A FEASIBILITY STUDY REPORT

FOR

A DME PROJECT

IN

ICELAND

(Summary)

The Ministry of Industry, Energy and Tourism

Orkustofnun / The National Energy Authority

The Innovation Center Iceland

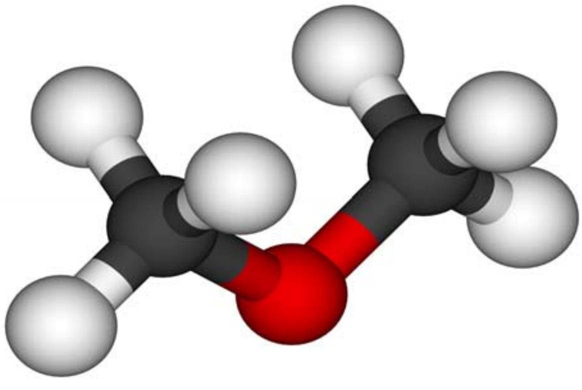
Mitsubishi Heavy Industries, Ltd.

Mitsubishi Corporation

Hekla hf.

NordicBlueEnergy

February 2010



＜Abstract＞

The Icelandic government has established a long term vision for zero percent hydrocarbon fuel emissions, and has been working to increase the use of renewable energy. However, imported fossil fuels are still used for road transport and fishing vessels, which is a big concern for an achievement of the vision due to the CO_2 emission from vehicles and ships.

A team of experts from Iceland and Japan, including representatives from Mitsubishi Heavy Industries, Ltd. (MHI), Mitsubishi Corporation (MC) and HEKLA ("Hekla") as well as the Icelandic government and Innovation Center Iceland has conducted the feasibility study of the synthesis gas Dimethyl ether (DME) as an alternative fuel.

The following technologies are adopted for producing DME:

- MHI's CO_2 recovery process which is the most advanced technology in the world
- H_2 generation process by electrolysis
- Methanol synthesis process which is jointly developed by MHI and Mitsubishi Gas Chemical Company, Inc. (MGC) featuring an advanced methanol synthesis converter "SUPERCONVERTER (SPC)"

Production process is as follows:

1) The CO_2 gas is captured from the exhaust gas of the ELKEM ferrosilicon plant
2) The H_2 gas is generated from water by electrolysis
3) Methanol is produced by synthesis from CO_2 and H_2
4) DME is produced from methanol as an alternative fuel

This fuel is considered carbon neutral, as it is produced from the recovered CO_2 gas and water.

Therefore this project will contribute to Icelandic society by producing alternative carbon neutral energy and reducing CO_2 emission from the ferrosilicon plant. As the result of that, consumption of diesel fuel and the emission of CO_2 can be reduced in Iceland.

The feasibility study has the following conclusions:

- There are no technical or environmental concerns to go forward with the planned

project of the construction of the DME plant.

- Production cost (CAPEX/OPEX) is at a fairly attractive value taking into consideration the contribution to Icelandic society.
- This project is considered to be feasible, subject to a strong and dedicated support by the Icelandic government.

CONTENTS

1. Background of the Project

The Ministry of Industry, Energy and Tourism (the "Ministry"), the National Energy Authority ("NEA") and the Innovation Center Iceland ("ICI") represent the Icelandic government and its subordinate organizations of the Republic of Iceland in this study.

The Icelandic government has established a long term vision for zero percent hydrocarbon fuel emissions. Since early in the 20th century, the Icelandic government has been actively working to increase the use of renewable energy, with the result that all of the country's electricity is generated by geothermal and hydropower systems today. As Iceland is still importing fossil fuels for transport and fishing, the government is investigating the possibility of introducing alternative fuels in this field. Due to the abundance of renewable electricity available, the government is keen on research and development of electricity based transport, such as hydrogen or fuel-cell vehicles and is attracting an attention from the world as one of the leading countries of clean-energy utilization.

