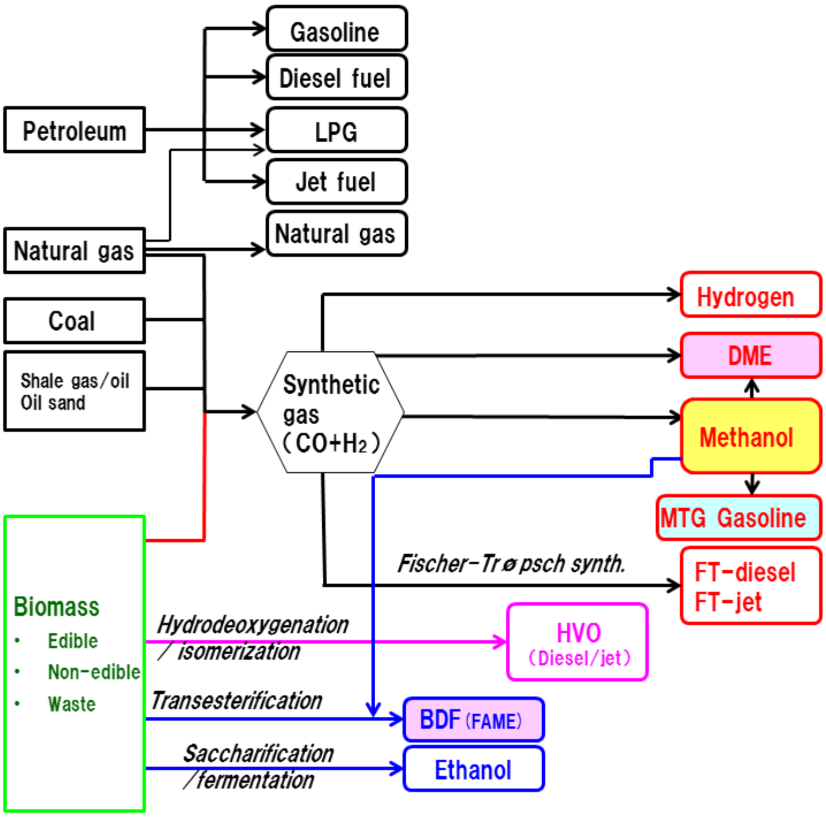
Chapter 4

Biomethanol as an Energy Carrier

1. Introduction

Seventy one million tonnes of methanol per day is produced in the world, and it is mainly used as a petrochemical product and intermediate and as fuel. Methanol was partially used as transportation fuel as well as fuel additive like methyl tertiary butyl ether. However, it has not been used because of the environment influence at present. On the other hand, various transportation fuels such as biodiesel fuel (fatty acid methyl esters), dimethyl ether (DME) and methanol-to-gasoline fuel are produced from methanol. In particular, biodiesel fuel is widely used in Europe and the Association of Southeast Asian Nations (ASEAN) region.

Figure 4.1-1. Energy Pathway

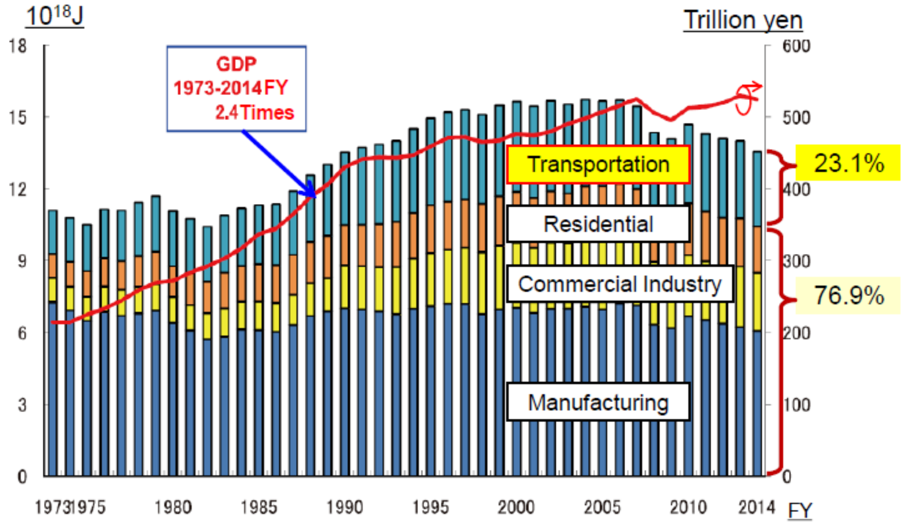


Source: Authors.

Currently, methanol is mainly produced from fossil resources. As shown in Figure 4.1.1, methanol can be produced from synthetic gas through gasification of natural gas, coal, shale gas, oil sand, and biomass. This means biomethanol is a seamless fuel, moving step by step from fossil fuel to renewable fuel. If methanol can be produced from biomass (biomethanol), the raw materials of biodiesel fuel (vegetable oil and methanol) can be obtained entirely from renewable resources. Possible CO_2 emissions reduction may be achieved through the conversion of methanol production from fossil resources into biomass in the wide field from petrochemistry to transportation fuel.

Figure 4.1.2 shows energy consumption and gross domestic product in Japan. Energy consumption, especially in the transportation sector, has been decreasing after 2005 while gross domestic product has been growing. However, energy consumption in the transportation sector still occupies about a quarter of total consumption. The percentage is higher in ASEAN countries (Thailand 37% [2016] and Indonesia 39% [2013]).

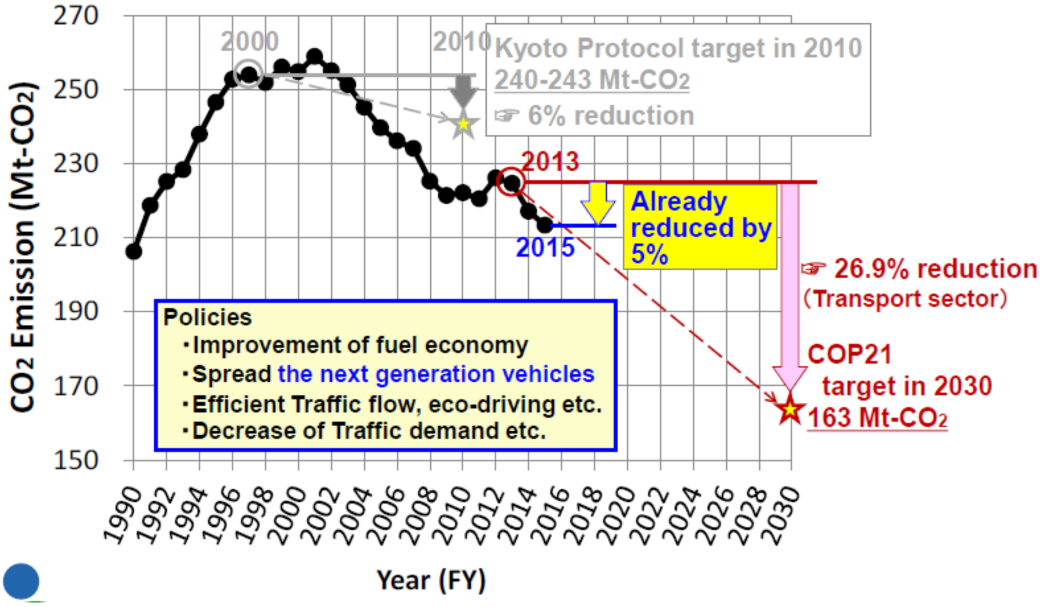
Figure 4.1.2. Energy Consumption and Gross Domestic Product Trend in Japan



Source: Ministry of Economy, Trade and Industry, Japan, 2017.

Figure 4.1.3 shows the CO_2 emissions trend from the transportation sector and the CO_2 reduction target in Japan. The Kyoto Protocol target in 2010 was achieved and the new 2030 target of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) was also achieved in 2015. The reduction will slow year after year, so we have to use a variety of ways to reduce CO_2 emissions. One possible CO_2 emission reduction method is to convert methanol production from fossil resources to biomass. The CO_2 reduction effect is expected to become larger in ASEAN, because these countries are consuming a large amount of methanol produced from fossil resources as a raw material of biodiesel fuel.

Figure 4.1.3. CO_2 Emissions from the Transportation Sector and the CO_2 Reduction Target in Japan



Source: International Energy Agency, 2017.

