Manufacturing plant for 2nd generation bio-diesel in the Port of Egersund, Norway.

A pre-study for identification of Technology, Potential and Costs.

Prepared by
N-DIESEL AS

PREFACE.

The present pre-study summarising the conclusions of almost one year's research and investigation for determining the outlined variables connected to the idea of establishing a large-scale production facility for 2nd generation bio-fuel in the Port of Egersund, Norway. The main incentives for initiating the project to improve the utilisation of industrial attractive areas based on future oriented, environmental advanced and sustainable activities. Acknowledging the decline of the traditional fishery activities, particularly within the fish rendering sector, the need of new and innovative alternatives have been desired for a certain period of time. And, in view of the wide international discussion of CO_2 accumulation with "The Greenhouse Effect", the timing for initiating this project also seemed very appropriate.

From the initial state of enthusiasm and optimism, the results from the investigations throughout the pre-study period has convinced us all this line worth to further following. What pace to choose and which steps to be made must be left to the following project organisation to decide.

This pre-study must not be considered as an intellectual product, nor a report from extensive investigation related technology and business aspects. It is simply a collection of adequate information, which hopefully can serve as an appropriate tool for commissioning the upcoming project phase.

Finally, the working group wants to express sincere thanks to:

- Innovation Norway for positive attitude and financial support for the pre-study.
- Eigersund kommune for positive respond and support.
- Per Nygård, PFI, for his enthusiastic and professional support.
- Matthias Rudloff, Choren, for his hospitality and valuable assistance.

Egersund, June 2007.

N-DIESEL AS

ABSTRACT.

The perspective of global heating also referred to as The Greenhouse Effect, caused by CO_2 accumulation in the atmosphere, has gained tremendous focus in recent time. Probably one of the most serious challenges mankind must face in the years to come. The consequences of global heating, melting of the alpine and polar ice and dramatic change in regional climates predicted to change the world's population pattern in ways very hard, perhaps impossible to imagine at this stage. And as this global heating assumed to be man made, principally by discharge of CO_2 to the atmosphere by combustion of fossil fuels, the need of alternatives energy sources indisputable. Furthermore, combined with the traditional situation of political instability in several crude oil producing countries, the need of alternative fuel sources even more obvious.

In order to reduce the CO_2-emissions from the transport sector, international standards for blending bio-fuel into fossil fuels have been introduced. EU-directive 2003/30/EC recommending a level of 3,5% within 2007 increasing to 5,75% in 2010, measured en energy percentages. Another example the Swedish vision concluding all fuels used after 2030 from biological origin.

The term Bio-fuel in general referred to as a fuel produced from renewable raw materials. Implying the same quantity of CO_2 released through combustion absorbed by the plant by reproduction. Thus, when included in the natural circuit, it does not contribute to the global heating the same way as fossil fuels with more discharge than nature can handle.

The distinction between 1st and 2nd generation bio-fuel basically from the raw material origin, simplified as follows:

- The 1st generation bio-fuels generally accepted to be ethanol produced from sugar or starch crops and bio-diesel made from vegetable oils and animal fats.
- The 2nd generation normally described as ethanol produced from lingo-cellulose feedstock through advanced bio-chemical or bio-thermal processes. Also including FT-distillates produced from biomass synthesis gases.

Due to the natural limitation of available raw materials for the 1st generation bio-fuels, today most of the focus is directed towards 2nd generation technology and the vast raw material potential represented by forestry and biological waste. In Norway the policy now to increase the utilisation of forestry raw materials from present 15 to 45 TWh. For verification, as the area productive forest per capita in Norway approx. 16 decares, in Sweden with 25 decares per capita, the annual bio-energy production from forestry 110 TWh. Based on the domestic resources, the Norwegian potential of bio-fuel supply for transportation estimated to between 20 and 30%.

Unlike 1st generation bio-fuel, the 2nd generation does not conflict with food supply. Or the main "competing" application, wood for house building, one implication could be an increase in market price. The main challenge, however, more related the logistic aspects and how to provide the raw material at a competitive price.

The present pre-study examining the possibility of introducing a large-scale, modern manufacturing plant for bio-fuels, located to the Port of Egersund on the southwest coast of Norway. Main incentive behind the project idea to utilize the logistic and manufacturing advantages represented by available and very attractive area dedicated for industrial activities.

Furthermore, this pre-study mainly dedicated the topic of adequate technology and product aspect; the details around raw material supply and logistics to be followed up in later project phase.

Although the pre-study implying examination of various alternatives products and processes, all scenarios have been oriented to the 2nd generation categories, mainly due to the limitation in the raw material aspect of the 1st generation. So far, the main bio-fuel commodities originated from sugar beet (ethanol) and vegetable or animal oils (FAME/ RME). However, in view of the strategic plan of The European Union, should all required bio-fuel for the domestic European market originate from 1st generation technology, this production of vegetable oilseeds will occupy some 30% of the total agricultural area. Unacceptable both with respect to food supply and price development.

Depending on the feedstock, the main alternatives of the 2nd generation thus limited to ethanol and BTL bio-diesel. For the Holevika/ Kaupanes scenario, the recommended solution BTL manufactured through gasification and Fischer-Tropsch as basic processing modules. Although not yet completely developed commercial-wise, this technology in our opinion the most feasible and flexible by means of various feedstock and end product profiles. The company directing this technological branch, CHOREN of Germany, at the moment commissioning their demonstration plant in Freiberg, the so-called Beta-generation plant, with a capacity of 2 tons of bio-diesel per hour.

The available site in Holevika/ Kaupanes has a very attractive location transport-wise. Situated in a good and sheltered harbour with short and easy access to The North Sea, most elements in place for a swift and efficient handling of incoming feedstock and outgoing products. Depending on actual capacity scale, the available area, although at first may seem narrow, can be configured and optimised in a non-traditional and innovative combination with the logistic variables.

Regarding manufacturing capacity and investment for the future plant, somewhat difficult to state a definite level at present stage. There are many variables to be further evaluated before determining the actual parameters. Also, much depending on whether first to install a pilot plant before the final step up full manufacturing capacity. As an example; the CHOREN Sigma-plant generation, ranging manufacturing capacities 100-200.000 tons of bio-diesel per year, implying investment levels of 150-250 million Euros. Naturally, the final figures will very much depend on size and complexity.

The space requirement perhaps even more critical; as the present available area of 100 decares may seem narrow, the logistic solution very critical how to compromise the need of with available area. As the raw material storage and handling by far the consuming factor area-wise, some limitations assumed to be accomplished by the favourable port facilities and capacity of handling several vessels per day.

Regarding the feasibility of the total project, very much depending on the prices of raw materials and utilities, as also the market price of the final product. As for raw materials, wood from forestry and other biomass materials, the main supplies assumed from domestic suppliers. In order to maintain stable raw material market prices, however, very important also with import alternatives. CHOREN has already having established their own raw material trading division, both for own consumption and for prior sales. At present, market price for chopped wood approx. 70 Euros per dry ton CIF.

As stated introduction-wise, today the topic of bio-fuel has become extremely hot. The introduction and development of the 2nd generation bio-fuel technology and production expected to generate an employment of more than 10.000 people in Norway only. For the Egersund and Dalane region in total, somewhat difficult to predict. However, as the plant alone expected to host 100-150 employees, not unrealistic to triple this number for the total region when including all services and disciplines included in such activity.

Hence, as recently stated from the local city council; this initiative could well serve as a Signal Project for the future industrial development of the region.

TABLE OF CONTENTS.

Port of Egersund

2. INTRODUCTION.

The increase in discharge to atmosphere of CO_2 from fossil fuel and the corresponding Greenhouse Effect has in recent years made mankind more and more aware of the dangers of climatic changes. From the common concern of KFK-gases and reduction of the atmosphere ozone-layer a couple of decades ago, today the general focus worldwide how to minimize the load of greenhouse gases. In addition, the political unstable situation in some principal oil producing regions has reinforced the search of a global altered energy picture.

In today's technological perception, the ultimate solution for a non-polluting automotive technology fuel cells based on use of hydrogen and discharge of H_2O to the atmosphere only. In a longer perspective, the combustion approach may be fully eliminated by advanced electric-magnetism technology. At present, the fuel cell H_2 alternative assumed to reach a commercial level at earliest around 2050. In the mean time, alternative fuels derived from sustainable raw materials enabling a recovery of the atmosphere CO_2-balance immediately required.

Fuel derived from biomass is certainly not a new term. As a matter of fact, both the Otto- and Diesel-engines originally designed for operating on bio-fuels. When the first Diesel engine was introduced at the Paris world exhibition year 1900, it was operating on peanut oil. Why the change to fossil fuels is another and far more complex story and not considered any further comment in this report. During the 1980ies, the idea of utilizing bio-fuel was re-introduced in USA for using excess vegetable oil as fuel for large agricultural machines. Hence, although of limited knowledge, the bio-fuel indeed has an interesting history.

The growing environmental comprehension combined with the acknowledgement of climatic changes caused by the previous described Greenhouse Effect concluded in the EU-directive 2003/30/EC: "Bio-fuels in the European Union, a vision for 2003 and beyond". From a first level of 3,5% bio-fuel blend into fossil fuel (2007), this document staking the development increasing to a 5,75% level in 2010. Combined with the "IEA-Task 39: Liquid Bio-fuels from Biomass", the international community today having a defined technology platform how to implement the targeted levels.

At present, the targeted 3,5% is far from being accomplished, partly due to technology issues, partly due to raw material potentials and logistic aspects. All bio-fuels so far being introduced to the market of the so-called 1st generation; i.e. originating from vegetable or animal oils. Popular defined, this bio-fuel produced from the fruit of the plant only and hence with limited utilisation of raw material potential. One serious matter with this 1st generation technology also the competition aspect with respect to balance with food applications for same raw materials.

The extension of the bio-fuel term into the 2nd generation technology opening up a radically different window of opportunities with respect to raw material and production volumes. Processing lingo-cellulose raw materials into syngases, mixture of Hydrogen and Carbon Monoxide, and subsequent hydrocarbon formation by Fischer-Tropsch technology enabling utilisation of the total biomass. Provided containing cellulose and/ or lignin, most biomass raw materials applicable for this manufacturing technology. And with attention to the Norwegian context, a tremendous potential for utilising the large forest resources. The main challenge, however, when stepping from 1st to 2nd technology class the vast increases in logistic and technology complexities. This will be partly evaluated in following sections.

The Port of Egersund has a long tradition in fisheries and processing. Until the mid 1970ies hosting five fishmeal and one soybean extraction plants, plus a number of frozen fish and packaging facilities. Since then, the activity in the fishing sector has been in decline and partly replaced by mechanical manufacturing. But still, some very attractive on-water areas available for new industrial activities.