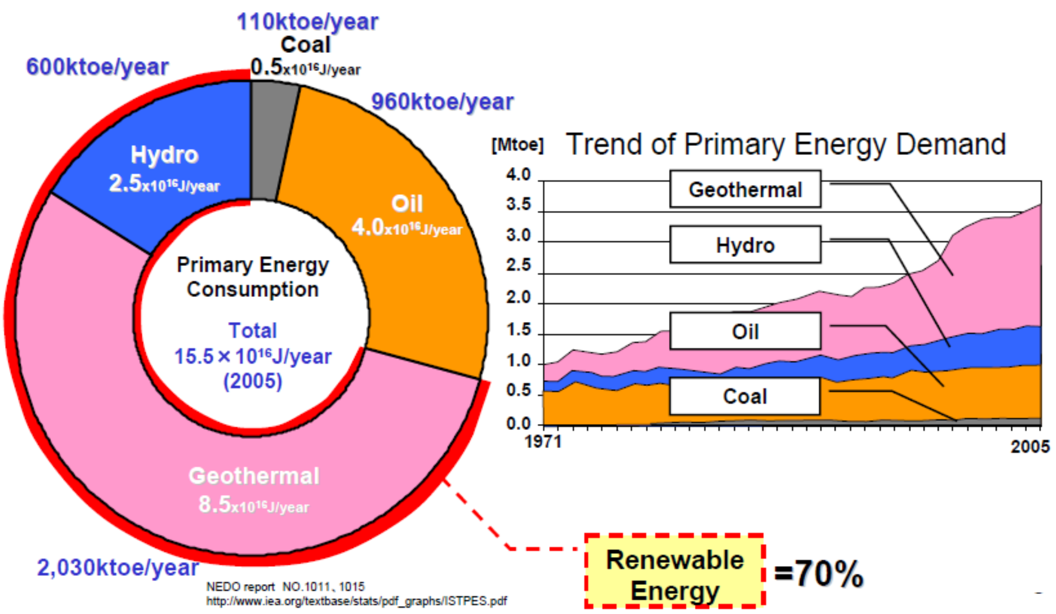


Figure 1.1 Energy supply and demand situation in Iceland

Mitsubishi Heavy Industries, Ltd. ("MHI") is one of the world's leading heavy machinery manufacturers and plant engineering contractors, with its diverse lineup of products and services encompassing shipbuilding, power systems, chemical and environmental plants, industrial and general machineries, transportation systems, aerospace equipments, etc. MHI has supplied a total of 15 turbines to Icelandic geothermal power generation plants and supports the country's energy policy as mentioned above.

Mitsubishi Corporation ("MC") is one of the world's leading trading houses engaged in trading, financing and investment activities in the global industry, including machinery, petrochemicals, oil and gas, renewable energy, metals, food and general merchandise. MC, together with MHI, has collaborated with Icelandic power companies on geothermal power projects for more than 30 years.

HEKLA ("Hekla") is a service company, specializing in sales and servicing of automobiles and heavy machinery. The company's goal is to lead the field as regards to customer service and the marketing of goods sold and serviced by the company. HEKLA represents companies renowned all over the world for quality and reliability, including Mitsubishi Heavy Industries and Mitsubishi Motors from the year 1979. HEKLA's heavy machinery division is located at Klettagardar in Reykjavik. HEKLA has dealers and service agents in all major towns in Iceland.

NordicBlueEnergy is an Icelandic company specializing in sustainable and environmentally friendly projects. Our aim is to merge technical knowledge with stakeholders to develop financially viable ventures that lead to a better and cleaner environment for all.

On September 19th, 2008, the Ministry, NEA, MHI, MC and Hekla signed a Memorandum of Understanding (MOU) agreeing to collaborate on investigating potential introduction of various technologies related to a long term vision of zero percent hydrocarbon fuel emissions society in Iceland. Based on this comprehensive MOU, the above 6 parties (i.e. the above 5 parties who signed the comprehensive MOU + ICI) agreed to sign a MOU to study the feasibility of a DME synthesis plant project for a potential application as an alternative fuel for certain vehicles and fishing vessels. This MOU was signed on November 21st, 2008.

2. Objective of the Feasibility Study

The objective of this study is to evaluate the possibility of constructing a DME production plant and its infrastructure in Iceland. The Parties will consider the use of DME as fuel for fishing vessels and vehicles in this respect from a technical and an economic perspective.

In addition, the Partys will also evaluate the DME synthesis as a measure to reduce CO_2 emission, since the synthesis DME can be considered as carbon neutral fuel. Because the DME will be produced from the feed material of both H_2, which generated from renewable energy of hydro and/or geothermal power, and CO_2 captured from existing flue gas.

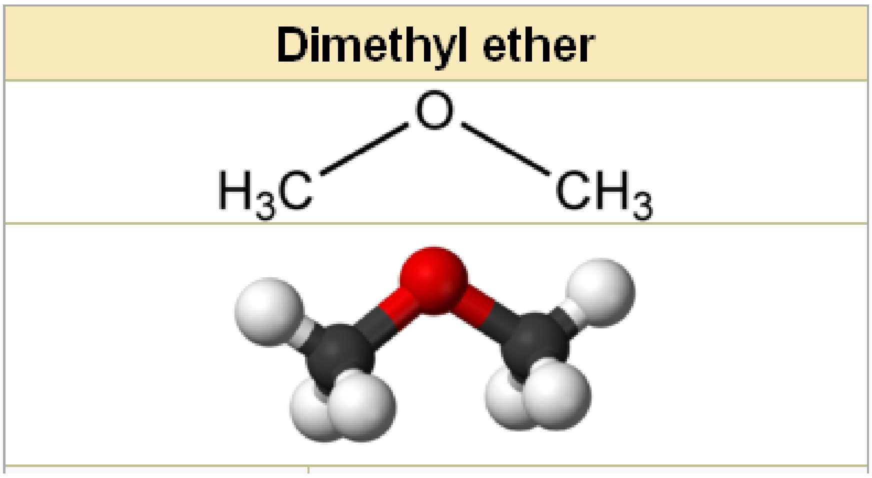
The following studies have been conducted in feasibility study:

1) An evaluation of the potential feed gas source (amount, composition, impurities etc.) and the selection of a suitable site for building a DME plant.
2) A preliminary design of the carbon dioxide recovery plant and the DME production plant.
3) A calculation of the cost of the construction and operation of the DME production plant based on the preliminary design.
4) The evaluation of the economic feasibility of the DME production compared to existing energy sources.
5) An initial evaluation comparing CO_2 emission reduction due to DME production and use with CCS (Carbon Capture and Storage).

3. About DME

DME is an organic compound with the formula CH_3OCH_3 (refer to Figure 3.1). The simplest ether, it is a colorless gas that is a useful precursor to other organic compounds and an aerosol propellant. DME is non-poisonous if inhaled. Vapor pressure is 0.6MPa at 25C and boilig point is -25C. DME is also promising as a clean-burning hydrocarbon fuel.

Figure 3.1 Molecular Architecture of DME



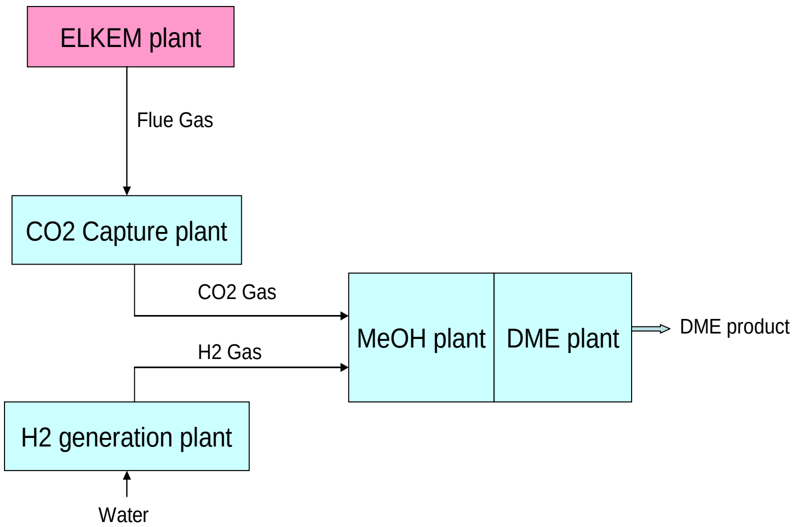
Today, DME is primarily produced by converting hydrocarbons, predominantly sourced from natural gas, to synthesis gas. Synthesis gas is then converted into methanol in the presence of catalyst, with subsequent methanol dehydration in the presence of a different catalyst resulting in the production of DME. As described, this is a two-step (indirect synthesis) process that starts with methanol synthesis and ends with DME synthesis (methanol dehydration).

DME is a promising fuel in diesel engines, and gas turbines owing to its high cetane number. Only moderate modification are needed to convert a diesel engine to burn DME. The simplicity of this short carbon chain compound leads during combustion to very low emissions of particulate matter, NOx, CO. For these reasons as well as being sulfur-free, DME meets even the most stringent emission regulations in Europe, U.S., and Japan.

4. Configuration of DME production plant

The configuration of the DME production plant is shown on the Figure 4.1 below.

Figure 4.1 DME production Plant Configuration



The DME production plant consists of following 4 process plants and common utility/ offsite system.

The design capacity of the DME production is set at 500MTPD (Metric Tons Per Day)

(Process Plants)

1) CO_2 Capture Plant :

The flue gas from the ELKEM ferrosilicon plant will be fed to a Carbon Capture System to recover the CO_2 from the stream. Before feeding the flue gas into the Carbon Capture System, it needs to be pretreated to remove sulfur. To that end, the MHI Carbon Capture System technology, including Flue Gas Desulfurization system (FGD), is adopted. The captured CO_2 is then fed to the Methanol Plant after compression.

2) H_2 Generation Plant :

The purpose of the hydrogen generation system is to convert water to H_2 and O_2 by electrolysis. A multi-unit system is required to satisfy the high H_2 feedstock demand. Commercially available electrolyser units are considered applicable.

The produced H_2 is then fed to the Methanol Plant after compression.

3) Methanol Plant

CO_2 and H_2 fed from above mentioned respective plants are mixed in the appropriate ratio for a methanol synthesis reaction. The mixture, called a synthesis gas, will be compressed further and fed to methanol synthesis unit where Mitsubishi Gas Chemical (MGC) developed methanol synthesis catalyst and MHI/MGC SUPERCONVERTER (SPC) are used.