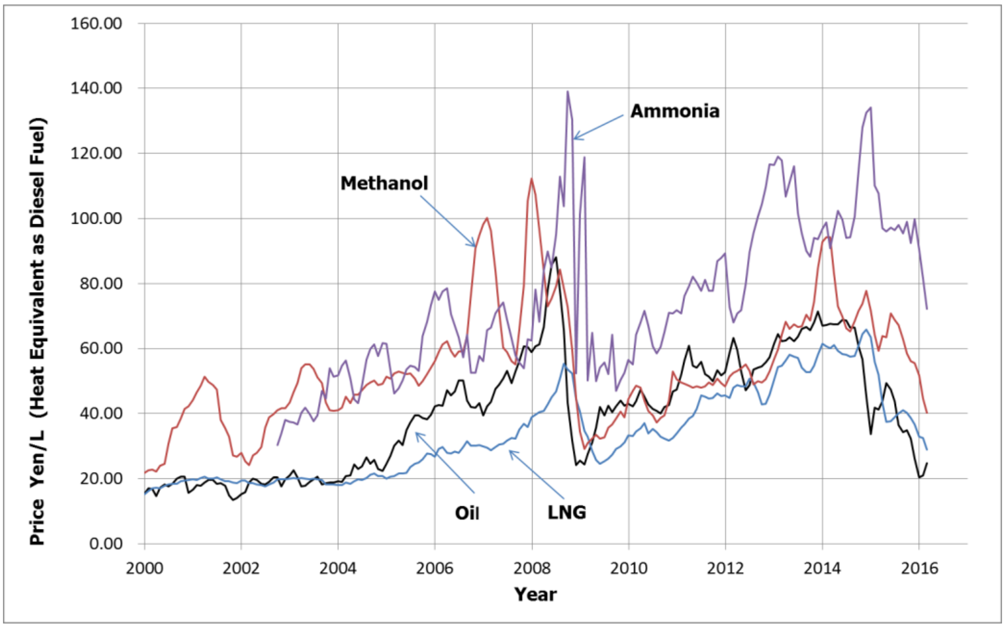
The purpose of this survey is to investigate the current methanol production process from biomass and utilisation of methanol as a new energy source for producing transportation biofuel.

2. Methanol Production Trend

Figure 4.2.1 shows the global methanol production trend. As methanol is now produced principally from liquefied natural gas (LNG), the market price of methanol follows that of LNG.

From 2000 to 2009, the production amount was small, at about 40 million tonnes per year, and the price fluctuated when one production plant stopped due to renovations. The production amount increased step by step after 2009. Methanol prices became stable during 2009 and 2013, and production went up to 71 million tonnes per year in 2015. Since the price of methanol generally follows that of LNG, the price will usually become stable. We can have a clear price target even if it is produced from biomass.

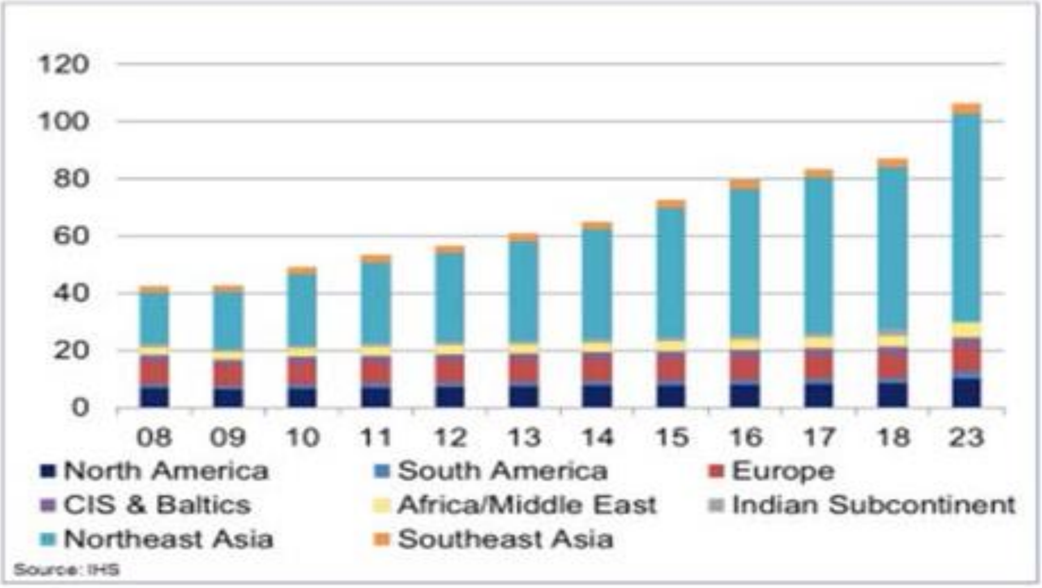
Figure 4.2.1. Trend of Methanol Production



Source: Authors.

Figure 4.2.2 shows the global demand and forecast of methanol. Recently the demand for methanol in Northeast Asia, mainly China, has increased greatly.

Figure 4.2.2. Production and Forecast of Methanol



Source: Requested from IHS Markit (2018) website.

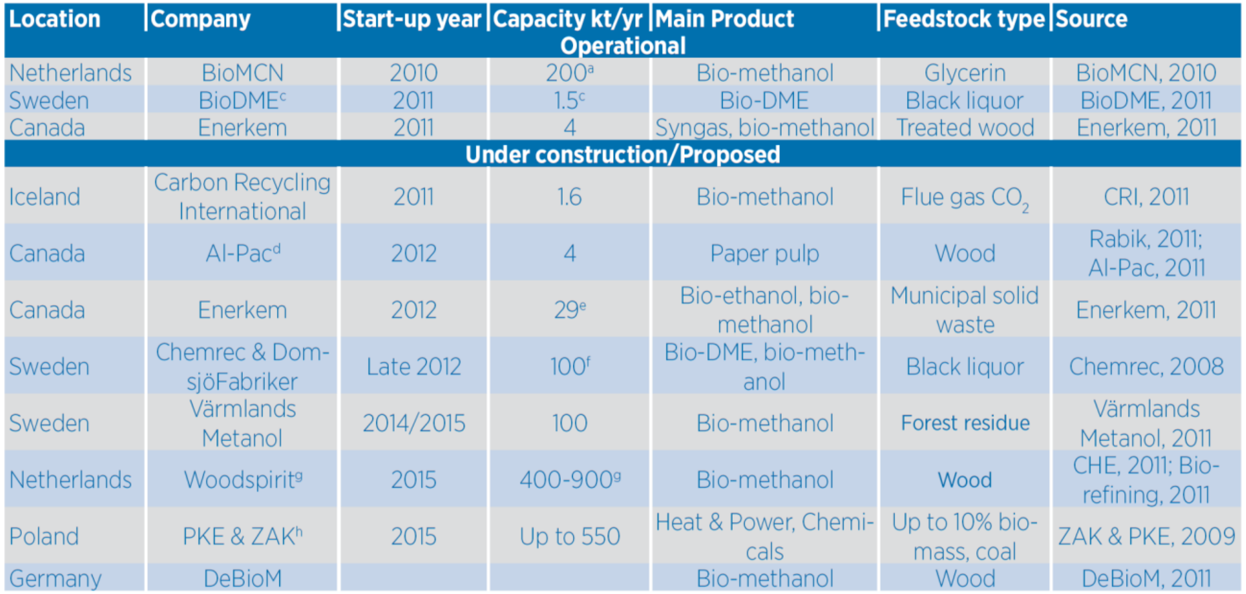
3. Current Status of Biomethanol Production

3.1 Process for Biomethanol Production

The technologies used in the production of methanol from biomass are relatively well known since they are similar to coal gasification technology, which has been applied for a long time. The process for biomethanol production usually consists of synthetic gas (mixture of carbon monoxide and hydrogen) production by gasification of biomass and methanol synthesis by catalytic reaction over Zn-Cr oxide and Cu-Zn oxide catalysts. Solid biomass, waste, and biogas (methane formed by biomass fermentation) are used as resources for gasification.

Table 4.3.1 provides an overview of facilities (in operation or planned) that produce biomethanol. Technically, any carbon source can be converted into syngas, but current projects for biomethanol mainly focus on using by-products from other industrial processes as this offers several advantages. Details are shown as follows.