The idea of "N-DIESEL" originating from two incentives:

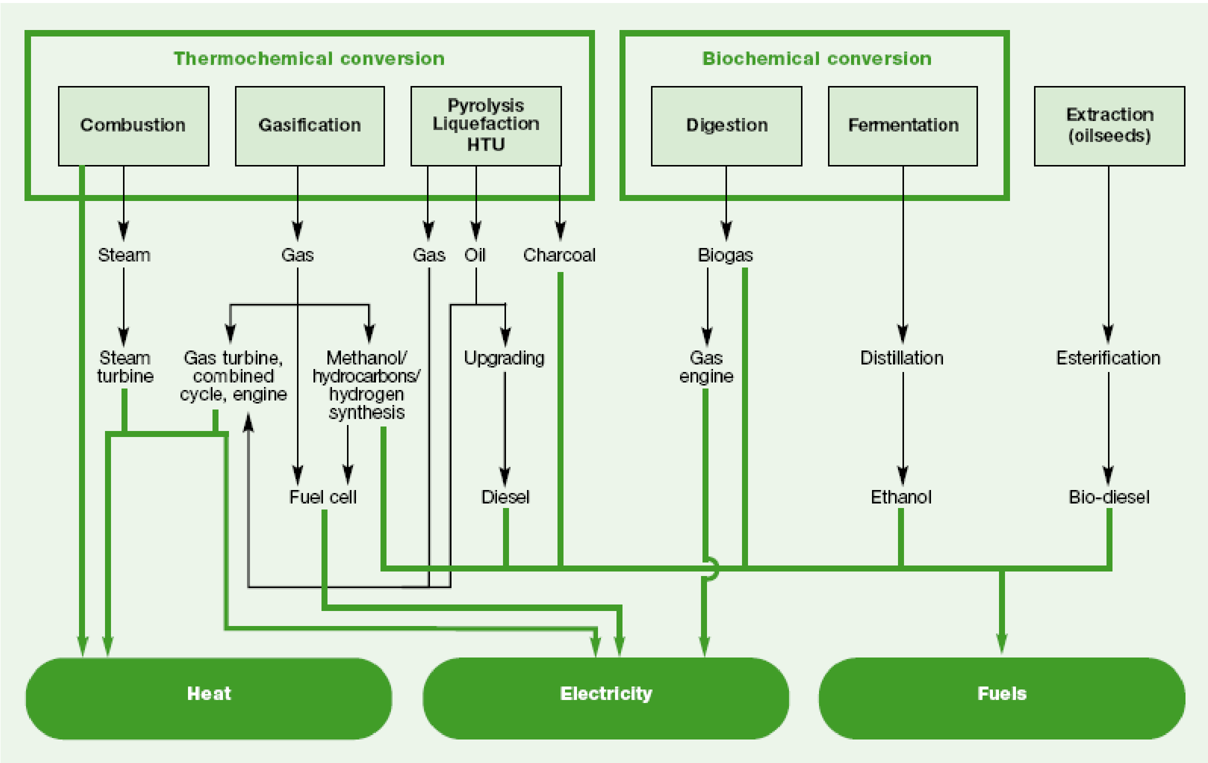
- Desire of utilising available industrial area for future-oriented activities.
- Desire of developing a highly required, environmental oriented industrial facility, generating labour and boosting the general local business activities.

The present pre-study conducted by the group of local initiators, four persons with individual different backgrounds, has spent a year of investigating and evaluating the different aspects by introducing a 2^{nd} generation bio-fuel manufacturing plant at the location Holeviga. The main incentive of the pre-study to identifying any critical parameters in favour for or against such establishment. Besides common technology research, particular activities participation in work-shops, excursions, etc. We have also succeeded generating good relations to domestic and foreign research and industrial organisations for general and 2^{nd} generation bio-fuel.

The pre-study has been fortunate receiving financial support from Innovation Norway.

3. THE PRESENT BIO-FUEL SITUATION.

The world derives about 11 % of its energy from biomass, this means about 44 exajoules (mostly traditional biomass, as for cooking etc.), but the biomass potential is considerable, counting 2900 exajoules as theoretically harvestable bio-energy. But more interesting is the 270 exajoules that could be considered technically available on a sustainable basis. In the context of rising demand of environmental concerns and with biomass well distributed all around the world, the option of extended use of biomass should be considered seriously. The main biomass energy conversion routes are shown in the below figure.



Main biomass energy conversion routes

The current project focuses on bio-fuels, seen as the third product in the figure. But in many biomass conversions there are considerable potentials of energy savings and better economy through production of more than one product at one site, e.g. production of fuels and heat from a bio-diesel plant.

Improving energy security, decreasing vehicle contributions to air pollution, industrial and commercial development of a new industry, and reducing or even eliminating greenhouse gas emissions are primary goals urging governments to identify and commercialise alternatives to the petroleum fuels currently dominating transportation.

In recent years, several candidate fuels have emerged, either as ideas, or more developed commercial available fuels like compressed natural gas (CNG), liquefied petroleum gas (LPG) and electricity for electric vehicles. These fuels feature a number of benefits over petroleum, but they are also affected by a number of drawbacks, like costly modifications to vehicles and the development of separate fuel distribution and vehicle refuelling infrastructure. Bio-fuels have the potential to leapfrog traditional barriers to entry because they are liquid fuels compatible with current vehicles and blend able with current fuels.

The transportation sector represents about 86 EJ/year (2000), or 21 % of the world primary energy consumption, and this share continuing to grow. Transportation fuels are today mainly dominated by fossil oil. It is useful with an overview of main reasons for introduction of bio-fuels:

- Reduced CO_2 emissions. Bio-fuels are principally CO_2 neutral, depending on the conversion route from biomass to fuel, and which additives that are being used.
- Decreasing vehicle contributions to local air pollution. Most bio-fuels have a cleaner burning than common fossil petrol and diesel. But expected development of engines and stricter emissions regime will probably decrease this difference.
- Higher reliability of energy supply. With more sources of fuel, the prices become more stable and shortage is less probable.
- Industrial and commercial development of a new industry, with increased employment and possibilities of development of intellectual capital. With introduction of bio-fuels follows employment in the whole chain from harvesting, processing and distribution.
- A developed R&D programme on bio-fuels points out different solution to the way out of fossil oil dependence.

The idea of bio-fuel is as old as the idea of the vehicle with an engine. When Henry T. Ford first designed his Model T automobile in 1908, he expected ethanol, made from renewable resources to be the fuel. About the same time in Germany, Rudolf Diesel thought that his compression ignition engine would be run on vegetable oils.

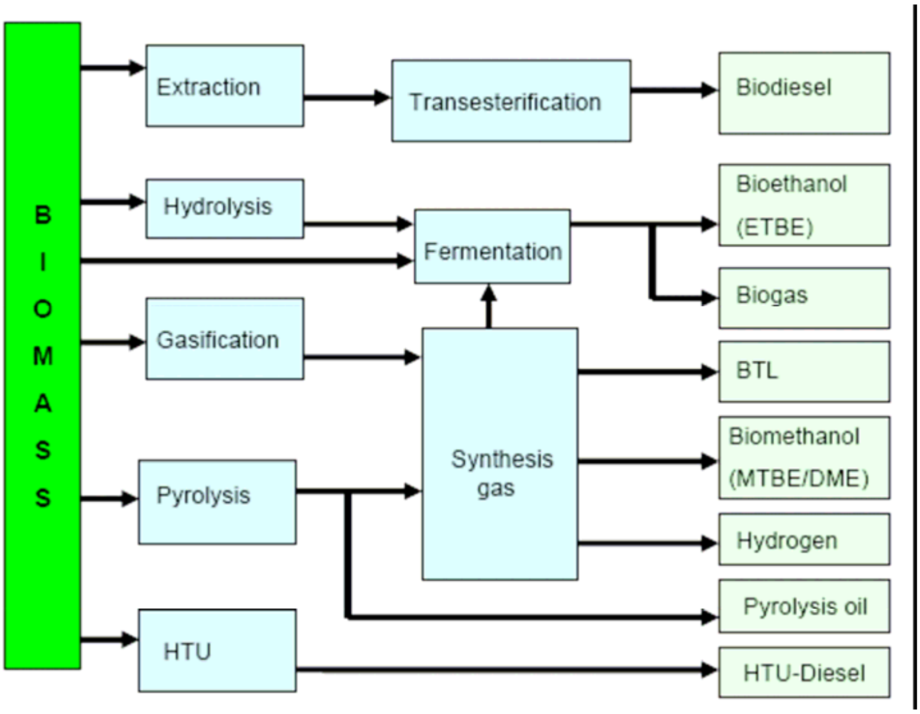
Feedstock and products
The resource base or feedstock of bio-fuels are diverse, but can be presented in four main groups:

- Cereals, grains, sugar crops and other starches can easily be fermented to produce ethanol, which might be used pure or as a blending with normal petrol.
- Cellulose materials like grasses, trees and different types of waste products and residuals from crops, wood processing, and municipal solid waste, can also be converted into alcohol or synthesis gas, but these processes are much more complex.
- Oil-seed crops (e.g. rapeseed, soybean and sunflower) can be converted into methyl-esters, which can substitute normal fossil diesel, and can be used pure or as a blending.
- Organic waste material, like fish waste (typically for Norway), marine and animal oil can be converted into bio-diesel. Mature and organic household waste might be converted into biogas. The availability is often limited, but the resource cost can be negative in some areas with a strict waste regime.

The products at the end of the conversion routes are diverse, but can be divided into five main groups:

- Biodiesel (mainly RME and FAME)
- Alcohols (ethanol/methanol)
- Biogas
- Synthetic fuel (BTL - biomass to liquid)
- Hydrogen

Some of the main routes from biomass to bio-fuel are shown in figure below:



Biofuel conversion routes

Some comments, abbreviations and explanations to figure 4:

- Bio-diesel is the diesel made from rapeseeds, soybeans and other sources of oils. Most common is RME (Rape Methyl Ether), and FAME (Fatty Acid Methyl Ether). The production capacity of bio-diesel is shown in figure 3.
- Bio-ethanol is the bio-fuel mainly produced in Brazil and USA from sugar cane and corn respectively. The production amounts are rising in Europe.
- Biogas is today locally used in small-scale applications, but require new infrastructure and engine modifications. More adaptable in energy systems with natural gas.
- Synthesis gas is a gas mainly consisting of CO and H2.
- The BTL (Biomass To Liquid) can use cellulose as feedstock, the resource potential is considerable, and also at attractive costs.
- Bio-methanol is possible to blend with gasoline, but ethanol is preferred. The use of methanol as blending with gasoline is also possible in blends up to 15 % methanol. This was done in Sweden in the early eighties. This study focuses at ethanol blends, though the differences between the two alcohols are small. Methanol drawbacks are: lower energy content, more toxic and it is more corrosive, but it might be produced at lower cost than ethanol. In production of biodiesel (FAME) there is a need for methanol, and this methanol should be produced from biomass to keep the use of fossil methanol low.
- DME (DiMethyl Ether) is widely used as propellant and often produced from natural gas. It is possible to use as engine fuel with modified engine technology, but this use has received minor attention, and will therefore not be considered in this study.
- MTBE (Methyl Tertiary Butyl Ether) is an octane enhancer and formerly used in every gallons of petrol in USA (substituted lead as octane enhancer in 1979). It is produced from methanol and isobutylene. A growing number of studies have detected MTBE in

ground water throughout the USA. The human health risks are discussed, and an increasing number of states propose the use of ethanol as octane enhancer. MTBE is therefore not considered in this study.