The crude methanol is produced in the SUPERCONVERTER.

4) DME Plant

The crude methanol is then fed to distillation and DME synthesis units for methanol purification and DME production.

The products are stored in storage tanks and shipped for sale.

(Utility and Offsite system)

The utility system consists of the following:

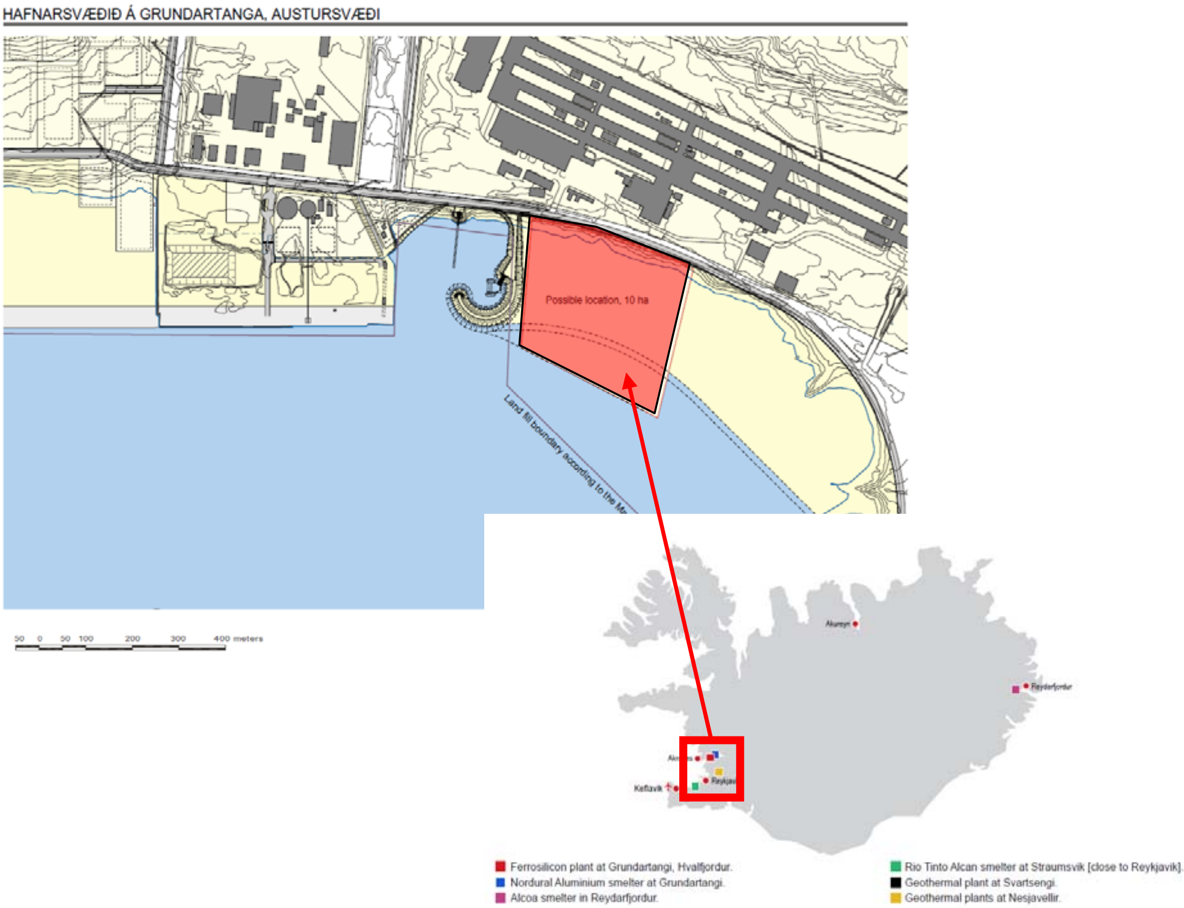
- The *electrical power supply* will be from an outside system, either from the national grid or a dedicated power station. Considering the electricity demand of the plant, which far exceeds the currently available surplus power, a new power generation and supply system will be required.
- The *cooling system* for the plant will be a closed circuit of clean water, where sea water, passed through a heat exchanger, is the cooling agent.
- The *raw water* will be from an outside water supply network and fed to inside water treatment for users.

- The *effluent water* will be discharged to the sea after being treated in the waste water treatment unit to meet regulations.
- *Steam* will be generated at the ELKEM plant utilizing the waste heat of the flue gas stream.
- *Boiler feed water* will be treated in a de-mineralized water treatment unit and sent to ELKEM for steam generation.
- *Instrument Air* will be generated by air compression and dryer system for plant demand.
- *Nitrogen supply* will be from a storage tank of liquid nitrogen.
- *Flare system* will flare off effluent gases.
- *Incinerator unit* will be provided to incinerate effluent flammable liquids.
- *Product storage* will be provided for both methanol and DME. The methanol loading to ocean tanker will be at the ELKEM berth. The DME lorry loading dock will be inside plant.