Table 4.3.1. Overview of Existing or Planned Facilities for Biomethanol Production



Location	Company	Start-up year	Capacity kt/yr	Main Product	Feedstock type	Source
Operational						
Netherlands	BioMCN	2010	200[a]	Bio-methanol	Glycerin	BioMCN, 2010
Sweden	BioDME[c]	2011	1.5[c]	Bio-DME	Black liquor	BioDME, 2011
Canada	Enerkem	2011	4	Syngas, bio-methanol	Treated wood	Enerkem, 2011
Under construction/Proposed						
Iceland	Carbon Recycling International	2011	1.6	Bio-methanol	Flue gas CO_2	CRI, 2011
Canada	Al-Pac[d]	2012	4	Paper pulp	Wood	Rabik, 2011; Al-Pac, 2011
Canada	Enerkem	2012	29[e]	Bio-ethanol, bio-methanol	Municipal solid waste	Enerkem, 2011
Sweden	Chemrec & DomsjöFabriker	Late 2012	100[f]	Bio-DME, bio-methanol	Black liquor	Chemrec, 2008
Sweden	Värmlands Metanol	2014/2015	100	Bio-methanol	Forest residue	Värmlands Metanol, 2011
Netherlands	Woodspirit[g]	2015	400-900[g]	Bio-methanol	Wood	CHE, 2011; Biorefining, 2011
Poland	PKE & ZAK[h]	2015	Up to 550	Heat & Power, Chemicals	Up to 10% biomass, coal	ZAK & PKE, 2009
Germany	DeBioM			Bio-methanol	Wood	DeBioM, 2011

Source: Energy Technology Systems Analysis Programme, International Energy Agency (IEA-ETSAP) and International Renewable Energy Agency (IRENA), 2013.

Figure 4.3.1 shows the Kyoto Bio Cycle Project. Local waste and forest biomass are used as energy resources. The project aims to demonstrate the regional circulation of renewable resources to be utilised, such as heat, electricity, and liquid fuels, as well as the reduction of carbon dioxide emissions.

Moreover, New Energy and Industrial Technology Development Organization (NEDO) projects have issued biomethanol production reports about using palm fruit bunches and stems. Further, MHI has tried new production methods.

Figure 4.3.1. Biomethanol Test Plant in Kyoto, Japan

Source: Japan Science and Technology Agency (J-Stage), n.d. and 2010

3.2 Biomethanol Production in the Netherlands

Biomethanol is produced from biogas, but it is chemically identical to methanol produced from LNG. It is a highly versatile product that can be used both as a fuel and as a feedstock to produce other biofuels.

As a fuel, biomethanol can either be blended with gasoline, or used as a feedstock for other environment-friendly fuels. It is also used for a variety of non-fuel applications including plastics and paints. New applications are continuously being developed in alliance with other innovative companies and research institutes.

Biomethanol can also be used as a chemical building block for a range of future-oriented products, including biomethyl tertiary butyl ether, bio-DME, bio-hydrogen, and synthetic biofuels (synthetic hydrocarbons).

New topics of BioMCN (10 May 2017) are as follows:

- Two methanol plants: nameplate capacity, 850 kilotonnes
- One plant (1974) running, one plant (1976) idle
- First biomethanol produced in 2009

Figure 4.3.2. BioMCN Biomethanol Plant

Source: BioMCN, 2018.

Figure 4.3.3. Overview of BioMCN Site

Source: Compagne, 2017.

3.3 Biomethanol Production in Canada

Enerkem Alberta Biofuels, located in Edmonton, Canada, is the world's first major collaboration between a large city and an innovative waste-to-biofuel producer. Together, they addressed the non-recyclable and non-compostable waste disposal challenge by diverting household waste destined for landfills. Using an exclusive thermochemical process, Enerkem converts household waste into clean biofuels and green chemicals, such as ethanol and methanol.

In 2016, the facility obtained certification from the International Sustainability and Carbon Certification (ISCC) system. In 2017, the Enerkem Alberta Biofuels facility received the lowest carbon intensity value ever issued by the British Columbia Ministry of Energy and Mines under the Renewable and Low Carbon Fuel Requirements Regulation. It is also the first-ever waste-to-biofuel facility to sell its ethanol under the United States Renewable Fuel Standard after receiving a registration approval from the United States Environmental Protection Agency in 2017.

- Type: single-line methanol-ethanol production commercial facility
- Status: initiated production of methanol in 2015 and ethanol in 2017
- Feedstock: post-sorted municipal solid waste (after recycling and composting)
- Products: methanol, ethanol
- Capacity: 38 million litres/10 million gallons per year

Figure 4.3.4. Enerkem Alberta Waste-to-Biofuel Plant

Source: Enerkem, 2018.

3.4 Biomethanol Production in the United States

Maverick Oasis is the first small-scale modular methane-to-methanol production plant that can be co-located at the source of methane. These factory-built gas-to-liquids (GTL) methanol plants are skid-mounted and can be rapidly deployed onsite to produce thousands of gallons per day of ultra-clean methanol from natural gas or methane-rich (biogas, landfill gas, flare gas, etc.) waste gas.

- Feedstock: biogas (about 60% methane/40% CO_2, 3,000–7,000 ppm sulfur)
- Capacity: 8,300 gallons per day (25 metric tonnes/day)
- Output: methanol (performance guaranteed), AA grade that meets ASTM D1152
- Products: methanol and excess steam for use with co-located digesters or drying facilities

Figure 4.3.5. Maverick Oasis Modular Methane-to-Methanol Production Plant

Source: Maverick Synfuels, 2018 website

3.5. World’s First Commercial-Scale Biomethanol Plant in Hagfors, SWEDEN

Initially, the study looked at how Sweden’s need for motor fuel could be met by producing ethanol through fermentation of agro-crops. However, the study concluded that agro-based ethanol only had a marginal potential to substitute petrol, simply due to the fact that there was not enough arable land to produce the volumes needed.

Figure 4.3.6. Biomethanol in Sweden, BioMCN Biomethanol Plant

World’s first Commercial Scale Biomethanol Plant
in Hagfors SWEDEN

Flygfoto: Lars Nilsson   Montage: Streator

- VärmlandsMetanolAB : BioMass Based Liquid Fuel Company
- Biomass as received 111 MW
- District heat export 15 MW
- Methanol energy 74 MW ≈ 300 ton/day

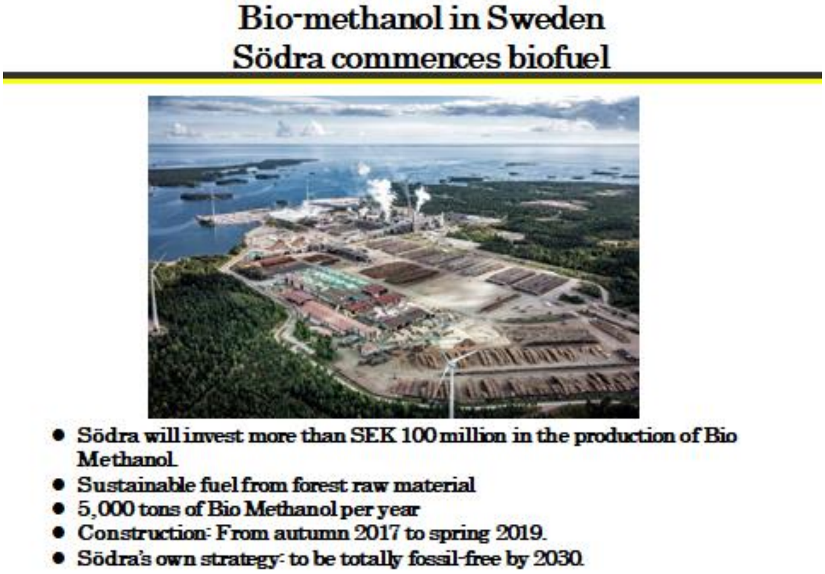
Source: VärmlandsMetanol AB, 2012.

On the other hand, the study showed that Sweden had a surplus of forest biomass, since the average annual forest growth/increment has exceeded felling by 30% since the 1920s. Hence, the study suggested that domestic production of a CO_2-neutral motor fuel should be based on forest residue and fast growing energy forest.

3.6. Södra Biomethanol Plant in Sweden

Södra will invest more than SKr100 million in the production of biomethanol, a sustainable fuel from forest raw material. The project was commenced in autumn 2017. It is scheduled to be ready for operation by spring 2019.

Figure 4.3.7. Södra Biomethanol Plant in Sweden



Bio-methanol in Sweden
Södra commences biofuel

- Södra will invest more than SEK 100 million in the production of Bio Methanol.
- Sustainable fuel from forest raw material
- 5,000 tons of Bio Methanol per year
- Construction: From autumn 2017 to spring 2019.
- Södra's own strategy: to be totally fossil-free by 2030.

Source: Södra, 2017.

The aim is to produce 5,000 tonnes of biomethanol per year at the new facility to be situated at Södra's pulp mill at Mönsterås. The long-term aim is to further increase production for passenger, truck, and ship transport.

3.7. Bio-dimethyl Ether in Sweden

Figure 4.3-9 shows some information about the bio-DME project in Sweden. The project uses black liquor of pulp companies as the raw material to reduce CO_2.

