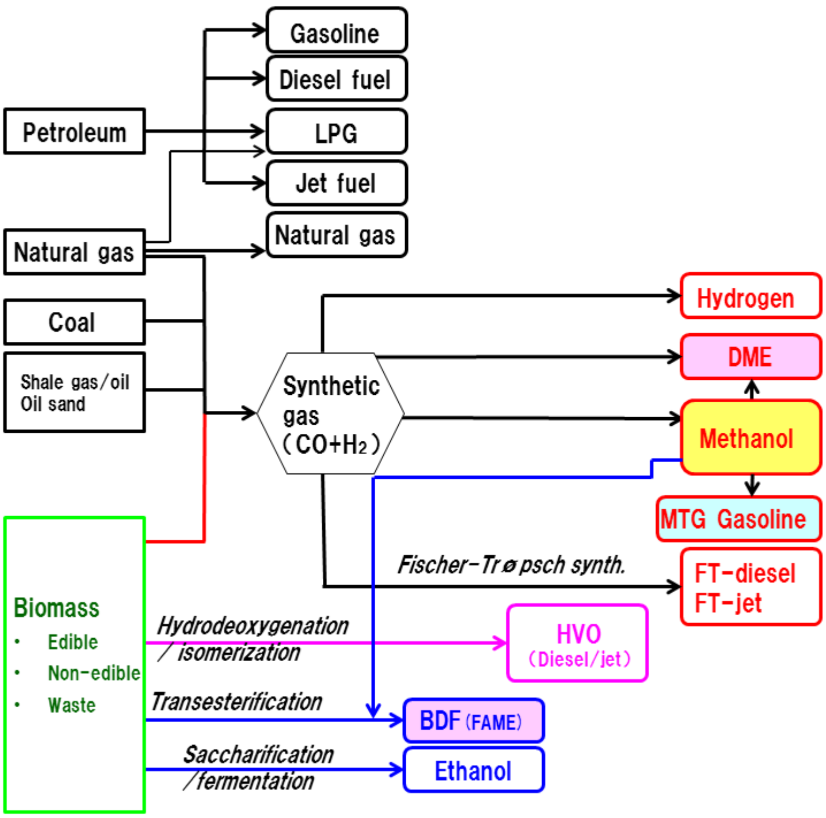
Chapter 4

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

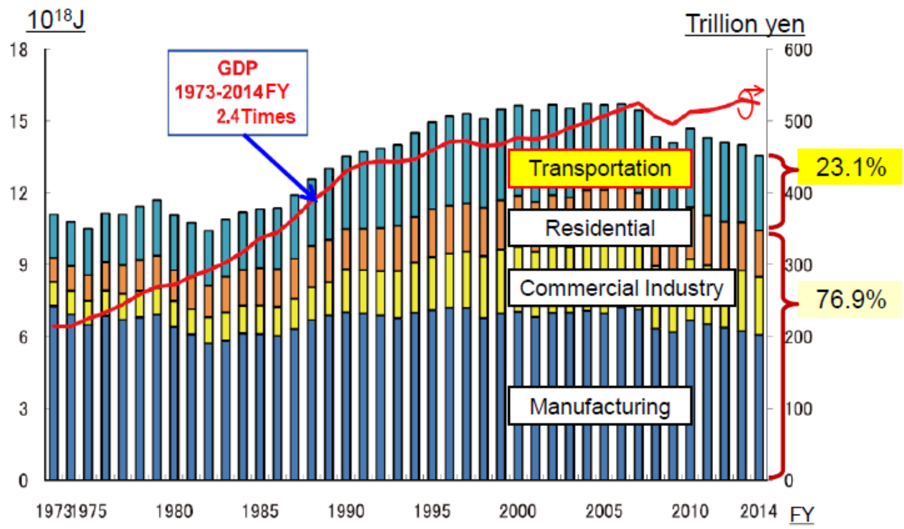


Source: Authors.

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]).