5. Location of the DME Production Plant

As the result of the study, the plant site near ELKEM ferrosilicon plant in Grondartangi has been selected as the best place for the DME production plant.

Refer to the figure below.



The CO_2 feedstock can be obtained from the ELKEM plant, which currently discharges significant amounts of CO_2 as flue gas to the atmosphere.

A landfill is planned in the selected area which is currently a coastal shore, according to a zoning plan. The site is connected to the main road network by already existing roads. The roads will also be upgraded further according to the zoning plan, thus the product delivery to the domestic consumer will be secured.

There is a marine loading/unloading harbor for ocean vessels adjacent to the ELKEM plant, where a marine loading system can be established for the project. The facility can be utilized for the construction equipments and materials unloading purposes as well.

Electric power is currently supplied to the area, where the ferrosilicon plant and aluminum smelter factory are receiving massive amount of electricity from the power grid and/or power station. The required power for this project can be supplied in same manner provided with extra supply capacity and transmission lines.

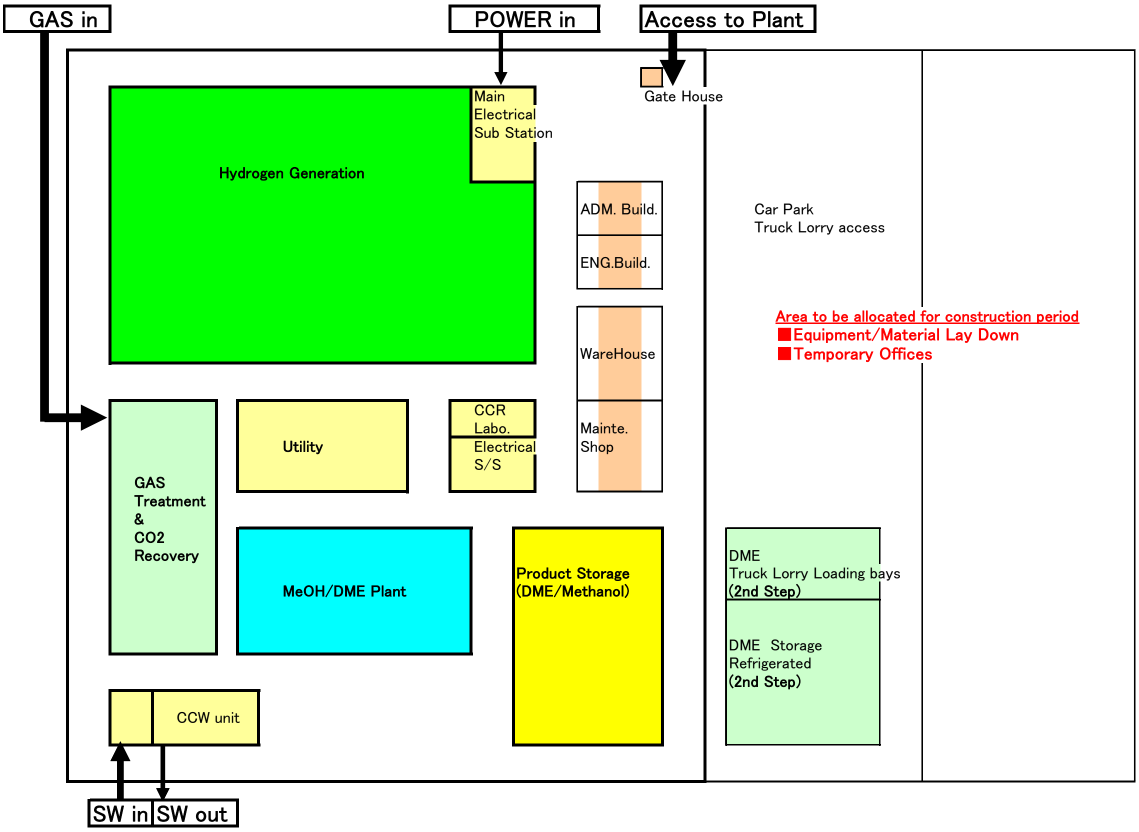
The fresh water supply is available for above mentioned existing factories, thus the required water can be received by the plant provided with extra capacity and supply pipe lines.

Since the plant site is located by the shoreline, cooling water for the plant shall be sea water taken from a deep fiord sea bed.

The plant location is an already industrialized area, for which environmental protection and natural conservation program has been implemented, thus the extra impact by this plant shall be evaluated. It is not difficult to meet the environmental regulations and/or requirements as described in later chapter.

6. General Plot Plan

The "**General Plot Plan**" below shows the allocated facilities Inside Battery Limit of the plant.