- Pyrolysis oil diesel can be a substitute to diesel, and cellulose can be the resource base. There has not been made much research in the field of pyrolysis oil diesel, much because of the upgrading demand, which is affected with high cost.
- HTU-diesel (Hydro Thermal Upgrading) is based upon soaked and rotted biomass. For HTU-diesel there are no studies on energy and greenhouse gas balances. The cost of upgrading to transportation fuel is considerable.

Today there is large scale production of ethanol only, and this production is mainly located in Brazil and North America. The fuels are produced from sugar cane and corn respectively. All petrol in Brazil has today a blending of 22 % - 26 % of ethanol, and 2 % of petrol consumption is ethanol in USA. The amount of produced ethanol has risen considerably since the start of the Brazilian PRO-ALCOOL programme in 1975. Over the last years has Europe had a rapid growth in ethanol production, but the amounts are still small compared to Brazil and North America. This is shown in figure 3:

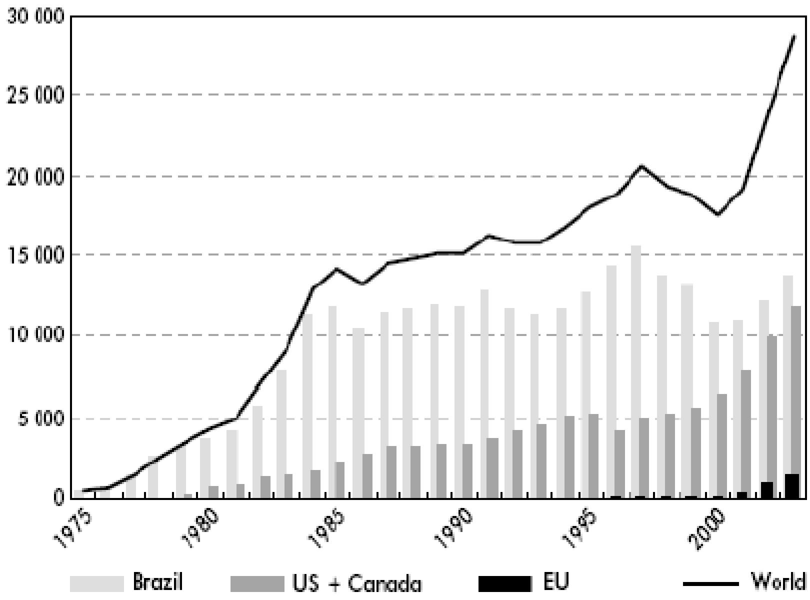
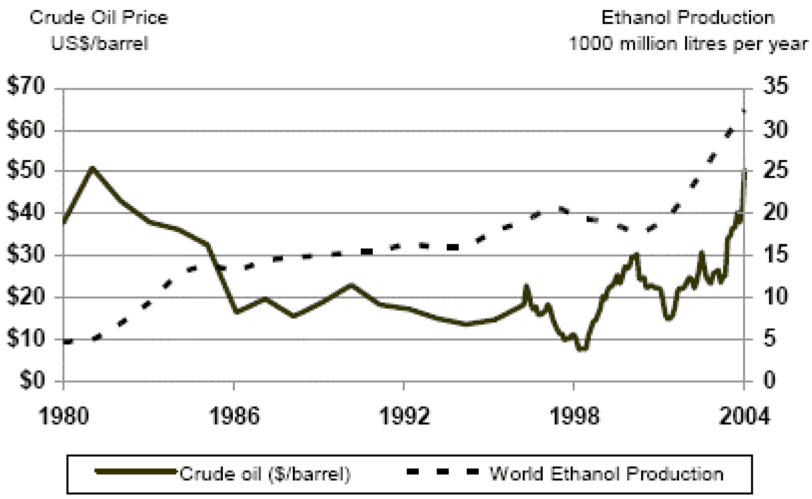


Figure 3: World and regional fuel ethanol production, 1975-2003 (million litres per year)

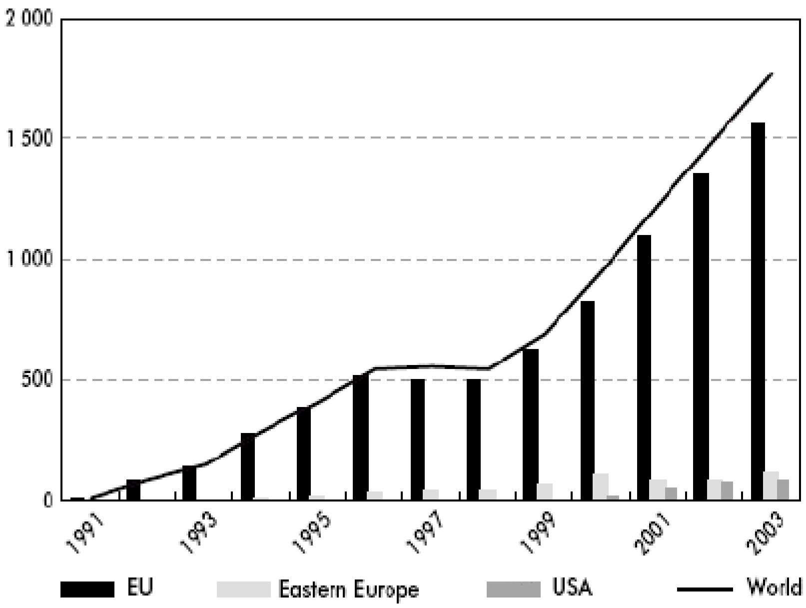
The production volume of ethanol is linked to the oil price. A dramatic increase in world ethanol production has been seen since 2000, corresponding with rapid increases in the price of oil and uncertainty over the supply of fossil resources.



Crude oil prices vs. ethanol production, 1980-2004

Rising demand for bio-based ethanol has increased the probability that other feedstocks, including lingo-cellulose biomass, could become viable options for the bio-fuel industry.

There is also a bio-diesel production of some amount, but this is limited compared to ethanol production (about 4 % of ethanol production in 2003). But the increasing production trend, especially in Europe, is clearly visible in figure 5, where the bio-diesel capacity is shown:



World and regional biodiesel capacity, 1991 – 2003 (million litres per year)

There is also other bio-fuels available, as ETBE (Ethyl Tertiary Butyl Ether) blended in petrol in France, or vegetable oil, used in very small extent in Germany and USA, and also small local use of biogas. An example is Fredrikstad in Norway, where four busses are fuelled with biogas from the local sewage treatment plant.

4. BIOMASS FOR 2nd GENERATION BIO-FUEL.

The source of energy and serving point is cellulosic material. For Scandinavian conditions the forests consist of mainly spruce, pine and birch, and these wood types have the chemical composition shown below [24] (weight %, ash included in extractives):

	Cellulose	Hemicellulose	Lignin	Extractives
Scandinavian Spruce	42	27	29	2
Scandinavian Pine	42	25	28	5
Scandinavian Birch	39	38	20	3

Cellulose is the main part of the cell wall, with the elementary formula $(C_6H_{10}O_5)_n$. It is a highly linear polysaccharide and similar to hemicellulose, but the latter has a more branched structure and is more susceptible to chemical degradation than cellulose. Lignins acts like the bounds in the cells, and gives rigidity to the cell wall. They are complex three dimension polymers of phenylpropane. Biomass contains the elements; carbon (45-55 weight %), hydrogen (5-7 weight %), oxygen (40-50 weight%) and small amounts of sulphur (0-0.05 weight %) and nitrogen (0-1.0 weight%). The carbon and the hydrogen are the combustible components of the wood. A proximate analysis is often used to determine the amounts of volatile material, ash and fixed carbon in the biomass. The ash content is important for the heating value, as heating value decreases with increasing ash content.

An important distinction in the field of wood processing is made between softwood and hardwood. The different density of the woods has influence on which technology to apply in the processing, as the density may differ considerable between different types of forest. For the same type of forest the altitude, age and location also influence the density variation with as much as +/- 50 kg/m^3. Some typical Norwegian densities are given below:

	Density* [kg/m^3]:
Scandinavian Spruce	380
Scandinavian Pine	440
Scandinavian Birch	500

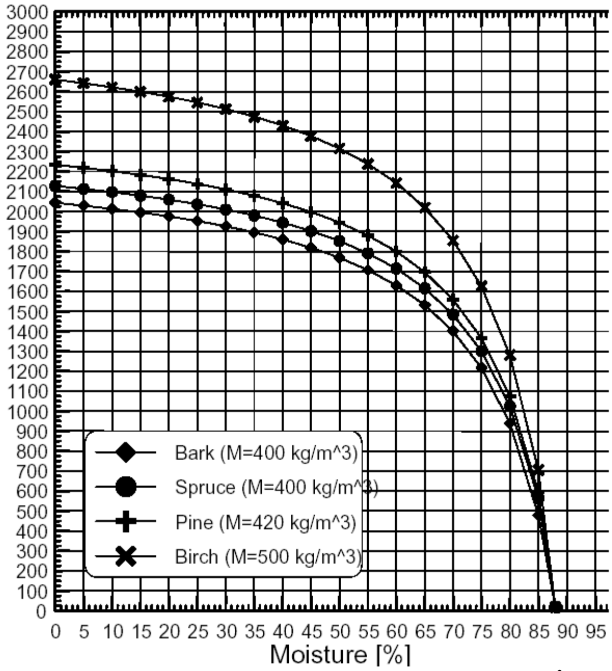
*kg dry wood per solid cubic

Density of Norwegian wood types

Spruce is typical softwood, and the birch a typical hardwood. The pine is also considered as softwood.

Another important parameter is the moisture content in the wood. As trees are dependent on water to grow, there is always a high content of water in recently chopped wood. As water evaporate considerable amounts of energy is required (2444 kJ/kg water at 25 °C), and less energy is available. The moisture content is therefore a major element in deciding the effective heating value (EHV). The effective heating value is defined as the lower heating value (LHV) subtracting the energy of evaporating the moisture content of the wood. The LHV assumes that the produced water is 100 % evaporated. The water might leave the process as liquid water and not as vapour. The resulting energy content is defined as higher heating value (HHV). The LHV has been used traditionally, and serve as the definition of energy content also in this study.

Many biomass pre-treatments start with drying, increasing the energy density. The importance of moisture content is shown in below figure:



The relation between moisture content and EHV [kWh/ m³]

At moisture content of 87 % the energy content of the wood is the same as the required energy to evaporate the moisture. The critical limit is 50 -55 % moisture, further increased moisture content above this level lowers the energy content dramatically, as seen in the above figure. But the moisture content should not always decrease to below a certain limit, as very dry biomass produces a syngas with less H_2. Cost increases also quickly with very dry biomass.