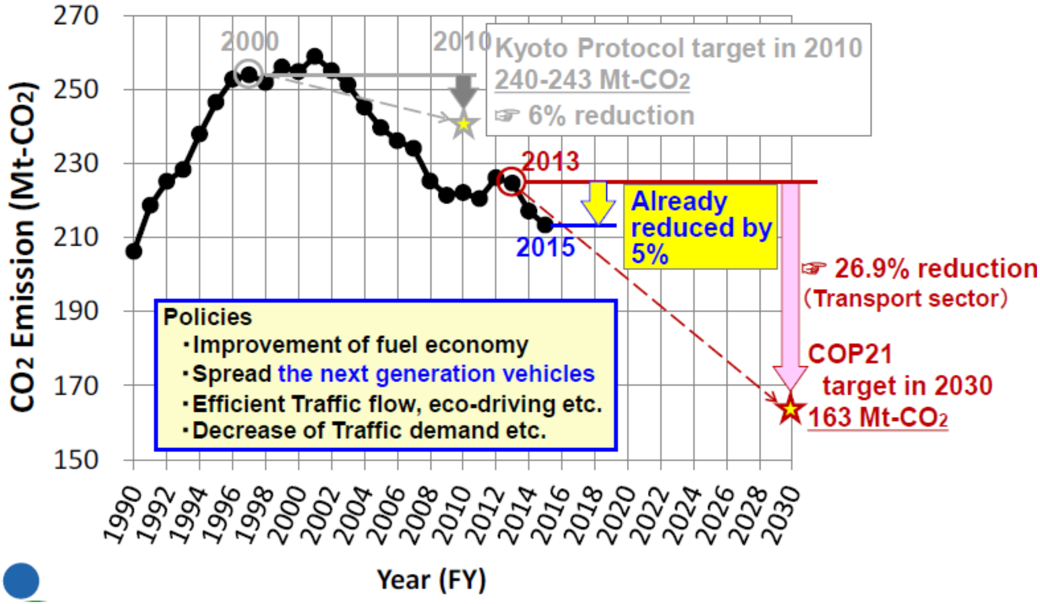
Figure 4.1.2. Energy Consumption and Gross Domestic Product Trend in Japan



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.

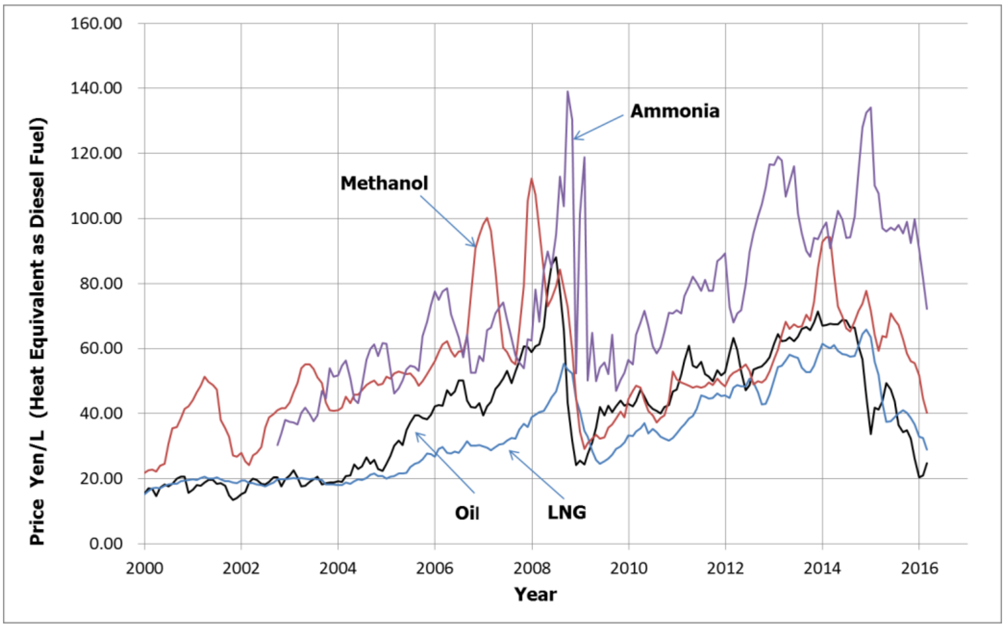
The purpose of this survey is to investigate the current methanol production process from biomass and utilisation of methanol as a new energy source for producing transportation biofuel.

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.