APPROX. PLOT AREA 400M × 300M → After 2nd step 400M × 400M

(12 ha) (16ha)

7. Environmental Impact Analysis

The plant emission has been evaluated based on the conceptual design of the plant. The key result is that the plant will abide by all environmental regulations and not discharge any material which is harmful to the environment. Furthermore, by treating the flue gas from the ELKEM plant, which is currently discharged to the atmosphere, the combined emissions from both plants will be much less, and thus the overall environmental impact is improved.

Also according to the Mannvit assessment on the information provided about the emission values for the IDME project, as a whole the emission to air and discharges to sea seem to be a minor issue and there is no indication of any problems to be expected in obtaining permit for the operation of such a plant.

In the process emissions from the ELKEM ferrosilicon plant at Grundartangi will be treated to provide CO_2 source for the process. In order to use the CO_2 from the plant, sulfur dioxide will be removed. The waste water consists of two streams. One sea water stream, used for cooling, indicating a 10°C rise in temperature. In Iceland there are several locations where warm water is flowing into the ocean. A 10°C rise in the water temperature will only raise the temperature of the sea slightly right at the discharge point as up mixing in the ocean at Grundartangi is very effective. The other waste water stream has emission value of BOD, COD and SS which are much in line with regulation 798/1999, on wastewater treatment. The waste water has a slightly higher max values from BOD and COD (30 vs. 25 and 150 vs. 125), than the regulation indicates for municipal waste water treatment. As the volume of the stream is low, this variance should be addressed in the Environmental Operating Permit, and is not expected to pose any problems.

When specifying emission and discharge value in an Environmental Operating Permit according to regulation 785/1999, Icelandic authorities refer as much as possible to the Best Available Technology Reference Documents of the European IPPC Bureau. DME production of this type is not really a part of the document on Large Volume Organic

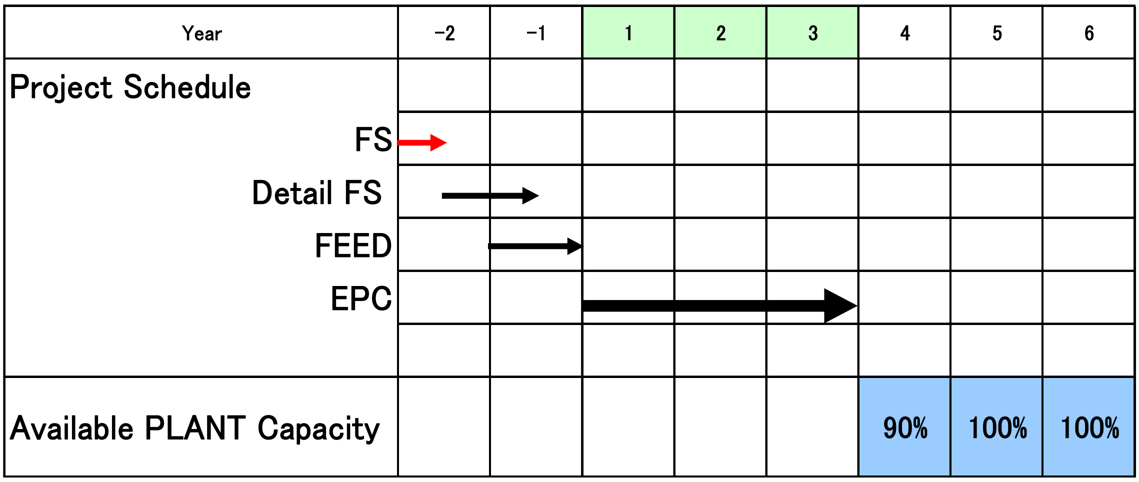
Chemicals or any other documents. Only the general issues and guidance of the documents will apply to this type of process.

8. Project Implementation Schedule

The **"Project Implementation Schedule"** is shown in the following figure 8.1.

Figure 8.1

ICELAND DME PROJECT Project Implementation Schedule



Total construction period of the plant including the hydrogen production plant is expected to be 3 years (36 months) for Engineering, Procurement and Construction (EPC) work.

9. Potential application and demand of DME in Iceland

1) Potential applications of DME in Iceland

There is significant consumption of diesel oil as transportation fuel for ships and automobiles in Iceland. Therefore, the potential of DME demand exists as a substitute for diesel oil, and DME as fuel has been widely used in China.

Potential applications for replacement of DME are summarized as follows;

1) Diesel fuel for automobile
2) Diesel fuel for ships
3) LPG blending component for households and industry
4) Coal / Natural gas / Oil for power generation

DME can be utilized with infrastructure of LPG and diesel engine, although some modification of engine, such as replacing the fuel injection pump and fuel tank, is required.

2) Potential demand of DME as a substitute for diesel oil in Iceland

Ships and automobiles will be the major potential consumers of DME as a diesel oil substitute, since there is no demand for power generation or LPG substitute in the country.