Figure 4.3.8. Bio-dimethyl Ether Project in Sweden

Bio DME Project in Sweden

- VOLVO, CHEMREC, DELPHI, ETC, HALDOR TOPSOE, TOTAL, PREEM, EU, Gov. of Sweden
- Period: 2008-2012
- Budget: €28,400,000

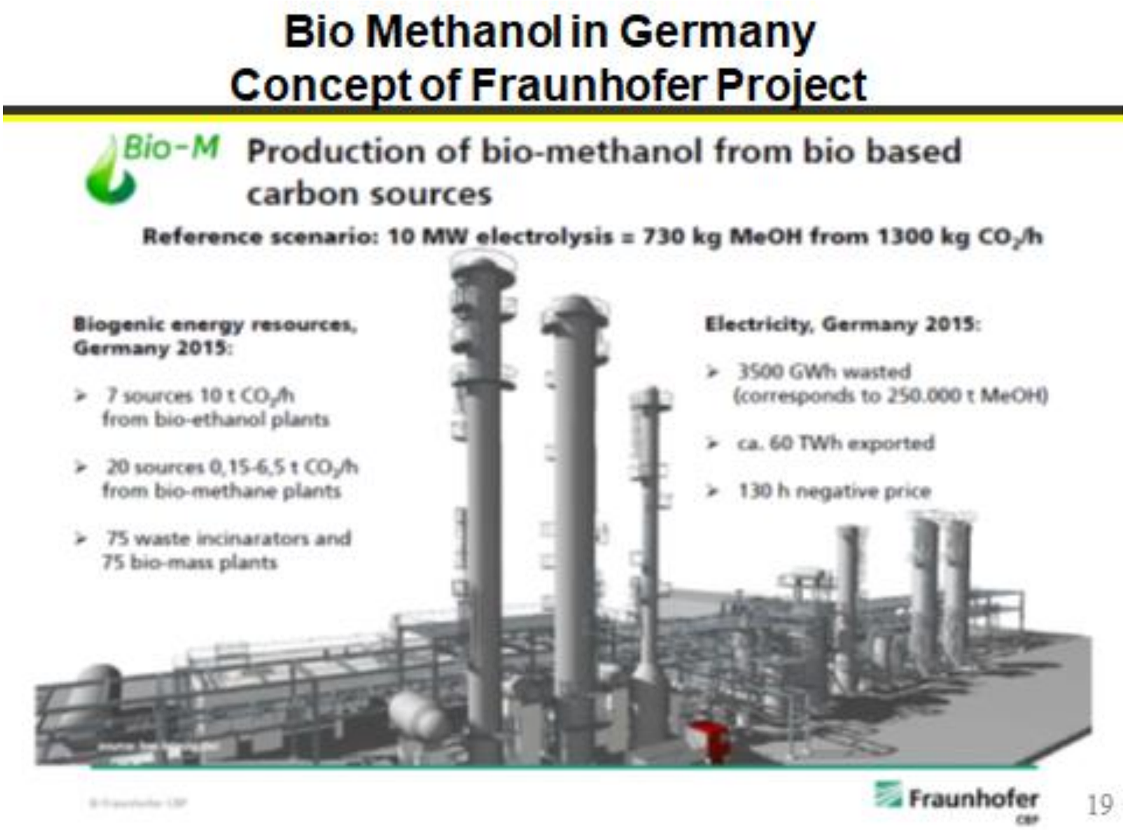
Source: Chemrec, 2012.

3.8. Fraunhofer Project in Germany

Bio-M produces biomethanol from biogenic CO_2 sources. Within the project, Bio-M has come up with a new flexible and sustainable process for the production of bioethanol from biogenic carbon dioxide and 'green' hydrogen is to be developed, demonstrating the project's technical feasibility as well as industrial relevance.

The advantages lie in the marketing possibilities of methanol as a biogenic platform chemical as well as energy and hydrogen storage in order to increase the volumetric energy density of hydrogen. The focus of the project is to develop and evaluate stress-resistant, stable catalysts, which meet the requirements of the real gas compositions as well as a fluctuating mode of operations. Process parameters are determined theoretically and practically and are used to evaluate the process.

Figure 4.3.9. Fraunhofer Project: Bio-M Production of Biomethanol from Biogenic CO_2 Sources



Bio Methanol in Germany
Concept of Fraunhofer Project

Bio-M Production of bio-methanol from bio based carbon sources

Reference scenario: 10 MW electrolysis = 730 kg MeOH from 1300 kg CO_2/h

Biogenic energy resources, Germany 2015:

- 7 sources 10 t CO_2/h from bio-ethanol plants
- 20 sources 0,15-6,5 t CO_2/h from bio-methane plants
- 75 waste incinarators and 75 bio-mass plants

Electricity, Germany 2015:

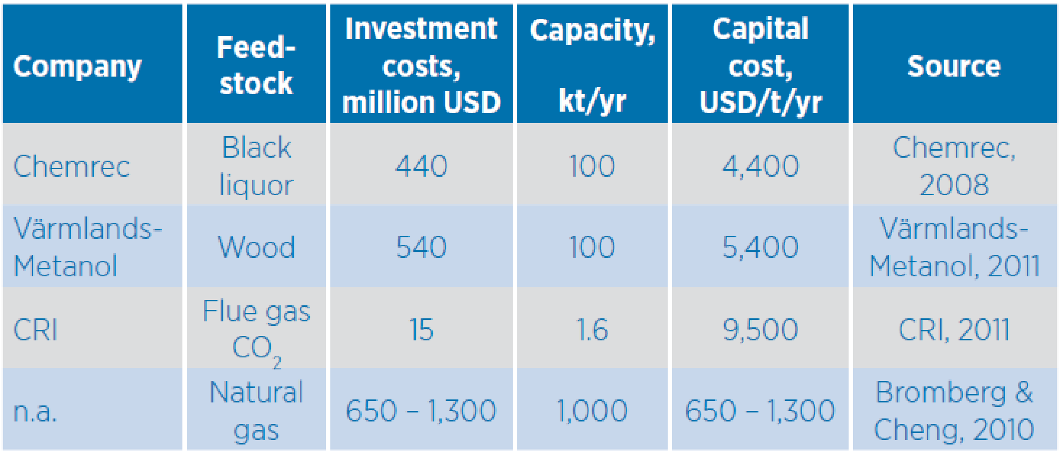
- 3500 GWh wasted (corresponds to 250.000 t MeOH)
- ca. 60 TWh exported
- 130 h negative price

Fraunhofer CBP

Source: Fraunhofer Project, https://www.cbp.fraunhofer.de/en/research/Projects/projects_of_chemical_processes/bio_m.html

Some results of the biomethanol cost estimation are shown in Table 4.3.2. The production cost of biomethanol is much higher than that of methanol from natural gas. If plant capacity can be increased, a cost reduction may be realised.

Table 4.3.2. Biomethanol Cost Estimation



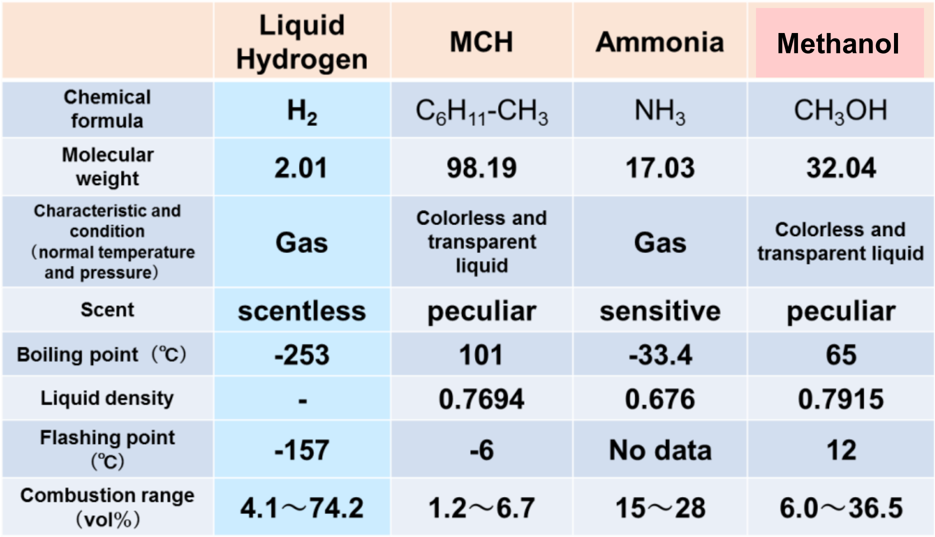
Company	Feed-stock	Investment costs, million USD	Capacity, kt/yr	Capital cost, USD/t/yr	Source
Chemrec	Black liquor	440	100	4,400	Chemrec, 2008
Värmlands-Metanol	Wood	540	100	5,400	Värmlands-Metanol, 2011
CRI	Flue gas CO_2	15	1.6	9,500	CRI, 2011
n.a.	Natural gas	650 – 1,300	1,000	650 – 1,300	Bromberg & Cheng, 2010

Source: IEA-ETSAP and IRENA, 2013.