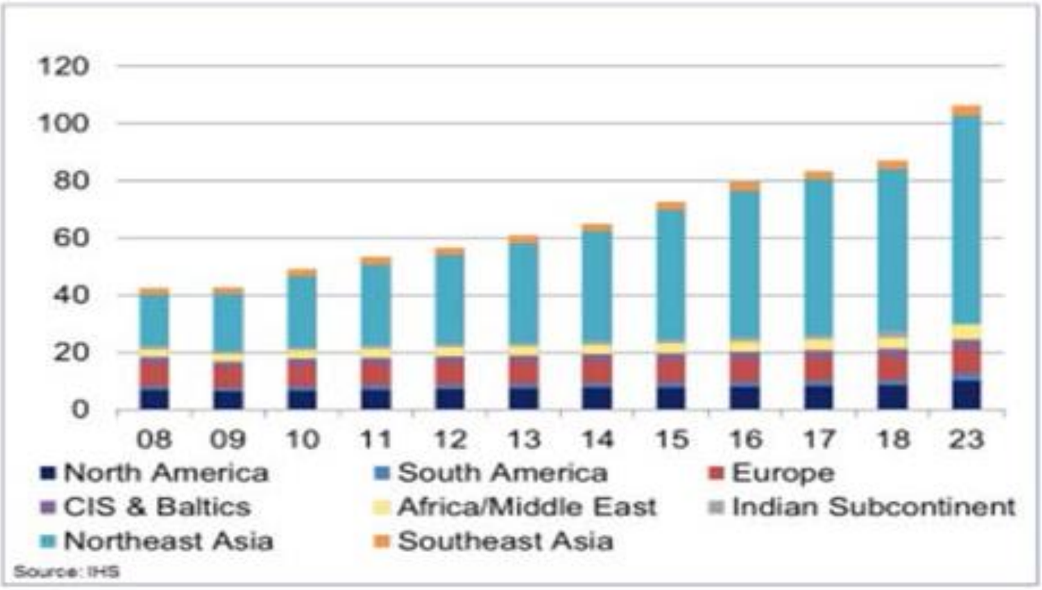
Figure 4.2.1. Trend of Methanol Production



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; Bio-refining, 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

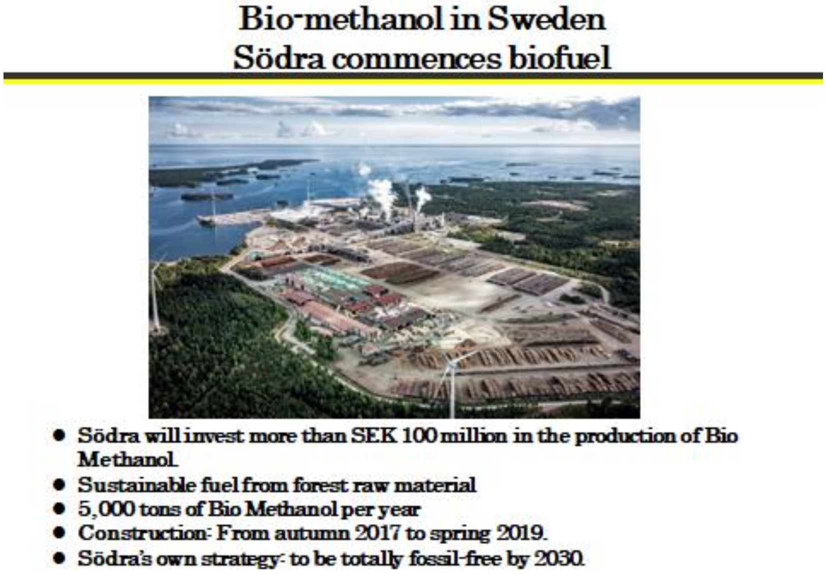
Source: VärmlandsMetanol AB, 2012.

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



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

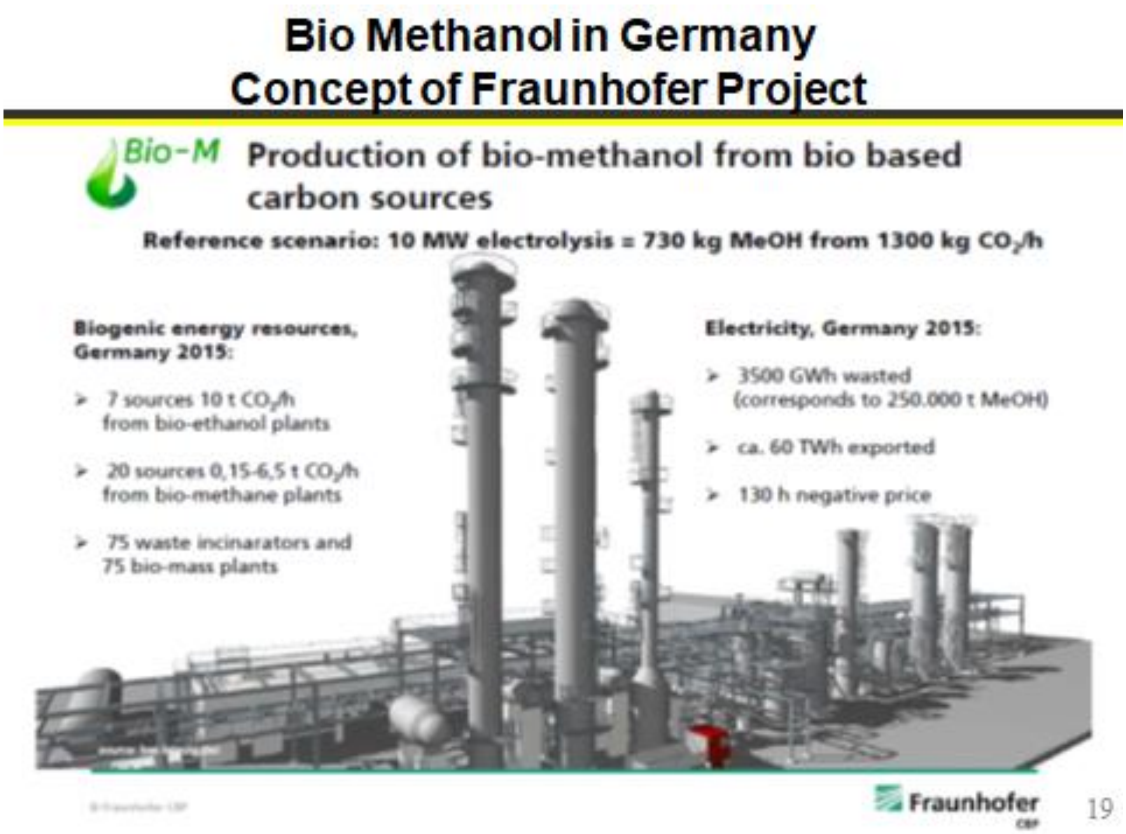
Source: Chemrec, 2012.