The daily average diesel oil sales for ships and vehicles, and the equivalent quantity of DME are shown in Table 9.1. More than 60% of this diesel oil is consumed by ships and the balance by vehicles. The main fueling area for both ships and vehicles is in Reykjavik. Table 9.2 shows the number and size of ships in Iceland.

Reykjavík is the logical supply center since:

1) Half of the total diesel oil demand in Iceland is consumed in Reykjavik (as shown in Table 9.1).

2) A large number of the total number of vehicles in Iceland are operated in the Reykjavik area and stay within 80 km radius of the city. Also, out of 550 buses under operation, 80 buses are operating within the city (fueled by a single filling station in the city).

Table 9.1 Diesel oil sold in Iceland in 2008 and equivalent quantity of DME

[ton diesel/day]	Ships	Trucks	Total
Reykjavik	222	139	361
West	22	28	50
West fjord	22	8	31
North	67	42	108
East	67	19	86
South	44	42	86
	444	**278**	**722**

[ton DME/day]	Ships	Trucks	Total
Reykjavik	299	187	486
West	30	37	67
West fjord	30	11	41
North	90	56	146
East	90	26	116
South	60	56	116
	598	**374**	**972**

Table 9.2 Number and size of ships in Iceland

Number and size of ships	2001	2002	2003	2004	2005	2006	2007
Vessels	1.067	1.136	1.135	1.128	1.135	1.128	1.128
Bruttoton	220.874	230.748	235.776	226.081	230.881	219.934	219.180
Open boats	1.361	1.329	1.273	1.237	1.209	1.183	1.181
Bruttoton	7.570	7.745	7.473	7.322	7.199	7.020	7.014
Total	2.428	2.465	2.408	2.365	2.344	2.311	2.309
Total Bruttoton	228.444	238.493	243.249	233.403	238.081	226.954	226.194

Design capacity of the DME production plant is set at 500 metric tons per day of DME.

10. Contribution to Icelandic Society

Currently, almost all energy for transport and fishing in Iceland comes from imported petroleum products. These products make up about 10% of the total value of imported goods to Iceland. On that basis alone, any domestic fuel must be considered as an attractive alternative.

DME produced by the method described in this report reduces the emission of CO_2 and so helps fulfillment of Iceland's international agreements and emission reduction goals.

Furthermore, the construction of the plant, which is expected to take three years, as well as running the plant will provide jobs and taxable income.

These aspects have not been analyzed in detail in this report, but should be looked into more thoroughly in a follow-up study.

11. Application of JI or GIS (CO_2 credit)

As this project considers utilizing currently emitted flue gas as feedstock, it may be possible to apply one or more of the Kyoto Mechanisms for CO_2 (carbon dioxide) credit. The Kyoto Mechanisms are Clean Development Mechanism (CDM), Joint Implementation (JI) or Emission trading (GIS). Each Kyoto Mechanism has a different scheme to generate carbon credit and this is explained in the chapters that follow.

1) Clean Development Mechanism (CDM)

CDM, defined in Article 12 of the Kyoto Protocol ("the Protocol") allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party*) to implement an emission-reduction project in developing countries. Such projects can earn salable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets. A CDM project must provide emission reductions that are additional to what would otherwise have occurred. The projects must qualify through a rigorous and public registration and issuance process. Approval is given by the Designated National Authorities. Public funding for CDM project activities must not result in the diversion of official development assistance. The mechanism is overseen by the CDM Executive Board, answerable ultimately to the countries that have ratified the Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction or limitation targets.
Iceland is not a developing country, therefore this scheme is not applicable in this case.

2) Joint Implementation (JI)

JI, defined in Article 6 of the Protocol, allows a country with an emission reduction or limitation commitment under the Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO_2, which can be counted towards meeting its Kyoto target. Joint implementation offers Parties a flexible and cost-efficient means of fulfilling a part of their Kyoto commitments, while the host Party benefits from foreign investment and technology transfer.

A JI project must provide a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to what would otherwise have occurred. Projects must have approval of the host Party and participants have to be authorized to participate by a Party involved in the project.

If a host Party meets all of the eligibility requirements to transfer and/or acquire ERUs, it may verify emission reductions or enhancements of removals from a JI project as being additional to any that would otherwise occur. Upon such verification, the host Party may issue the appropriate quantity of ERUs. This procedure is commonly referred to as the “Track 1” procedure. If a host Party does not meet all, but only a limited set of eligibility requirements**, verification of emission reductions or enhancements of removals as being additional has to be done through the verification procedure under the Joint Implementation Supervisory Committee (JISC). Under this so-called “Track 2” procedure, an independent entity accredited by the JISC has to determine whether the relevant requirements have been met before the host Party can issue and transfer ERUs.