4. Advantage of Methanol as an Energy Carrier

Table 4.4.1. shows the physical characteristics of various energy carriers. The promising energy carriers to produce carry storage are liquid hydrogen, methylcyclohexane (MCH), ammonia, and methanol.

Table 4.4.1. Physical Characteristics of Various Energy Carriers



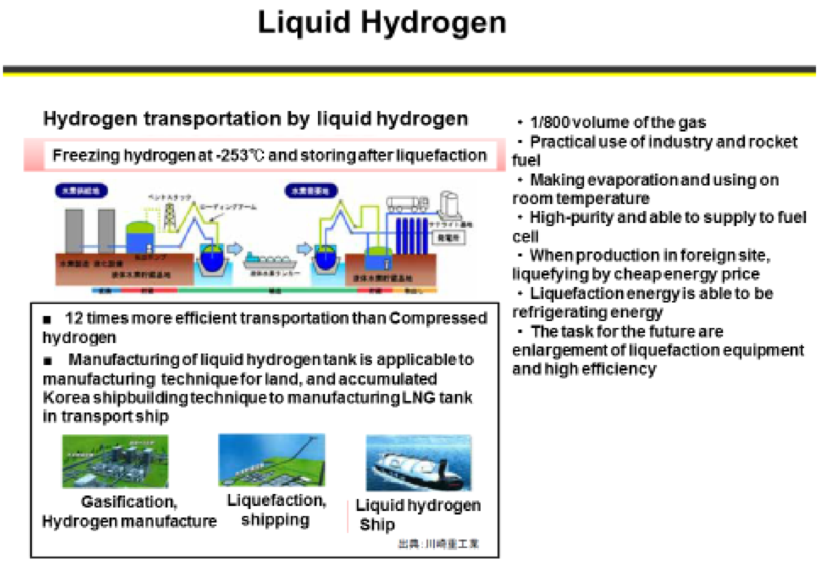
	Liquid Hydrogen	MCH	Ammonia	Methanol
Chemical formula	H_2	C_6H_{11}-CH_3	NH_3	CH_3OH
Molecular weight	2.01	98.19	17.03	32.04
Characteristic and condition（normal temperature and pressure）	Gas	Colorless and transparent liquid	Gas	Colorless and transparent liquid
Scent	scentless	peculiar	sensitive	peculiar
Boiling point（℃）	-253	101	-33.4	65
Liquid density	-	0.7694	0.676	0.7915
Flashing point（℃）	-157	-6	No data	12
Combustion range（vol%）	4.1～74.2	1.2～6.7	15～28	6.0～36.5

MCH = methylcyclohexane.
Source: Authors.

Carrying liquid hydrogen requires a high level of technology because the boiling point is –253°K. It may be a future fuel as it will take a long time to establish the technology to use. MCH is also an energy carrier, but has problems of cumbersome hydrogen in- and out-processes and hydrogen purity. Some companies focus on ammonia as an energy carrier. Its vapour pressure is not higher than hydrogen. However, a storage pressure tank like with liquefied petroleum gas is necessary. The price is high even if produced by fossil fuel (Figure 4.2.1). Moreover, usage devices like ammonia gas turbines are going to be necessary.

On the contrary, methanol has some excellent features as an energy carrier. Transportation is easy because methanol is liquid at room temperature. It is possible to use methanol as a chemical intermediate of various transportation fuels described earlier. MCH and toluene, a dehydrogenated product of MCH, are produced from petroleum at present. A simple manufacturing process of those compounds from the biomass has yet to be established. On the other hand, methanol can be produced by a two-step reaction: gasification of biomass and catalytic methanol synthesis. Utilisation of cheap raw materials and optimisation of the plant scale may enable a cost reduction in the future and biomethanol will be used as an energy carrier. The political investment of funds to reduce GHG emissions should be also considered in case biomethanol is introduced as an energy carrier.

Figure 4.4.1. Production and Transportation of Liquid Hydrogen



Liquid Hydrogen

Hydrogen transportation by liquid hydrogen

Freezing hydrogen at -253℃ and storing after liquefaction

- 12 times more efficient transportation than Compressed hydrogen
- Manufacturing of liquid hydrogen tank is applicable to manufacturing technique for land, and accumulated Korea shipbuilding technique to manufacturing LNG tank in transport ship

Gasification, Hydrogen manufacture

Liquefaction, shipping

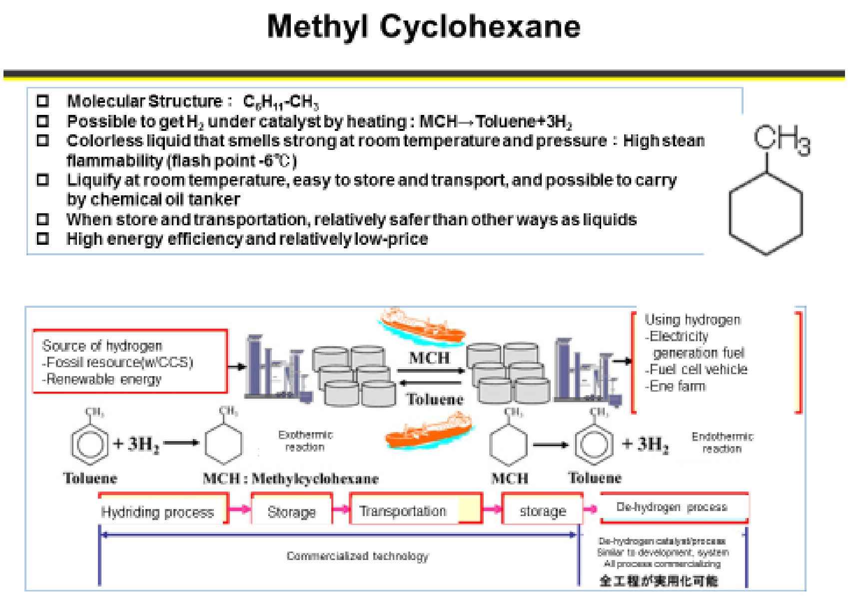
Liquid hydrogen Ship

出典：川崎重工業

- 1/800 volume of the gas
- Practical use of industry and rocket fuel
- Making evaporation and using on room temperature
- High-purity and able to supply to fuel cell
- When production in foreign site, liquefying by cheap energy price
- Liquefaction energy is able to be refrigerating energy
- The task for the future are enlargement of liquefaction equipment and high efficiency

Source: Originally adapted from the KHI home page.

Figure 4.4.2. Properties and Utilisation of Methylcyclohexane

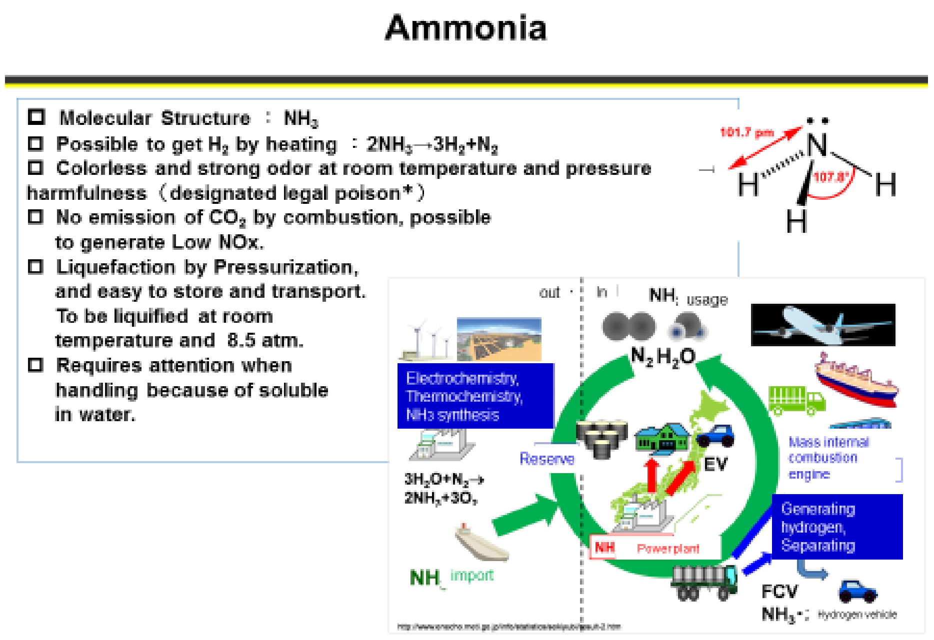


Methyl Cyclohexane

- ☐ Molecular Structure： C_6H_{11}-CH_3
- ☐ Possible to get H_2 under catalyst by heating : MCH→Toluene+$3H_2$
- ☐ Colorless liquid that smells strong at room temperature and pressure：High stean flammability (flash point -6℃)
- ☐ Liquify at room temperature, easy to store and transport, and possible to carry by chemical oil tanker
- ☐ When store and transportation, relatively safer than other ways as liquids
- ☐ High energy efficiency and relatively low-price

Source: Originally adapted from the Chiyoda Corporation home page.