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



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

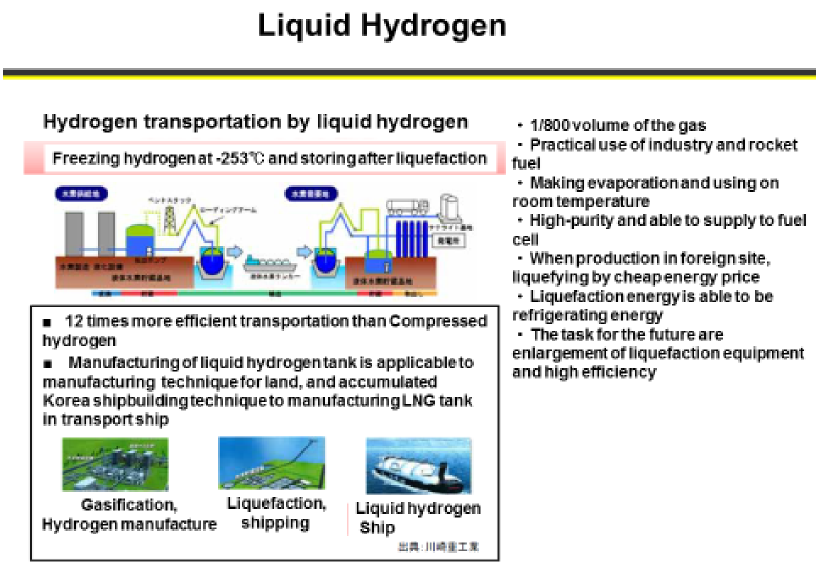
	Liquid Hydrogen	MCH	Ammonia	Methanol
Chemical formula	H_2	C_6H_{11}-CH_3	NH_3	CH_3OH
Molecular weight	2.01	98.19	17.03	32.04
Characteristic and condition (normal temperature and pressure)	Gas	Colorless and transparent liquid	Gas	Colorless and transparent liquid
Scent	scentless	peculiar	sensitive	peculiar
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.

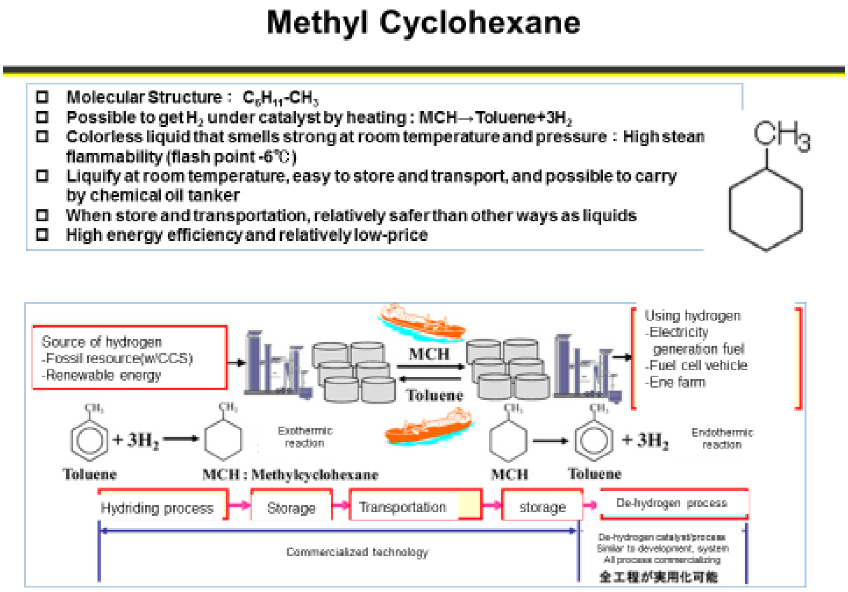
On the contrary, methanol has some excellent features as an energy carrier. Transportation is easy because methanol is liquid at room temperature. It is possible to use methanol as a chemical intermediate of various transportation fuels described earlier. MCH and toluene, a dehydrogenated product of 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