EHV can be calculated as an approximation with the following formula [kWh/kg]:

$$\mathrm{EHV} = 5.32 - 6.01 \cdot m_r \ \ [\mathrm{kWh/kg}]$$

Where m_r is the moisture content, calculated as the relation between mass of water and total mass of wood and water. This is only a linearization of the graph in figure 7. As a moisture content of 88.5 % leads to zero EHV, and biomass with 0 % moisture leads to an energy content of 2128 kWh/m^3 for spruce (density = 400 kg/m^3).

The higher heating value might be calculated from the molecular composition:

$$\mathrm{HHV} = 0.3491 \cdot X_C + 1.1783 \cdot X_H + 0.1005 \cdot X_S - 0.0151 \cdot X_N - 0.1034 \cdot X_O - 0.0211 \cdot X_{ash} \ [\mathrm{MJ/kg}]$$

It is evident how hydrogen and carbon atoms are contributing to the heating value, and how the oxygen content is contributing negatively. It is therefore an important step in some biomass conversion routes to de-oxidize the biomass in order to increase the heating value.

NORWEGIAN BIOMASS POTENTIAL FOR LIGNOCELLULOSE MATERIALS.

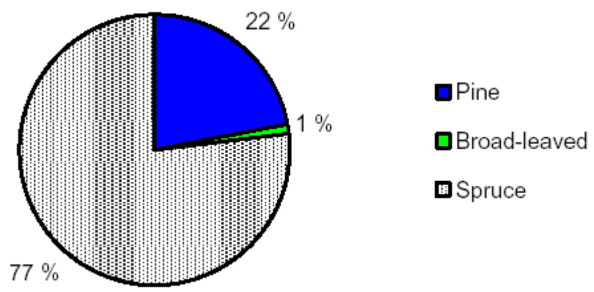
Norway is covered with 38 % forest, and 24 % is productive forest. Yearly is 7.4 mill. m^3 chopped and sold for industrial use, and 0.7 m^3 is chopped and used as firewood. The yearly growth is 25.4 mill. m^3 (increase in forest volume without bark), which is more than 3 times the yearly chopped volume. The price of wood has decreased over the last decades with almost 50 % (calculated with real value NOK). The unused forest counts 17.3 mill. m^3 per year, representing about 120 000 TJ with 50 % moisture. A conversion efficiency of 40 % gives 2730 million kg diesel or 3500 million litre of diesel. The total sale of diesel was 139 million litres. NVE has estimated a potential of totally 160 000 TJ of biomass in Norway. The theoretical potential of substituting fossil fuel is therefore considerable. NVE states a potential of 22 TWh as increased lignocellulosic based biomass use in Norway. The potential is for energy use and with technical and ecological limits applied. A conversion efficiency of 40 % gives 880 million litre of diesel, a third of yearly consumption of diesel.

The Norwegian forest has the composition shown in the table below. The price of pulpwood is per m^3 of solid wood without bark (2003):

Standing productive forest:	[1000 m^3]:	Pulpwood price [NOK/m^3]
Spruce (softwood)	661 532	221
Pine	210 651	160
Broad-leaved	144 790	221

Norwegian forest composition and price

But the spruce is the dominating sale product as figure below shows:



Commercial roundwood removals (2003) by species of tree, excluding wood fuel for direct burning in stove

One of the main questions left is what quantities can be delivered at low cost to a bio-fuels plant. A commercial plant requires large amounts of biomass, more than 1 TWh annually, to exploit the advantages of economy of scale. The available biomass potential and cost is therefore a prerequisite for a economic evaluation of a bio-fuel plant location.

5. CONVERSION ROUTES AND TECHNOLOGIES.

As seen from the previous table "Main Biomass Energy Conversion Routes", there are two main "technological highways" for manufacturing of bio-fuels:

- Thermochemical conversion
- Biochemical conversion

Both main groups with the purpose of converting the feedstock into adequate fuels through gasification and hydrocarbon synthesis. Today, both technology groups approaching the final commercial stages by large-scale production. The Thermochemical way headed by European (CHOREN) and the Biochemical by American research groups (Iogen). Both technological and commercial assessed, the European alternative found to be the most interesting for the N-DIESEL project. Hence, the pre-study mainly focused upon this solution.

Gasification is the process of gaseous fuel production by partial oxidation of a solid fuel. This means in common terms to burn with oxygen deficit. The gasification of coal is well known, and has a history back to year 1800. The oil-shortage of World War II imposed an introduction of almost a million gasifiers to fuel cars, trucks and busses. One major advantage with gasification is the wide range of biomass resources available, ranging from agricultural crops, and dedicated energy crops to residues and organic wastes. The feedstock might have a highly various quality, but still the produced gas is quite standardized and produces a homogeneous product. This makes it possible to choose the feedstock that is the most available and economic at all times.

Gasification occurs in a number of sequential steps:
• Drying to evaporate moisture
• Pyrolysis to give gas, vaporised tars or oils and a solid char residue
• Gasification or partial oxidation of the solid char, pyrolysis tars and pyrolysis gases

Not all the liquids from the pyrolysis are converted to syngas, due to physical limitations of the reactor and chemical limitations of the reactions. These residues form contaminant tars in the product gas, and has to be removed prior to a e.g. a Fischer-Tropsch reactor. Other impurities in the producer gas are the organic BTX (benzene, toluene and xylene (benzene components with one or two methyl groups attached)), and inorganic impurities as NH_3, HCN, H_2S, COS and HCl.

There are also volatile metals, dust and soot. The tars have to be cracked or removed first, to enable the use of conventional dry gas cleaning or advanced wet gas cleaning of the remaining impurities. There is mainly three ways of tar removing/cracking: thermal cracking, catalytic cracking or scrubbing.

Despite the long experience with gasification of biomass, there have been some problems with large scale reliable operation. Up to recently, no manufacturer of gasifiers have been willing to give full guarantee for technical performance of their gasification technology. Though they are sold commercially, they are not delivered with the same kind of operational guarantee as e.g. a gas turbine. This shows the limited operational experience and lack of confidence in the technology, but in comparison with alternative routes to utilize cellulose biomass gasification is well proven and one of the possible technologies to be introduced commercially as a major part of the energy route to bio-fuel. The CHOREN technology, however, now have reached a level where full guarantees are given both by means of performance and efficiency. The experience from the

Beta-plant scheduled in full operation within end of this year, one example of the progress of technological development.
The re-composition of syngases into hydrocarbons to be executed by a so-called Fischer-Tropsch reactor. Implying the synthesis gas produced from the gasification process can be delivered to a Fischer-Tropsch (FT) reactor, where long hydrocarbon chains are produced and it is possible to obtain large amounts of e.g. diesel. The FT synthesis is in principle a carbon chain building process, where CH_2 groups are attached to the carbon chain. Which reactions exactly taking place and how, is a matter of controversy, as it has been the last centuries since 1930's. The reaction can be presented as follows:

$$nCO + \left(n + \frac{m}{2}\right) H_2 \rightarrow C_nH_m + nH_2O$$

$$CO + 2H_2 \rightarrow -CH_2- \quad + \quad H_2O$$

This reaction is highly exothermic, and to avoid an increase in temperature, which results in light hydrocarbons, it is important to have sufficient cooling, to secure stable reaction conditions. The reaction is dependent of a catalyst, mostly an iron or cobalt catalyst where the reaction takes place. There is either a low or high temperature process (LTFT, HTFT), with temperatures ranging between 200-240 °C for LTFT and 300-350 °C for HTFT [20]. The HTFT uses an iron catalyst, and the LTFT either an iron or a cobalt catalyst. The FT process is well proven and an effective route from syngas to bio-fuel.

Two main characteristics of Fischer-Tropsch synthesis (FTS) are the unavoidable production of a wide range of hydrocarbon products (olefins, paraffins, and oxygenated products) and the release of a large amount of heat from the highly exothermic synthesis reactions. The synthesis of hydrocarbons from CO hydrogenation over transition metal catalysts was discovered in 1902, when Sabatier and Sanderens produced CH_4 from H_2 and CO mixtures passed over Ni, Fe, and Co catalysts. In 1923, Fischer and Tropsch reported the use of alkalized Fe catalysts to produce liquid hydrocarbons rich in oxygenated compounds; named the Synthol process.

The development of pressurized FT synthesis goes 80 years back, and starts about 1925 in Germany. Here the experiments took place in Franz Fischer's laboratory at the Kaiser Wilhelm Institute for Coal Research, and developed to an industry with 600 000 tons per year in 1945. At those times strategic reasons for liquid fuel production from coal exceeded economic aspects. In the last decades the interest in FT synthesis has changed as a result of environmental demands, technological developments and change in fossil energy reserves. A good example is the "oil-age" from 1955 – 1970 with plenty of cheap oil supply and as a result only a marginal interest in FT synthesis.

High oil prices increase the focus at alternative fuels, likewise as carbon dioxide concentration concern arises, being related to global warming, the focus at new technologies rises. Today the driving forces are environmental concern, but also higher oil price, limited oil reserves and increased focus at stranded gas.

The FT synthesis is in principle a carbon chain building process, where CH_2 groups are attached to the carbon chain. Which reactions exactly taking place and how, is a matter of controversy, as it has been the last century since 1930's. The resulting overall reaction can be presented as follows:

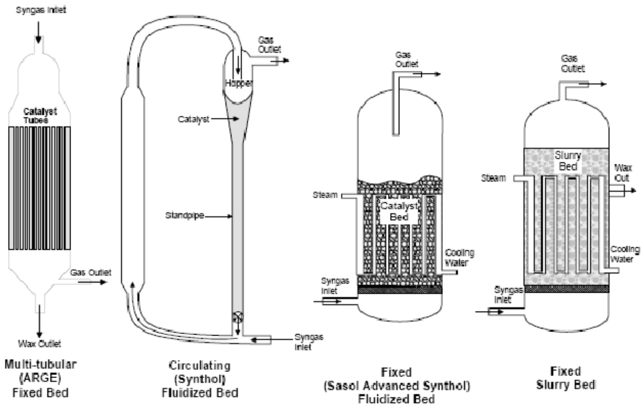
$$nCO + \left(n + \frac{m}{2} \right) H_2 \rightarrow C_n H_m + n H_2O$$

$$CO + 2H_2 \rightarrow -CH_2- \; + \; H_2O \qquad \Delta H^o_{FT} = -165\,kJ/mol$$

There are also other reactions taking place in the reactor, but the detailed behaviour of those reactions are not known and hence a theme of controversy. The reactions are highly exothermic, and to avoid an increase in temperature, which results in lighter hydrocarbons, it is important to have sufficient cooling, to secure stable reaction conditions. The total heat of reaction amounts to ca. 25 % of the heat of combustion of the synthesis gas, and lays thereby a theoretical limit on the maximal efficiency of the FT process.