Figure 4.4.3. Properties and Utilisation of Ammonia

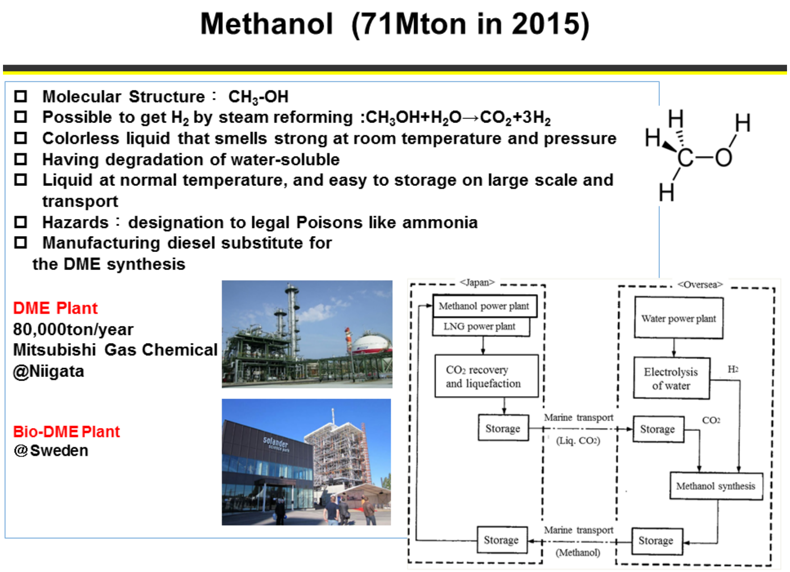


Ammonia

- ☐ Molecular Structure ： NH_3
- ☐ Possible to get H_2 by heating ：$2NH_3$→$3H_2$+N_2
- ☐ Colorless and strong odor at room temperature and pressure harmfulness（designated legal poison*）
- ☐ No emission of CO_2 by combustion, possible to generate Low NOx.
- ☐ Liquefaction by Pressurization, and easy to store and transport. To be liquified at room temperature and 8.5 atm.
- ☐ Requires attention when handling because of soluble in water.

Source: Originally adapted from various home pages.

Figure 4.4.4. Properties and Utilisation of Methanol



Methanol (71Mton in 2015)

- ☐ Molecular Structure : CH_3-OH
- ☐ Possible to get H_2 by steam reforming :$CH_3OH+H_2O \rightarrow CO_2+3H_2$
- ☐ Colorless liquid that smells strong at room temperature and pressure
- ☐ Having degradation of water-soluble
- ☐ Liquid at normal temperature, and easy to storage on large scale and transport
- ☐ Hazards : designation to legal Poisons like ammonia
- ☐ Manufacturing diesel substitute for the DME synthesis

DME Plant
80,000ton/year
Mitsubishi Gas Chemical
@Niigata

Bio-DME Plant
@Sweden

Source: Authors.

5. Utilisation of Methanol as an Energy Carrier for Dimethyl Ether Vehicles around the World

Figure 4.5.1 shows DME vehicles around the world. The DME Truck by the Isuzu Advanced Engineering Center (IAEC) has finished its modified vehicle registration. IAEC received official government approval of their application to register an Isuzu ELF, which was modified to operate on DME. It was the first DME truck registered in Japan, on 1 June 2015. DME vehicles have excellent emission characteristics without the need for a diesel particulate filter, because there is almost no exhaust soot. Moreover, NOx reduction hardware and a urea tank are also unnecessary.

IAEC acquired ministerial authorisation and has been carrying out road tests on public roads for many years. Based on operating data obtained from this test programme, IAEC has worked with the Japan DME Association to develop technical standards for DME vehicles and proposed these to the Ministry of Land, Infrastructure and Transport. With the modified vehicle registration finally obtained for the DME truck, it has been said that a new era has opened for DME vehicles in Japan.

Main specifications:

● Vehicle name:	Isuzu ELF
● Fuel:	Dimethyl ether (DME)
● Maximum load capacity:	3,500 kg
● Vehicle gross weight:	7,990 kg
● Engine displacement:	5.193 L
● Fuel tank volume:	135 L × 2 tanks
● Exhaust regulation:	Post New Long Term (Japan)

Figure 4.5.1. Dimethyl Ether Vehicles around the World

Source: Authors.

6. Policy Implications

Biomass can be easily converted into methanol through synthetic gas by gasification. The technologies used in the production of methanol from biomass are relatively well-known since they are similar to coal gasification technology, which has been applied for a long time. However, the scale of current production plants is relatively small and the production cost is high, because it is difficult to collect large amounts of biomass resources.

On the other hand, if methanol can be produced in the growing districts of biomass, long-distance transportation for accumulation would be unnecessary and the cost of methanol production may go down. For example, if a methanol manufacturing factory consisting of biomass gasification and methanol synthesis is constructed in a location next to a palm oil expression factory of a palm plantation, reduction of the production cost for methanol may be achieved by utilising the waste materials from the factory and disused old palm trees on the plantation. In addition, when a biodiesel manufacturing factory is built attached to a methanol plant, transportation costs of methanol to the biodiesel fuel factory can be reduced.

It will be necessary to carry out an estimation of the available biomass resources, cost calculation about methanol production based on the location of the factory, and life cycle assessment to inspect the CO_2 reduction effect in biomethanol production before making policy decisions.

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Appendix 1

Record of ERIA Working Group Meeting:
Study of Renewable Energy Potential and Its Effective Usage in East Asian Countries

First Working Group Meeting (2015–2016), 8–9 February 2016, Jakarta, Indonesia

1. Opening Address and Invited Lecture

The first meeting (2015–2016) of the ERIA Working Group (WG) was held in Indonesia, hosted by the BPPT (Agency for the Assessment and Application of Technology). WG Leader Dr Toba from the National Institute of Advanced Industrial Science and Technology, Japan (AIST) 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 third ERIA Energy Project and the WG title 'Study of Renewable Energy Potential and Its Effective Usage in East Asian Countries'. The present ERIA project focuses on three subjects:

1. Potential study of diversified transportation energy mix, which will discuss transportation energy including biofuels from the viewpoint of international trade, energy consumption in the transportation sector, and domestic and international strategies for biofuel promotion. It is headed by Mr Ichikawa from Toyota, Japan.
2. Research of next-generation biofuels, which will investigate the production technologies of next-generation biofuels, and discuss the policy to introduce biofuel. It is headed by Dr Toba from AIST, Japan.
3. Biomethanol as an energy carrier, which will investigate biomethanol production and discuss its role as an energy carrier. It is headed by Dr Goto from AIST, Japan.

In combination, these subjects aim to support three strategies under the ASEAN Plan of Action for Energy Cooperation (APAEC: 2016–2025):

1. Energy efficiency and conservation
2. Renewable energy
3. Regional energy policy and planning

The invited lecture on 'Progress in Indonesian Biodiesel' was given by Mr Imam Paryanto from BPPT, Indonesia. Indonesia's policy on development and implementation of bioenergy was elaborated to show the shape of Indonesian biofuel since 2007 with particular emphasis on the mandatory biodiesel road map according to the Energy and Mineral Resource Ministry Regulation.

2. Session I: Potential Study of Diversified Transportation Energy Mix

The session started with an outline of the subject presented by Mr Ichikawa. The scope covered five countries over the two years: Thailand, Indonesia, and the Philippines are the focus this current year, while Malaysia and Viet Nam are the focus in the following year. Measures for mitigating energy issues (gap between energy supply and demand) and achieving the policy target (energy conservation and alternative energy) will be investigated and proposed. Regional cooperation with ASEAN will be considered if necessary. The Thailand and Indonesia cases were given a preliminarily analysis.

Dr Nuwong from the National Metal and Materials Technology Center (MTEC), Thailand gave the 'Presentation from Thailand', in which he explained the Thailand Integrated Energy Blueprint (TIEB: 2015–2036) with emphasis on the Oil Plan, Energy Efficiency Plan (EEP), and Alternative Energy Development Plan (AEDP). Detailed targets of bioethanol and biodiesel were shown with action plans and consideration of feedstock supply.

Ms Ruby from the Philippine Department of Energy gave the 'Presentation from Philippines', in which she presented the government policy on biofuel, supply ability, and vehicle registration data. The Biofuel Act (Republic Act 9367) was passed in 2006 with targeted biofuel blends during 2013–2030 prescribed in the National Biofuels Program.