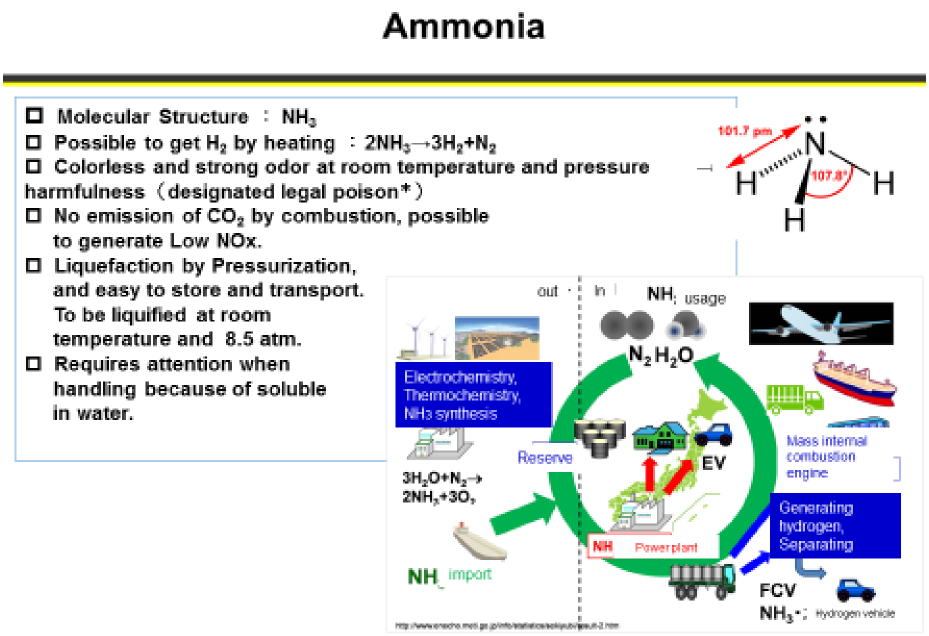
Source: Originally adapted from the KHI home page.

Figure 4.4.2. Properties and Utilisation of Methylcyclohexane



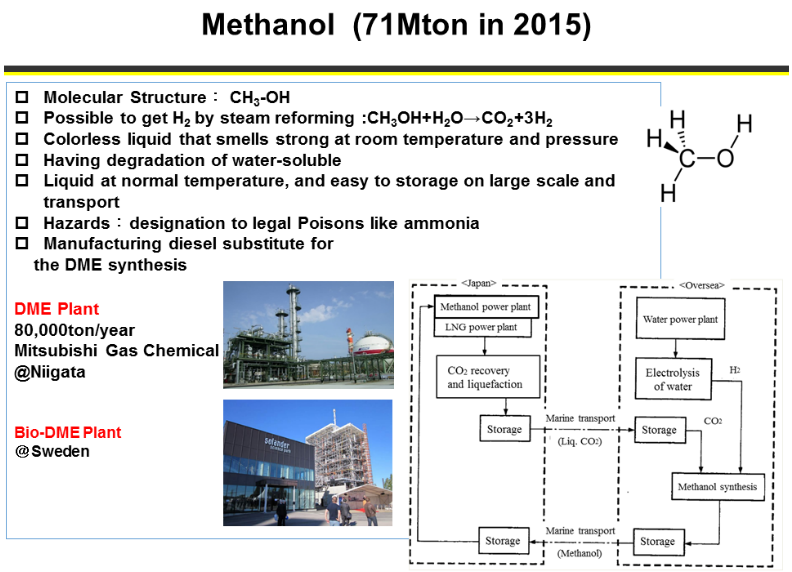
Source: Originally adapted from the Chiyoda Corporation home page.

Figure 4.4.3. Properties and Utilisation of Ammonia



Source: Originally adapted from various home pages.

Figure 4.4.4. Properties and Utilisation of Methanol



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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