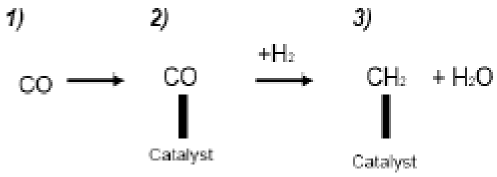
The reaction is dependent of a catalyst, mostly an iron or cobalt catalyst where the reaction takes place. There is either a low or high temperature process (LTFT, HTFT), with temperatures ranging between 200-240 °C for LTFT and 300-350 °C for HTFT. The HTFT uses an iron catalyst, and the LTFT either an iron or a cobalt catalyst. The different catalysts include also nickel and Ru based catalysts, which also have enough activity for commercial use of FT. But the availability of Ru is limited, thus forcing a high price. The nickel based catalyst has high activity but produces too much methane, and additionally the performance at high pressure is poor, due to production of volatile carbonyls. This leaves only cobalt and iron as practical catalysts, and this study will only consider these two. Iron is cheap, but cobalt has the advantage of higher activity and longer life, though it is on a metal basis 1000 times more expensive than iron catalyst.

For large-scale commercial FT reactors heat removal and temperature control are the most important design features to obtain optimum product selectivity and long catalyst lifetimes. Over the years, basically four FT reactor designs have been used commercially. These are the "multitubular fixed bed", the "slurry" or the "fluidized bed" (with either fixed or circulating bed) reactor. The fixed bed reactor consists of thousands of small tubes with the catalyst as surface-active agent in the tubes. Water surrounds the tubes and regulates the temperature by settling the pressure of evaporation. The slurry reactor is widely used and consists of fluid and solid elements, where the catalyst has no particularly position, but flows around as small pieces of catalyst together with the reaction components. The slurry and fixed bed reactor are used in LTFT. The fluidized bed reactors are diverse, but characterized by the fluid behaviour of the catalyst. The literature of FT contains details of the reactors, and Dry (2001) is one source of more detailed information. The fluidized bed reactor is used in HTFT.



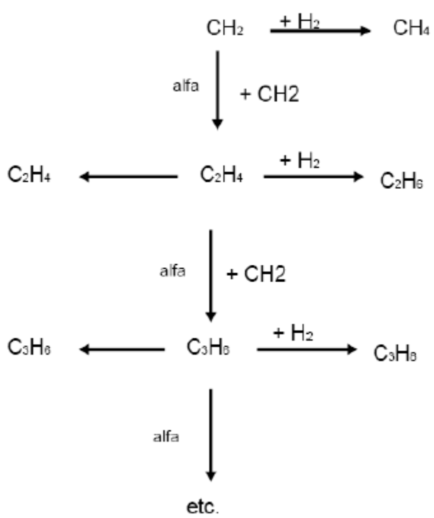
PRODUCTS.

The figure below shows how the chain building process starts, where CO reacts with H_2 to CH_2, with H_2O as a by-product.



Chain initiation

For a theoretical optimal and stoichiometric chain growth, there is a need for 2 hydrogen molecules for each CO molecule. This relation is the H_2/CO ratio and differs in the range between 1.7 : 1 and 3 : 1. The influence of the ratio is explained later in this chapter. The FT process produces different olefins and paraffins of different length. The process is basically a chain-building process, where the chain either gains length by adsorbing another CO group, or terminates and leaves the catalyst as either paraffin or olefin. This is graphically shown in below figure.



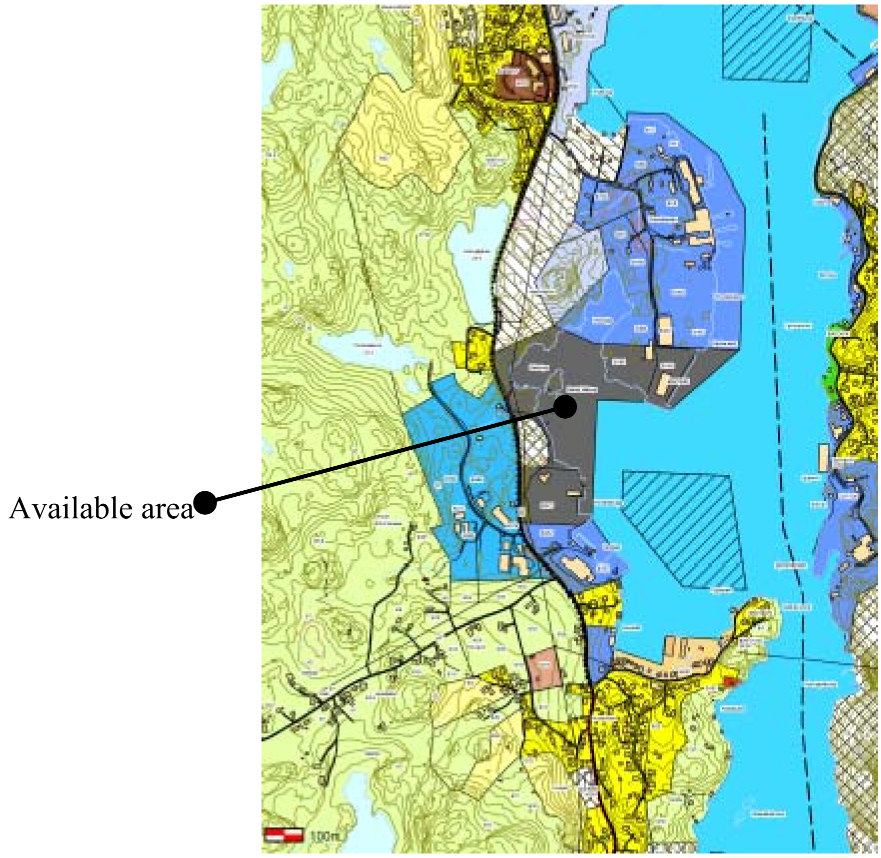
Chain growth and termination

The figure shows that there are two possibilities; either terminate to a paraffin (right side) or a olefin (arrow to the left), or to grow further with the absorption of CO and H_2 as CH_2.

Readers interested in further theoretical information are advised to look up in the reference list.

6. LOCATION AND PRESENTATION OF PROJECT “N-DIESEL”.

For a certain period of time, the general activities in The Port of Egersund tending in a decline direction. Partly caused by a distinct reduction in landings of fish for the reduction industry, partly due to general fluctuations in the import and export businesses. Furthermore, since some very attractive port sites have been prepared for coming industrial and sea-oriented activities, the wish of adequate initiatives has been required for a long time.



Thus, the idea of establishing a modern, 2nd generation bio-fuel manufacturing plant at this site seemed logic, with a long-term perspective with respect to technological and labour development. And as the site already having undergone a limited preparation for industrial activities, the objective with this pre-study mainly to identify as many critical parameters as possible in order to conclude whether or not to continue the line of establishment.

The site available for the intended bio-diesel plant a partly prepared area of approx. 100 decares, with possibility of further enhancement. Located directly at the port, very suitable for efficient and flexible handling of both feedstock and products. No secret the location itself a very important incentive and foundation of the whole project and the final feasibility. In general terms, although the 100 decares area considered in the narrow end of the scale regarding required space of such industrial activity, the excellent port location and possibilities of non-traditional storage and handling enabling justifying less area compared to standard norm.

Supply of electrical power and freshwater also assumed realistic without too much complications.

Environmental-wise, the plant to be equipped with standard purification and recovery systems satisfying the required effluent quality norms. And with further references to industrial norms in general; and noise in particular.

When the plant has been brought on stream, the activities related the operation expected to generate a significant number of employment. Furthermore, being highly advanced and sophisticated process, very likely to expect a positive development of the technological environment in the region.

The company N-DIESEL AS registered 2006. Working group counting four participants:
Jarl Dyrnes
Arnfinn Ervik
Rasmus Gundersen
Tor Andreas Svanes

The pre-study is sponsored by Innovation Norway and has been granted first right of refusal for the site from the city counsel of Egersund for a period of one year.

Besides regular meetings since the establishment last year, the working group has participated in workshops conducted by The Norwegian Bio-fuel Committee. Within a short period of time, valuable contacts considered vital for the coming project phase have been established. Our network today counting a number of key persons within the national and international bio-fuel community. The visit to the Choren R&D-centre in Freiberg, Germany, in particular has convinced us about the potential and reality of this project.

7. PREFERRED TECHNOLOGICAL CONCEPT. THE CHOREN TECHNOLOGY.

Choren has developed a process for production of diesel through a synthesis gas production process with subsequent Fischer-Tropsch reactor. After conducting extensive tests between 1998 and 2001 in a 1 MW_{th} pilot plant, Choren reported that the process produces a tar-free gas without the use of any catalysts. Other Choren milestone accomplishments include 12,000 hours of operation and successful integration of the gasifier with gas engines. By using oxygen as the oxidant the process should be able to produce synthesis gas suitable for conversion to liquid fuels. The references are from the Choren website, as also from visiting Choren in May 2007 (ref. M. Rudloff).

Choren uses an entrained-flow gasifier, which has the advantages of elimination of hydrocarbons and methane to a convincing degree and in addition providing the simplest and most elegant scale-up option for units with an output of up to 1,000 MW.

Compared with previous, low efficiency gasifiers, the high-efficiency gasification solution of the Choren technology arising from the pre-treatment stage. This pre-treatment is more expensive than conventional pre-treatment for power production, but as the FT products has a higher value and require a produces gas almost without impurities, this solution considered as optimal.

Entrained-flow gasifiers are only suitable for the use of gaseous, liquid or dusty materials. If solid biomass is to be used, combined processes are required, where the solid biomass is turned into a gaseous, dusty or liquid substance in the initial stage.

In the Choren Carbo-V® process, process heat is first used to dry the biomass to ensure that it only contains 15 – 20 % water. The biomass is then broken down into biocoke (a type of charcoal) and a low-temperature carbonization gas containing tar during the NTV (a low temperature gasification) stage. This involves partial combustion (carbonization) using gasification agent at temperature between 400 °C and 500 °C. This process produces two intermediate products:

The low temperature gas, containing tars and the dusty biocoke (charcoal). These are separated and inserted into the gasifier at two different locations. The low-temperature carbonization gas is then fed into the combustion chamber and is partially oxidized using oxygen as the gasification agent.

The heat, which is released as a result of the oxidation process, warms up the carbonization gas to temperatures that exceed the ash melting point of the fuels that have been used, i.e. 1300 °C-1500 °C. At these temperatures any non-desired longer-chain hydrocarbons, e.g. tar and even methane, are broken down. The gas that is produced primarily consists of carbon monoxide, hydrogen, carbon dioxide and steam.

The biocoke is discharged from the NTV process, cooled, ground down to pulverized fuel and is then blown into the stream of hot gas coming from the combustion chamber. A huge amount of heat is absorbed when gasifying the biocoke and this allows lowering the temperature of the gas to 800 °C – 900 °C in a matter of seconds.