Dr Arie from BPPT, Indonesia gave the 'Presentation from Indonesia' with various statistics on national energy resources/production, energy mix, infrastructure power, and fuel for the transportation sector. The National Energy Policy (NEP) was presented in detail with its target and road map. Alternative fuels, such as biodiesel and compressed natural gas (CNG), were discussed with the possibility of electric vehicles (EVs). Finally, some vehicle registration data were presented.

3. Session II: Research of Next-Generation Biofuels

In this session, Dr Toba presented the details on this subject. From previous WG recommendations on common and individual strategies, this subject aimed to (1) clarify technological problems to produce and introduce next-generation biofuels; and (2) investigate the feedstock availability and energy policy for next-generation biofuels.

The focus of the discussion on next-generation biofuels was the following:

1. Biofuels from non-edible feedstock via both conventional and new technologies resulting in conventional fuel (e.g. first generation).
2. Drop-in fuel via new technology resulting in synthetic hydrocarbon.
3. Sustainable aviation fuel as it is an international issue rather than a domestic issue in the case of automobile fuel.

The definition of 'drop-in' was clarified with discussion among WG and ERIA members.

Dr Nuwong presented the current situation of next-generation biofuels in Thailand based on biohydrotreated diesel (BHD), bio-jet fuel, partially hydrogenated fatty acid methyl ester (H-FAME), and compressed biogas (CBG).

4. Session III: Biomethanol as an Energy Carrier

In this session, Dr Goto presented the details on this subject. With the growing number of vehicles worldwide, low-carbon energy sources are preferred for vehicles to reduce greenhouse gas emissions. Various sources of hydrogen carriers, such as liquid hydrogen, ammonia, methyl cyclohexane, and methanol, were explained with emphasis on methanol availability in linkage with dimethyl ether (DME).

The following presentation was on 'On-road test of DME vehicle' by Mr Seta from Isuzu, Japan. Isuzu has been developing a DME engine and vehicle since 2001. In-depth results of DME from on-road and chassis-dynamometer tests showed better emissions, high efficiency than diesel, and no engine problems.

All members were taken to visit the BPPT research laboratory.

Second WG Meeting (2015–2016), 26–27 April 2016, Chiang Mai, Thailand

1. Opening Address and Invited Lecture

The second WG meeting (2015–2016) was held in Thailand, arranged by MTEC.

Mr Yamamoto from ERIA gave the opening remarks to welcome and acknowledge the help from foreign experts in this WG. He also proposed the direction of the research.

The WG members visited the Energy Research and Development Institute (ERDI), Chiang Mai University (CMU). ERDI Deputy Director, Assistant Professor Dr Sirichai Koonaphapdeelert gave a presentation on the 'Overview of R&D Activities at ERDI, CMU'. ERDI manages the research and innovation on biogas, biomass, and energy management.

The invited lecture was on 'Current Trend of Bio-oil Research in Thailand', which was given by Assistant Professor Dr Adisak Pattiya, Head of Bio-Energy and Renewable Resources Research Unit, Mahasarakham University (MSU). The principle and advantage of the fast pyrolysis process were explained, before going through the bio-oil research activities in selected research organisations, namely MSU, Thailand Institute of Scientific and Technological Research (TISTR), MTEC, Chulalongkorn University (CU), King Mongkut's University of Technology North Bangkok (KMUTNB), and PTT.

2. Session I: Potential Study of Diversified Transportation Energy Mix

This session started with the agreed scope and target of this subject from the first WG meeting, where all three countries (Thailand, Indonesia, and the Philippines) helped collect and supply the necessary data for the model. The biofuel blending ratio among the three countries was shown for comparison to understand each country's setting and policy direction. The results of the analysis of energy issues of the three countries were shown, and possible measures to achieve policy target of each country were proposed.

Thailand, Indonesia, and the Philippines took turns to present an update of their situation with regard to the biofuel (bioethanol and biodiesel) policy/target, as well as main fossil fuel.

3. Session II: Research of Next-Generation Biofuels

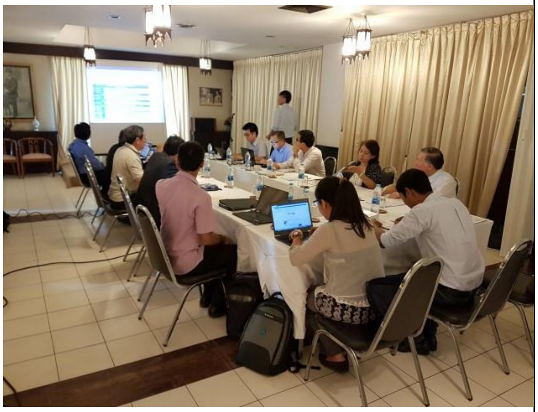
The important points and the problems that should be solved in the introduction of next-generation biofuels were clarified based on the survey results reported at the first WG meeting. The availability of raw materials and the cost for producing next-generation biofuels were proposed as next subjects of investigation.

4. Session III: Biomethanol as an Energy Carrier

General characteristics and details of various energy carriers such as liquid hydrogen, ammonia, methyl cyclohexane, and methanol were introduced before focusing on biomethanol production. Methanol itself can be an energy carrier, as well as precursor for DME to substitute diesel fuel.

5. Wrap-up and Closing Address

The WG Leader asked the members to prepare an annual report according to the proposed content.

First WG Meeting (2016–2017), 5–6 December 2016, Hanoi, Viet Nam

1. Opening Address

The first WG meeting (2016–2017) was held in Viet Nam, arranged by the Hanoi University of Science and Technology (HUST). Dr Tuan joined the meeting as a WG new member from Viet Nam. Dr Toba, WG Leader, gave an overview of the progress of the project.

2. Session I: Study of Diversified Transportation Energy Mix

Mr Ichikawa explained the objective, which was to find the best fuel mix based on cost-effectiveness and scope for Indonesia, with various case studies with respect to fuel economy improvement, biofuel, and CNG introduction.

The methodology and required information were presented for the case of Viet Nam with input and discussion by Dr Tuan in order to conduct analysis in the current year.

This was followed by presentations on Viet Nam, Thailand, and the Philippines, delivered by Dr Tuan, Dr Nuwong and Ms Ruby, respectively. For Viet Nam, the presentation focused on HUST and related research outcomes in the field of biomass/bioenergy with some information on Vietnamese transportation statistics. For Thailand, the presentation focused on the Thailand Integrated Energy Blueprint (2015–2036), which is composed of the Power Development Plan (PDP), Energy Efficiency Plan (EPP), Alternative Energy Development Plan (AEDP), Gas Plan, and Oil Plan.

For the Philippines, the presentation focused on the biofuel target, production capacity, supply–demand outlook, and related activities with discussion on the current concerns regarding the B5/E10 mandates. As for Indonesia, Dr Arie was absent, but his presentation was submitted for viewing during the meeting.

3. Session II: Research of Next-Generation Biofuels

This session started with objectives, first-year outcomes, and the second-year focus of theme 2. The main investigation themes in the second year were to clarify promising resources and technological problems for producing next-generation biofuels. Dr Toba elaborated on the three pillars of sustainability, namely social, environmental, and economic aspects for biofuel production with examples of greenhouse gas savings from biofuel production and cost comparison. Then, the status of the biomass potential in ASEAN was presented with technical analysis on raw materials and their implications on fuel properties. Information from research institutes and researchers to enhance the research and development (R&D) network on renewable energy technology development and utilisation was presented with a case study of the Japan–Thailand collaboration on biofuel through the Japan International Cooperation Agency (JICA) Third Country Training Program (TCTP) as a channel to disseminate research outcomes in ASEAN.

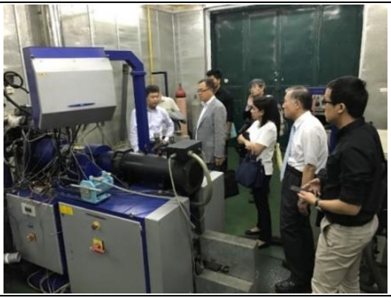
4. Session III: Biomethanol as an Energy Carrier

This session started with a general energy pathway to show that both fossil fuel and biofuel can be interchanged with characteristics and details of various energy carriers such as liquid hydrogen, methyl cyclohexane, ammonia, and methanol. Each carrier was presented with details on production and transportation. Next, methanol production and price were highlighted, as were alternative sources for use with possible biomethanol technology on a large production scale and bio-DME that uses biomethanol as feedstock. Finally, the International Energy Agency Implementing Agreement on Advanced Motor Fuel (IEA AMF) network was highlighted as a way to disseminate research outcomes via their newsletter.