JI scheme may be applicable to the DME project. According to the website*** of United Nations Framework Convention on Climate Change (“UNFCCC”), Iceland fulfills all the eligibility requirements. If Iceland prefers JI for the DME Project, “Track 1” would be preferable because “Track 2” needs more time to set up the project as a JI project. MHI may consider preparing the project design document for Iceland’s approval of the project as a JI project following its national JI rule. The national JI rule should be regulated by the Ministry of Industry.

3) Green Investment Scheme (GIS)

Parties with commitments under the Kyoto Protocol (Annex B Parties) have accepted targets for limiting or reducing emissions. These targets are expressed as levels of allowed emissions, or “assigned amounts,” over the 2008-2012 commitment period. The allowed emissions are divided into “assigned amount units” (AAUs). Emissions trading, as set out in Article 17 of the Protocol, allows countries that have emission units to spare - emissions permitted them but not "used" - to sell this excess capacity to countries that are over their targets.

GIS is one kind of emission trading. Under GIS, a Party to the Protocol expecting that the development of its economy will not exhaust its Kyoto quota, can sell the excess of its Kyoto quota units (AAUs) to another Party. The proceeds from the AAU sales should be “greened”, i.e. channeled to the development and implementation of the projects either acquiring the greenhouse gases emission reductions (hard greening) or building up the necessary framework for this process (soft greening).

To set up GIS, the governments of Iceland and Japan need to negotiate. If Iceland prefers GIS, MHI will initially explain about this project to the Japanese government, and then the Japanese government will work on developing GIS with Iceland.

In sum, for the DME project, both JI and GIS schemes may be considered for potential application. However, at the present situation, both schemes are uncertain as to continuation after 2012 “post Kyoto”. The continuation of JI and GIS is yet to be determined after 2012.

12. Summary of Feasibility study and Way Forward

A Feasibility Study was conducted for a DME production complex comprised of the following:

- A CO_2 capture plant (Feedstock: Flue gas from a ferrosilicon plant)
- A hydrogen generation plant (Electrolysis basis. Feedstock: Water and electricity)
- A methanol synthesis plant (Feedstock: CO_2 and hydrogen)
- A DME plant (Feedstock: methanol)

Summary and Way Forward of this Feasibility Study is as follows:

1) Since all process technologies applied for this project consist of proven technologies like MHI's CO_2 recovery process and MHI/MGC's Methanol/DME synthesis process which are employed for many existing plants, there are no concerns technically or environmentally to go forward with the planed project for the construction of the synthesis DME plant.

2) The DME production cost after deduction of carbon credit is nearly equivalent to tax added diesel retail price for land transport in Iceland, assuming that plant infrastructure cost, e.g. land, electricity grid etc, and corporate tax are negligible. This indicates that the cost of producing a carbon neutral fuel, i.e. a synthesis DME produced with alternative carbon neutral energy, is nearly equivalent to tax added retail price of the conventional fossil fuel for land transport. The price for marine diesel oil is, however, much lower as there are less taxes on such oil. The production cost can be seen as a fairly attractive value taking into consideration the contribution to Icelandic society at the point of not only producing alternative renewable energy but also reducing the emission of existing CO_2 in Iceland.

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3) **This project is considered to be feasible** subject to a strong and dedicated support to the project rendered by the Icelandic government, although further detail study is required for application systems described as item 6) below.

Note: There are cases in other countries where government support is provided for renewable energy. e.g. a feed in tariff for solar energy in Germany and a bioethanol subsidy in the United States.

4) Hydrogen generation cost is very large and has a substantial impact on the project economics since it requires many electrolysers for a plant of this size and electricity consumption is very large. Further development of the electrolysers for hydrogen generation will improve the overall economics of the DME synthesis.

5) As for the CO_2 treatment measure in Iceland, synthesis DME project is more superior than CCS in a commercial point of view, because synthesis DME project has an merit of not only reducing CO_2 emission, but also making revenue of alternative fuel, even CAPEX and OPEX of DME project are bigger than those of CCS project. In addition, the project can reduce foreign currency expenditure to import diesel oil. Therefore, synthesis DME projects in Iceland will consolidate the vision of zero emission society according to an availability of a clean and low price electricity.

6) A further detailed study is required to realize synthesis DME project in Iceland. Such a study would include:

- A demonstration and cost investigation of DME application systems such as DME transportation network, DME fuelling stations and the modification of engines and tanks of automobiles and ships
- Partners, such as a DME marketing company, which can enhance the viability of the project
- A finance plan (investments and debt financing)
- Support of Icelandic Government
    a. Reduction of applicable taxes on the project, i.e. taxes on DME sales, corporate tax on the Project Company etc, or provision of subsidies for DME project.
    b. Competitive operation feedstock, not only for electricity, but also CO_2, water & steam etc.
- Investigation of further development of the hydrogen generation plant to reduce

OPEX/CAPEX.

- Investigation into possible improvements of electrolyser technology