This “chemical quenching” process produces a tar-free gas with a low methane content and with high proportions of combustible carbon monoxide and hydrogen. This hot raw gas is then cooled, and dust particles and any unwanted substances (e.g. chlorides, sulfides, etc.) are removed using a multi-stage gas scrubbing process. The gas is then transmitted to the synthesis unit, where the FT process takes place at 200 °C and 20 bar, with help of a cobalt catalyst. The solids in the raw gas, i.e. residual coke and fuel ash, which have been separated during the dry dust removal stage, are fed back into the hot combustion chamber pneumatically. The ash elements melt and flow down the inside wall of the combustion chamber into a water bath at the foot of the reactor. The vitrified, solid ash can then be used as a slag granulate, e.g. for road building purposes.

Choren confirms in principle, all feedstock that contains carbon and has average moisture content below 40 % can be gasified. For a specific projects, the proposed mixture based on a feedstock analysis has to be evaluated.

At the β-plant, which is currently being built at Freiberg to manufacture SunDiesel, an overall degree of efficiency of 45 – 55 % is achieved with regard to the manufacture of the liquid product (diesel), depending on which operating method is used. If biomass is used as the exclusive source of energy and if the electrical energy requirements for the auxiliary units and the air separation from the residual gas and waste heat are covered by the process itself (basic self-sufficient scenario), the degree of efficiency is lower than if the yield of diesel fuel is maximized, in which case 6.6% of the total input energy must be obtained as electrical energy from outside sources (partially self-sufficient scenario).

The first industrial BTL production plant in the world, the now closed Choren α-plant, has the following parameters:

- Biomass flow rate: 10.5 t/h, equal to about 50 MW feed
- Biomass supplies: 5 days, “just in time” deliveries dried wood chips, air-dried wood chips waste wood, straw-like biomass (0 – 30 % share)
- Preparation using in-house drying facilities
- Oxygen gasification with system pressure at 4 bar with Carbo-V® FT synthesis at 30 bar
- Production of 1.8 t/h (13,000 t/a) of synthetic automotive fuel (diesel fuel)

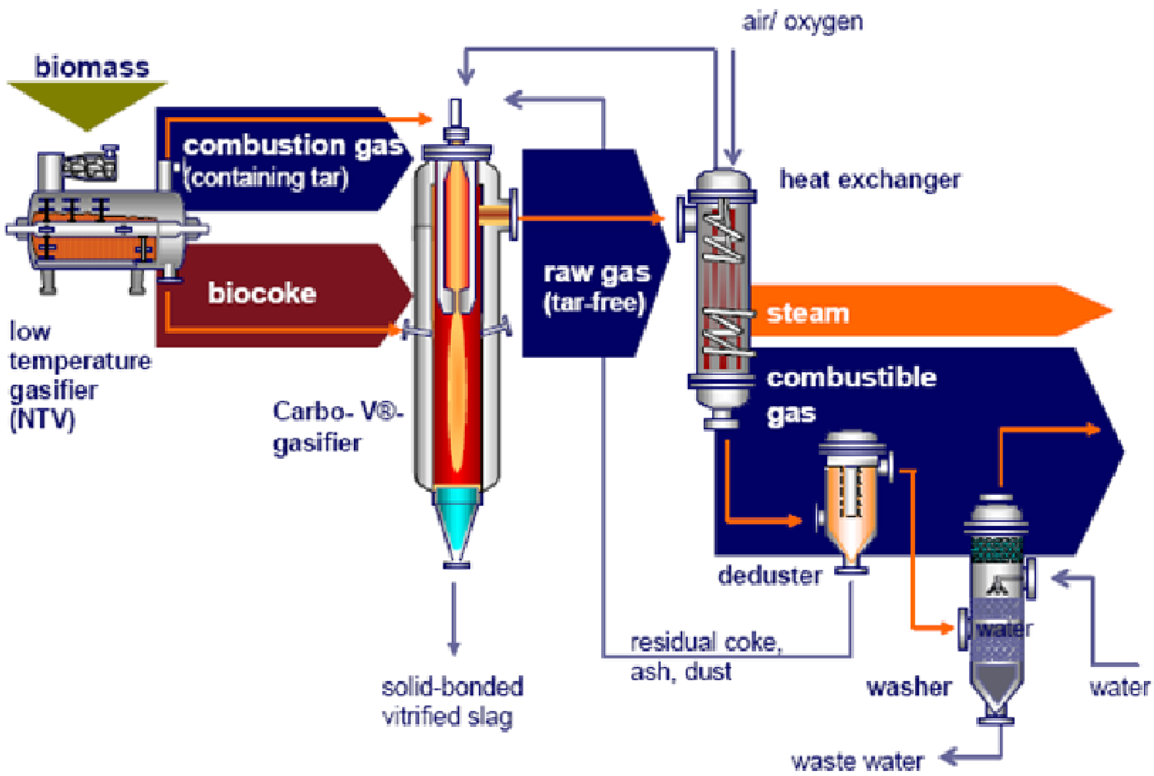
CHOREN β-plant in Freiberg

Choren is seeking to construct several production units, each with a production capacity of 200,000 t of diesel every year. The first plant is expected to produce diesel in Lubmin near Greifswald from 2009 onwards. The requirements for a suitable location are:

- Adequate local supply of biomass
- Good transport infrastructure (railway, roads, shipping)
- Integrated network with existing chemical plant/refineries
- Area to disposal > 10 ha a

A commercial plant has to have a minimum size of 300 MW feed, referring to a fuel output of 100 000 ton/a.

Choren is one of few who have managed to produce FT diesel based on biomass outside the laboratory. They offer commercial plants, but keep a low profile with regard to detailed technology description and results. The FT research done world wide communicated through journals and reports go on without the results from Choren. If (when) a commercial plant is build by Choren, they have to stand the severe market test. Because of limited access to experiment results etc. it is hard to evaluate the technology, but the claimed conversion efficiency is among the highest reported in the whole literature.



Choren Carbo-V process

Manufacturing process of SunDiesel®.
The CHOREN CARBO-V® PROCESS.

1. Biomass hopper and feeder system. Dried and schredded biomass is fed into the low temperature gasifier.
2. Low temperature gasifier. The biomass is heated to 400-500 ^{o}C and broken down into tar-rich volatiles and solid char.
3. Carbo-V Gasifier. The volatiles pass into the high temperature combustion chamber of the Carbo-V gasifier where they are partially oxidized with oxygen and steam. Above 1400 ^{o}C the ash particles melt and the long chain hydrocarbons are broken down to CO and H_2.
4. Chemical quenching. The milled and pulverized char is blown into the hot gases beneath the combustion chamber. The endothermic gasification of the char causes an almost instantaneous drop in temperature to 800 ^{o}C producing a raw gas with a high heating value.
5. Recuperator. The tar-free gas, now at around 800 ^{o}C, is cooled by the heat exchanger yielding steam for industrial processes or power generation.
6. Dust removal. Ash particles and char, that have not been entirely converted, are separated from the gas in the de-duster. These are then recycled back into the Carbo-V combustion chamber where the melted ash build a protective fluid slag coating and completes the gasification process. The gas is then fed via a gas reactor to th scrubber for further treatment.
7. Scrubber. Contaminants such as chlorine and sulphur are washed out by fluid sprayed into the gas stream.
8. Fischer-Tropsch synthesis. The Fischer-Tropsch synthesis employs a cobalt catalyst to recombine carbon and hydrogen into long chain paraffin liquids and waxes. Fischer-Tropsch is a synthesizing reaction involving following steps:
   - Adsorption of the carbon monoxide and hydrogen into catalyst surface.
   - The chain growth begins once the carbon monoxide has been broken down, enabling the coupling of carbon and hydrogen and the separation of oxygen.
   - Chain growth continues by adding further carbon monoxide and hydrogen.
   - Chain growth termination and de-sorption of the molecule from the catalyst surface.
9. Upgrading. The finished SunDiesel® is then derived from the raw synthesis product in a multi stage process. The hot product spectrum of the reactor is cooled resulting in separation to constituents hydrocarbon and water. The final Fischer-Tropsch product can now be distilled and hydro-treated to yield high cetane SunDiesel®.

8. MARKET AND LOGISTICS ASPECTS.

As in most cases for establishing new business activities, the market and economical aspects the unalterable critical parameters. No point in succeeding technology- and operation-wise, if not the final products to be offered having the attractive market properties and price.

In the present global market of energy and fossil fuels, apart from the Greenhouse discussion, the competitive position of 2nd bio-fuels isolate regarded perhaps as attractive as preferred. Mainly due to the high investment cost related the establishing of a high capacity, modern plants. Also, the cost of bringing the raw materials, particularly forestry, to the processing destination of radical different magnitude compared to the 1st generation bio-fuel as also fossil plants.

But in view of the current environment situation, or The Greenhouse Effect, certain actions necessary in order to obtain the targets set in national and international standards. The taxation policy hence the only obvious tool in order to balance market mechanism with environmental policy. To handle this the appropriate way and secure the political targets to be accomplished first and foremost a task for the political society. Some proposed tools are as follows:

- Enforced blending of bio-fuel into fossil fuel. Required % bio-fuel according to approved standards. Penalty for not meeting standards.
- Direct investment support.
- Non-taxation policy for bio-fuels.
- Certificate practice. Bio-fuels to be credited according to accomplished reductions in CO_2 emissions.

In the "Soria Moria" announcement from 2005, the Norwegian government has clearly stated:

"The government will execute an introduction program for use of bio-fuels according to EU-directive 2003/30/EF." This statement should be understood as an explicit support for any project with the objective of bio-fuel production, particularly 2nd generation.

Thus, the political course is clearly set and targets likewise defined. For comparison, the Swedish incentive furthermore targeting a 2030 energy scenario, totally independent from import of fossil fuel. Recent recommended values from the Norwegian Agency of Environment more or less in accordance with the EU-standard, with a 2% bio-fuel blend within this year, increasing to 4% in 2010. Defined target according to the EU-directive 7,5% within 2010.

The raw material side is both interesting ands challenging. As modern 2nd generation bio-fuel processes can operate with a whole complex of variable raw materials, most feedstocks with biological origin potential raw materials. Assuming forestry as the top of the range, the domestic Norwegian situation at present that less that 15% of the annual growth today being utilised. The remaining part simply decomposing naturally. The estimated potential today some 45 TWh per year; roughly 3 times the present utilised biomass used for energy generation.

Considering the special geographical and topographical condition in Norway, the raw material logistics in many places representing some real challenges. Also the owner structure could become an obstruction by means of maintaining adequate market price levels. For this reason, import of forestry from Central and Eastern Europe might become an alternative. For an import scenario, the location of the N-DIESEL plant considered almost ideal.