5. Technical Visit

A technical visit was arranged to three laboratories where WG members could learn about the research conducted in HUST:

1. Laboratory of Heat Engineering, School of Heat Engineering and Refrigeration
2. Laboratory of Materials, Advanced Institute of Science and Technology
3. Laboratory of Internal Combustion Engine, School of Transportation Engineering



Second WG Meeting (2016–2017), 16–17 March 2017, Kuala Lumpur , Malaysia

1. Opening Address

The second WG meeting (2016–2017) was held in Malaysia, arranged by the University of Malaya (UM). Dr Ong (UM) joined the meeting as a new WG member from Malaysia. Dr Toba, WG Leader, gave an overview of the progress of the project.

2. Session I: Study of Diversified Transportation Energy Mix

This session started with the scope and target of the activity within theme 1, which covered five ASEAN countries (Thailand, Indonesia, Philippines, Viet Nam, and Malaysia), aiming to propose measures for mitigating energy issues in the transportation sector and achieving the policy target. For this meeting, analysis on Malaysia and Viet Nam were presented in detail. Given the characteristics of each country's fuel consumption, the imbalance between gasoline and diesel can be reduced by cross-border trading of biofuel (ethanol and biodiesel) within the ASEAN region.

Next, country presentations on Malaysia, Viet Nam, Thailand, and Indonesia were delivered by Dr Ong, Dr Tuan, Dr Nuwong, and Dr Arie, respectively. For Malaysia, the energy policy was presented with emphasis on biodiesel development. For Viet Nam, the energy policy was presented with emphasis on the ethanol road map (E5 and E10). For Thailand, an update on the energy policy, Thailand Integrated Energy Blueprint, was presented with the current status of biofuel, both bioethanol and biodiesel, and recent bioeconomy initiative as part of the new S-Curve campaign. For Indonesia, the national energy balance was presented along with the renewable energy policy framework focusing on transport fuel (biodiesel, bioethanol) with the funding mechanism, as well as electricity generation from renewable resources.

3. Session II: Research of Next-Generation biofuels

This session started with objectives, first-year outcomes, and second-year focus of theme 2. Dr Toba presented a feasibility study of alternative diesel production, where fuel production cost can be reduced by use of cheap resources (due to the large influence of the biomass price on biofuel cost) and improvement of technologies (due to the variety of available technologies with various levels of possible cost reduction). The conclusions of the analysis were the following:

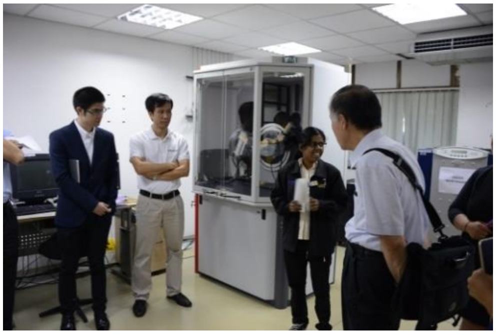
1. Utilisation of non-conventional resources contributes to reduction of feedstock cost. In particular, it is effective for producing conventional biofuels.
2. Various cheap raw materials are available for production of next-generation biofuels.
3. The production process of next-generation biofuels has not been established.
4. In producing next-generation biofuels, improving the manufacturing process is more effective than using the raw material price for cost reduction.

4. Session III: Biomethanol as an Energy Carrier

This session started with the general energy pathway to show that both fossil fuel and biofuel can be interchanged with characteristics and details of various energy carriers such as liquid hydrogen, methyl cyclohexane, ammonia, and methanol. Each carrier was presented with details on the production and transportation, highlighting methanol production and price as alternative sources and where biomethanol technology can be applied on a large production scale.

5. Technical Visit

A technical visit to the Nanotechnology & Catalysis Research Centre (NANOCAT), University of Malaya was arranged. WG members discussed research subjects on biomass conversion technology with NANOCAT researchers.



First WG Meeting (2017–2018), 23–24 November 2017, Manila, Philippines

1. Meeting with Director, Renewable Energy Management Bureau, PDOE

Dr Toba and Dr Goto visited the Renewable Energy Management Bureau, Department of Energy, Philippines (PDOE) on 22 November. Dr Toba explained the contents of the current WG project to Ms Marissa P. Cerezo, Director of the Renewable Energy Management Bureau. The current situation in the transportation sector and the government policy in the Philippines were discussed also.

2. Opening Address

Dr Venkatachalam Anbumozhi gave opening remarks on behalf of ERIA to acknowledge the contribution from this WG with anticipation for outcomes of this WG. Dr Toba gave an overview of the progress of the project, which was divided into three subjects.

3. Session I: Study of Diversified Transportation Energy Mix

This session started with the scope and target of the activity within theme 1, which covered five ASEAN countries (Thailand, Indonesia, Philippines, Viet Nam, and Malaysia), aiming to propose measures for mitigating energy issues in the transportation sector and achieving the policy target. For this meeting, the analysis on all five countries was reviewed in detail in order to propose a measure for mitigating energy issues in the transportation sector through regional cooperation to achieve appropriate biofuels utilisation. A proposal of alternative oil reduction in all five countries was presented with a summary of biofuel demand and supply in 2030. However, the projection of biofuel demand and supply in some countries needed further revision.

4. Session II: Research of Next-Generation Biofuels

This session started with the objectives and outcomes of the past 2 years, followed by the third-year focus. Linkages between biomass price and biofuel cost, the process selection, and production cost for bio-jet fuel were shown for a few technological processes, with an illustration of the total cost distribution and cost sensitivity to confirm that improving the manufacturing process is more effective than using the raw material price for cost reduction in producing next-generation biofuels.

5. Session III: Biomethanol as an Energy Carrier

This session started with a review of the energy pathways to show how various fuels are connected with hydrogen. Thus, investigating the pros and cons of hydrogen as a carrier via various pathways (liquid hydrogen, methyl cyclohexane, ammonia, and methanol) is important. The global status of methanol was reviewed, followed by introduction of poly dimethyl ether (oxymethylene or OME) as a new candidate.

6. Technical Visit

A technical visit to Chemrez biodiesel plant (Quezon City) was arranged, where coco methyl ester (CME) was produced at a capacity of 300 kilolitres per day (6,000 kilolitres storage tank) using Lurgi technology with investment costs amounting to 650 million pesos.

Second WG Meeting (2017–2018), 30–31 January 2018, Bangkok, Thailand

1. Opening Address

The second WG meeting (2017–2018) was held in Thailand, arranged by MTEC. Dr Toba, WG Leader, gave an overview of the progress of the project. All WG members had submitted preliminary reports to the WG Leader before the meeting for final discussion.

2. Session I: Study of Diversified Transportation Energy Mix

The possibility of multilateral cooperation was discussed based on the simulation results of biofuel supply potential in 2030 in each country. Necessary measures to realise the idea included unified biofuels specification and reduction of barriers to prevent import/export of biofuels.

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3. Session II: Research of Next-Generation Biofuels

The scale merit for producing next-generation biofuels was clarified based on the articles of simulation. The influence of other factors such as energy supply for operating factories was also discussed.

4. Session III: Biomethanol as an Energy Carrier

Biomethanol plants around the world were introduced to understand resource supply, plant scale, and cost.

5. Wrap-up and Closing Address

The WG Leader indicated the crucial items of the final report to all WG members and the deadline for submission was decided.

Appendix 2

Abstracts of Invited Lectures

The WG invited two lecturers to give lectures about production, utilisation, and testing of biofuels.

Progress in Indonesian Biodiesel

Mr Imam Paryanto (BPPT, Indonesia), a submember of this WG, gave a lecture at the first WG meeting in Serpong, Indonesia. He first introduced the energy situation in Indonesia. Currently, Indonesia imports large amounts of crude oil and diversification of the energy source is strongly desired. To achieve this, the Indonesian government promotes its policy on the development and implementation of bioenergy. He himself is engaged in research and evaluation of biodiesel fuel to generate useful information for its safe use. In this lecture, he reported on B20 (20% of biodiesel blended diesel) tests on vehicle engines and roadshows. These results will contribute to the safe use of fuels when high biodiesel-blended diesel is introduced to the market.

Current Trend of Bio-oil Research in Thailand

Assistant Professor Adisak Pattiya (Mahasarakham University, Thailand) gave a lecture at the second WG meeting in Chiang Mai, Thailand. He first explained the production processes of bio-oil (fast pyrolysis) and advantages of the process. Many kinds of solid resources can be used as feedstock for bio-oil production. This is one of the advantages of this technology. Next, he introduced the bio-oil research situation in Thailand. Currently, fast pyrolysis technology development is at the R&D stage. Several organisations such as national institutes, universities, and petroleum refinery companies are working on this technology. Finally, he pointed to future directions for bio-oil R&D in Thailand.