The market potential with respect to volume must be considered close to insatiable. At present the total annual Norwegian consumption of gasoline and diesel for the transport sector some 5 mill tons, distributed approx. 50-50%, but with growing use of diesel. Considering a period of 3-4 years for completing the current project and have a bio-diesel production on stream, year 2010 is exceeded as also the target level of 7,5% (EU). Furthermore considering the total European potential, the prospects are overwhelming.

The advantage of introducing diesel blends, i.e. fossil diesel added the required part bio-diesel, the readiness within the present distribution system of handling this fuel. Test has proven the use of bio-diesel blends up to 30% without problems for state-of-the-art diesel engines. The bio-diesel alternative thus the most practical and flexible solution for rapid and easy market introduction.

An unalterable condition for a successful market introduction no doubt how to determine the price of the various new bio-fuel alternatives. Raw material, transportation, manufacturing and distribution cost are all factors which within certain frames can be optimised both total and individually. The most important factor, however, how the different countries choosing to tax the new bio-fuel blends compared to conventional fossil fuels. For the case of 2nd generation bio-diesel manufacturing plants, the high investment costs no doubt requiring a non- to low-tax level on the product in order to become feasible. Also, governmental financial support considered a very important incentive for help pushing such large projects off the pit.

9. CONCLUSIONS.

As stated in the introduction, the main objective with this pre-study to evaluate as many aspects as possible related establishment of a large-scale 2nd generation bio-diesel plant; in principal to uncover any negative or less positive factors. Throughout the working period, the interest group has become increasingly convinced the project idea definitely worthwhile brought forward to the next level; project initialisation and capital raising.

Besides coinciding nicely with the local incentive of further industrial development, plus an optimum utilisation of a so far non-exploited industrial area, the timing in view of both national and international climatic discussions close to perfect. Already, the European Union and rest of the international society way behind targets set in various directives, as the previous referred 2003/30/EC. In view of the total raw material and technological situation, there should be no doubt the only solution for accomplishing the targets set a significantly increase of the volumes of 2nd generation bio-fuels.

Since the initiative origin in mid 2006 and start of the pre-study in January 2007, the N-DIESEL group has worked systematically in order to explore available technologies applicable for an annual manufacturing of minimum 100.000 tons of bio-fuel. Several models have been evaluated; from a step-wise implementation through pilot-plant stage with successive enhancement up to full-scale, versus a direct jump all up to the final version. Regarding 2nd generation systems, the 2 highways identified being:

- The Thermo-chemical alternative with bio-diesel as product
- The Bio-chemical alternative with ethanol as product.

The conclusion, particularly after visiting the Choren plant in Freiberg, Germany, the bio-diesel alternative regarded the most realistic. Although none of the alternatives yet ready for commercial production, the development of the Thermo-chemical technology has reached a stage considered as proven. This with particular reference to Choren and their gasification solution. The final conclusion hence to follow up this technological line in the project to follow this pre-study.

A very important subject has been the evaluation of the available site of approx. 100 decares area. Compared to the recommended area for a Choren Sigma-plant, this at first seemed somewhat narrow. However, as the location is next to the sea, i.e. the port of Egersund, much of the handling and storage challenges can be simplified by the flexibility of partial on-board storage. A minimum land-based storage through required for keeping wheels running as such plants normally requiring a run-up and run-down period of 3-4 days respectively. For preliminary quantification, the target capacity of 10 tons of diesel per hour based on a feedstock of 5 times the product rate with present technology and efficiency. Which furthermore implying an average feedstock of 50 tons per hour; or 1.200 tons per day.

After an entire positive conclusion of this pre-study, the proceeding now to enter the first project-phase by employing a project-manager responsible for conducting all the disciplines included in this phase. Besides building up the required project structure, perhaps the most important task to further develop and expand the company N-DIESEL. The work of developing the asset structure must be initiated as soon as possible.

Based on the assumed required schedule for completing the project, both from a practical but also from the present technological stage, we picture a time frame of 3-4 years. Compared with other known and similar projects, we feel confident to be a front-runner and at the same time in no guinea-pig situation. Within the Norwegian and later also European bio-fuel society, our project has become well known in a short period of time. One major upside with our concept we consider our direct and less complicated approach for establishing a rather large and advanced industrial activity. The year of investigation has convinced us there is no need of re-invent the wheel for accomplishing what by now seems being a well proven concept. We will follow the coming commissioning of the Choren Beta-plant closely and feel confident having the sufficient flexibility, time-as also concept-wise, to re-adjust as the process evolving.

10A. BIO-FUELS IN THE EUROPEAN UNION.

The EU transport sector accounts for more than 30% of the total energy consumption in the Community. It is 98% dependent on fossil fuels with a high share of imports and thus extremely vulnerable to any market disturbance. The growing transport sector is considered to be one of the main reasons for the EU failing to meet the Kyoto targets. It is expected that 90% of the increase of CO_2 emissions between 1990 and 2010 will be attributable to transport. The current production of liquid bio-fuels in the EU 25 is about 2 million tons, which is less than 1% of the market. Although there have been marked increases in production and use in recent years, the market share is to be significantly below the EU policy target for 2010 of 18 million tons used in the transport sector.

The EU has a significant potential for the production of bio-fuels. It is estimated that between 4 and 13% of the total agricultural land in the EU would be needed to produce the amount of bio-fuels to reach the level of liquid fossil fuel replacement required for the transport sector in the Directive 2003/30/EC. Furthermore, bio-fuels can contribute to the EU's objectives of securing the EU fuel supply while improving the greenhouse gas balance and fostering the development of a competitive European (bio-fuels and other) industry.

There is a need for a well-co-ordinated strategy for the production of bio-fuels. As an important step, the recent Commission communication on Bio-fuels describes seven policy axes which will regroup the measures the Commission will take to promote the production and use of bio-fuels. The proposed European Technology Platform for Bio-fuels should provide and help implement a strategy for bio-fuels, particularly in the transport sector. By so doing, and by making best use of EU knowledge and scientific excellence, the Technology Platform will contribute to the establishment and growth of a world-class, cost competitive European industry. The purpose of the present document is to address all relevant issues and provide a vision and outline strategy, with emphasis on RTD&D, to increase, markedly, bio-fuels production and use in the EU.

An ambitious and realistic vision for 2030 is that up to one-fourth of the EU's transport fuel needs could be met by clean and CO_2-efficient bio-fuels. A substantial part is to be provided by a competitive European industry, using a wide range of biomass resources, based on sustainable and innovative technologies. Bio-fuel development will create opportunities for biomass providers, bio-fuel producers and the automotive industry. Also, the European technology will be used in 2030 in many countries exporting bio-fuels to Europe.

Diversification of primary energy does not necessarily mean a different kind of fuel. It will be beneficial if the new fuels are similar to, or at least compatible with, today's fuel types and specifications. Ability to mix fuels from alternative sources with current, conventional fuels without jeopardising the standard fuel specification is a very effective means for the implementation of these fuels.

As there is no serious replacement available on the engine technology side, the majority of power-trains available in 2030 will require liquid fuels, although their carbon and hydrogen ratios and molecular composition might have evolved from today's fuels. Bio-fuels will mostly be used in gasoline and diesel internal combustion engines. However it is possible that specialised engines will be used in certain applications or in dedicated fleet.

Thus, the challenge is to increase substantially the production of bio-fuels by using innovative processes and technologies, which are commercially viable. To achieve this, it will be necessary, while supporting the implementation of currently available bio-fuels, to promote the transition towards second generation bio-fuels, which will be produced from a wider range of feedstock and which will help to reduce costs of “saved” CO2. It will also be necessary to transform into bio-fuels biomass fractions that are presently discarded and to make the best use of the whole plant.

The expected growth of the bio-fuels market and the development of new transformation pathways, such as gasification, make it timely to investigate new integrated refining schemes. The co-production of fuels and co-products in integrated bio-refineries will enhance the overall economy and competitiveness of bio-fuels. The bio-refineries will be characterised by an efficient integration of various steps, from handling and processing of biomass, fermentation in bioreactors, chemical processing, to final recovery and purification of the product.

For supply of the biomass feedstock, sustainable land strategies must be created that are compatible with the climatic, environmental and socio-economic conditions prevailing in each region. The production and use of both the primary and residual forms from agricultural, forestry and industrial operations should be promoted. Research on improving crop yields, energy input/ output as well as key quality characteristics using advanced technologies should be taken carefully into account

A full deployment of bio-fuels can be expected by 2030. To achieve this, a phased development is envisaged based on short-term improvement of existing technologies, RTD&D and commercial production of 2nd generation bio-fuels (from lingo-cellulose biomass) and RTD&D and implementation of full-scale integrated bio-refineries.

A good co-ordination between major European actors will be essential and would be facilitated by large joint research and innovation programmes and joint operation of large experimental facilities.

The Bio-fuels Technology Platform also will provide the scenarios and strategic guidance for decision makers to set up the proper policy framework.

10-B. IEA Task 39 – Executive Summary.

IEA Bioenergy is an international collaborative agreement set up in 1978 by the International Energy Agency (IEA) to improve international co-operation and information exchange between national bioenergy RD&D programmes. The IEA Bioenergy Vision is "To realise the use of environmentally sound and cost-competitive bioenergy on a sustainable basis, to provide a substantial contribution to meeting future energy demands."

The IEA Bioenergy aim is "To facilitate, co-ordinate and maintain bioenergy research, development and demonstration through international co-operation and information exchange, leading to the deployment and commercialisation of environmentally sound, sustainable, efficient and cost-competitive bioenergy technologies."

Twenty countries plus the European Commission, take part in IEA Bioenergy: Australia, Austria, Belgium, Brazil, Canada, Croatia, Denmark, Finland, France, Ireland, Italy, Japan, The Netherlands, New Zealand, Norway, South Africa, Sweden, Switzerland, the United Kingdom, the USA and the European Commission. Work in IEA Bioenergy is carried out through a series of Tasks, each having a defined work programme.

One of the Tasks is Task 39, Liquid Fuels from Biomass. The objectives of this Task are to:

- Provide information and analyses on policy, regulatory and infrastructure issues that will help participants encourage the establishment of the infrastructure for bio-fuels as a replacement for fossil-based bio-fuels.
- Catalyse cooperative research and development projects that will help participants develop improved, cost-effective processes for converting lingo-cellulose biomass to ethanol.
- Provide information and analyses on specialized topics relating to the production and implementation of bio-diesel technologies.
- Provide for information dissemination, outreach to stakeholders, and coordination with other related groups.

As part of Task 39's ongoing program of promoting the commercialisation of bio-fuels, the task has commissioned three reports that address specific market or policy barriers. These barriers have been identified by members of Task 39 and through analysis of independent reports.

First generation bio-fuels are generally accepted to include ethanol produced from sugar or starch feedstocks and bio-diesel (methyl or ethyl esters produced from vegetable oils and animal fats). These fuels are being produced and marketed in many regions of the world. Second generation bio-fuels can be produced from lower value feedstocks (ethanol from lingo-cellulose materials), through different production processes (thermo-chemical conversion instead of biochemical pathways), or produce a liquid fuel other than an alcohol or an ester (Fischer Tropsch diesel or similar hydrocarbon). These new fuels or production processes are anticipated to offer some advantage over the existing fuel production pathways.

The advantages may include improved environmental performance, lower production costs, greater production volumes, more attractive performance properties or other benefits.

While these fuels may offer some relative advantages in some areas, they may also have attributes that are less desirable. The objective of this work is to consider several of these second generation bio-fuels from the perspective of the "Market Barriers" that bio-fuels in general face and determine if these new fuels will reduce the barriers or could face new barriers as they are developed.

The specific objectives of this work are to:

First generation bio-fuels, which are generally accepted to be ethanol produced from sugar or starch crops and bio-diesel (methyl esters) made from vegetable oils and animal fats, have been introduced and used commercially as transportation fuels in a number of countries around the world. These first generation bio-fuels do provide some environmental benefits, have supported agriculture and rural economic development, and have diversified the transportation fuel supply system in many countries. These fuels have generally required some financial support from governments, adjustments to the fuel distribution system to allow their introduction, and in many regions there has been some resistance from the existing market participants to adopt these fuels.

There are other bio-fuel production processes that are being developed and promoted that may offer some advantages over the existing bio-fuels. These fuels have been called "2nd generation bio-fuels" and while there is no official definition, they are generally accepted to be any bio-fuels other than, ethanol produced from starch or sugar feedstocks, and bio-diesel produced by the trans-esterification of vegetable oils and animal fats. It is claimed that these 2nd generation bio-fuels may offer even greater benefits in terms of environmental performance, better overall energy efficiency, the ability to use lower cost and more widely available feedstocks, and be more easily integrated into the existing fuel supply and distribution system.

The 2nd generation bio-fuels can describe ethanol produced from lingo-cellulose feedstocks via either a biochemical production process or a thermo-chemical production process. The term has also been used to describe synthetic natural gas made from the gasification of biomass. There are other liquid fuels such as butanol that could be made from biomass via either biochemical or thermo-chemical pathways, or from sugar and starch, that have also recently been called 2nd generation bio-fuels. All of these pathways produce a fuel that is suitable for use in spark ignited engines.

For fuels for compression ignition engines there are a number of candidates that can be called 2nd generation bio-fuels. These include FT distillates that are produced from syngas produced from biomass. Bio-DME is promoted as a 2nd generation bio-fuel in some regions. All of the fuels mention so far are produced from lingo-cellulose material but a process that converts the vegetable oils and animal fats into hydrocarbons via hydro-treating is also being classified as a 2nd generation bio-fuel by many industry observers.

The primary 2nd generation bio-fuels are briefly described with the significant advantages and disadvantages relative to the existing bio-fuels highlighted. Many of the developers of new technology do not divulge a great deal of information about their technologies so in many cases information can only be obtained from relatively general publications and statements, although more information on some technologies is available from public R&D sources this is not necessarily indicative of the status of individual process developers.

The fuels have been grouped as fuels for spark ignited engines (gasoline) and fuels for compression ignited (diesel) engines.

The IEA reviewed 22 case studies of what they determined where successful energy market developments in IEA countries over the past twenty years. In studying the cases, the IEA considered three perspectives on deployment policymaking. These three perspectives have developed over the last quarter of a century:

The Research, Development and Deployment Perspective, which focuses on the innovation process, industry strategies and the learning that is associated with new technologies;

- The Market Barriers Perspective, which characterizes the adoption of a new technology as a market process, focuses on decisions made by investors and consumers, and applies the analytical tools of the economist;
- The Market Transformation Perspective, which considers the distribution chain from producer to user, focuses on the role of the actors in this chain in developing markets for new energy technologies, and applies the tools of the management sciences.
- The IEA concluded that the adoption of clean energy technologies would not be likely to succeed unless all three perspective were considered and that it is necessary to:
- Invest in niche markets and learning in order to improve technology cost and performance;
- Remove or reduce barriers to market development that are based on instances of market failure; and
- Use market transformation techniques that address stakeholders' concerns in adopting new technologies and help to overcome market inertia that can unduly prolong the use of less effective technologies.

The market barriers facing bio-fuels are quite similar for both ethanol and bio-diesel. The two most significant barriers have been the price of bio-fuels compared to petroleum fuels and the difficulty marketing the product through the established fuel distribution companies.
New enterprises almost always face finance and business risk barriers during the start-up phase of the industry. In many countries ethanol and bio-diesel projects have struggled with issues such as project financing, uncertainty with being able to design and construction facilities with new technology and dealing with the risk of commodity prices. In some countries these issues are mostly behind the industry as plants have been built and experience has been gained with dealing these issues. In other countries that are just beginning to develop their bio-fuels industries these are still issues that companies must face. Ethanol and bio-diesel have also faced less significant barriers in terms of price distortion and inefficient regulation. The industry has learned either how to deal with the issues or the removal of some of the other barriers, such as the competitive price issue, has also addressed or reduced the price distortion barrier.

UNCOMPETITIVE PRICE
The cost of producing bio-fuel is often higher than the cost of petroleum fuels, although the absolute value of the difference between the two is a function of commodity prices. In times of high crude oil prices and low agricultural prices, the gap can be small (or not exist at all) and when fossil energy prices are low, the gap can be large. In the regions of the world where biofuels have been used as a petroleum fuel blending component or fossil fuel substitute the gap has been eliminated through the use of tax incentives provided by

governments. These tax incentives can be viewed as learning investments. The incentive mechanism itself can take many forms such as producer payments, payments to the biofuel blenders, or reduced consumer taxation. Governments have also invested in research and development in order to help to drive down the costs of production.

INEFFICIENT MARKET ORGANIZATION

Inefficient market organization applies when one firm or a small group of firms act in a similar manner and using the advantages of being the incumbent suppliers to resist the market penetration efforts of the new technology. In the case of transportation fuels, there are many end users of the fuel but they all purchase the product from a limited number of companies. These are also the companies that produce the competing product, gasoline or diesel fuel. In order for biofuels to penetrate the market and be available for the ultimate end user, they must be integrated into the existing distribution system.

BUYER'S RISK

The Buyer's Risk could also be termed business risk and it is important to note that it is the perception of risk that may be more important that the actual risk. The gap between perception and actual risk is larger when an industry is new and one of the measures that reduced this gap and the buyer's risk for any venture is experience. Perhaps the best descriptions of risk for fuel ethanol plants can be found in the prospectus' and managements discussion of results of ethanol plants that are public companies. The issues are quite similar in the reports of the different companies. Typical categories for the issues are:

- Risks related to equity financing
- Risks related to debt financing
- Construction and development risks
- Operation risks
- Ethanol production risks
- Organizational structure risks

FINANCE

A barrier that is somewhat related to Buyer's Risk is that of finance. Most projects are financed by a combination of equity and debt. Raising the debt portion can be challenging for a number of reasons including imperfections in market access to capital. Debt providers generally have no opportunity to participate in any project upside so they focus on ensuring that there are no downsides to their participation. They focus on the issues of what could go wrong.

Lenders have many opportunities presented to them and they chose those opportunities that provide them with their best returns or most limited risk. Many lenders also specialize in certain sectors of the economy. These are sectors which they understand the risks and rewards. New sectors require lenders to become comfortable with the risks or at least the perception of the risks. The first projects are therefore the most difficult to finance since there is no track record which lenders can rely on. It is extremely important that the first projects be successful. Problems or failures with early projects increase the difficulty in demonstrating that new projects won't have the same problems.

Note that in cases where there is imperfect access to capital, finance barriers could be considered a market failure barrier and increased government involvement may be warranted. The involvement could include special funding, third party financing options, loan guarantees or other approaches.

PRICE DISTORTION

Price distortion arises when some of the costs or benefits that arise from using a product are not reflected in the selling price. The most common example of this is the environmental costs that arise from using products that pollute the environment. These costs are real and are paid for by society through reduced crop production, increased maintenance costs and higher health costs. They are not generally included in the product cost.
In the case of bio-fuels, the lifecycle analysis indicates that there are greenhouse gas reductions from using the fuel and there are also reductions in the emissions of some of the tailpipe contaminants from using the fuel. These should have some value and could be used to offset the higher cost of the fuel.

EXCESSIVE/INEFFICIENT REGULATION

Regulations and standards are often prescriptive and not directly performance driven. This can be effective and efficient in cases where there is significant experience with a product and the performance can be controlled in a prescriptive manner. The system does not function particularly well when new products are introduced that may not have the wealth of experience associated with their use and may not behave in exactly the same manner as the incumbent technology.

2nd GENERATION BIO-FUELS

The 2nd generation SI and CI bio-fuels have the potential to process lower cost and more abundant feedstocks. In the case of 1st generation bio-fuels, it has only been recently that concerns have been raised concerning the strain on resources that increased bio-fuels may cause. It must also be noted that feedstocks that are used for these 1st generation fuels have generally suffered from an imbalance in the supply and demand and that has been one of the drivers for bio-fuels, to try and bring the supply and demand back into a balance and hopefully raise farm income in the process. The availability of feedstocks has thus not been a barrier for the 1st generation bio-fuels to date.

For most of the 2nd generation bio-fuels the ability to use lower cost feedstocks does not currently result in lower cost bio-fuels. The feedstock cost savings are offset by higher chemical costs and much higher projected capital costs. Very large “learning investments” will be required to address the capital cost barriers that these fuels currently face. Considering the large investments involved plus the design, build, operate cycle (a minimum of three years) for these bio-fuels plants it will take 5 to 10 years of experience before there will be enough experience gained that will lead to a large enough reduction in capital costs for these plants to be finance able as commercial ventures.

The other benefits of the 2nd generation bio-fuels do not really lead to the significant reduction of the other market barriers that faced the 1st generation bio-fuels. While the development of the 2nd generation bio-fuel technology is important, these processes are not likely to replace the 1st generation bio-fuels for many years, if ever. The greatest potential for these fuels likely lies in their ability to process lower value, more abundant feedstocks and not in their ability to produce lower cost bio-fuels. It will be many years before the capital costs for the 2nd generation bio-fuels can be reduced to the point where the return on investment is comparable to that from 1st generation plants.

The real benefit of 2nd generation bio-fuels is in their ability to process a wider range of feedstocks than the 1st generation bio-fuels. In most regions of the world the 1st generation fuels have not yet reached a limit on market share due to feedstock availability and thus the need to switch to other processes is not yet a major driving force. Given the length of time that will be required to commercialise some the 2nd generation processes it is appropriate that governments support their development well before they are required by the marketplace.

The benefits of 2nd generation bio-fuels do not address most of the barriers that the 1st generation fuels have faced and in fact many of the 2nd generation fuels will face the same market barriers as the 1st generation fuels. It is important therefore that efforts to implement the production of 1st generation fuels not be reduced or postponed because of the promise of 2nd generation fuels. Doing so would only delay the eventual adoption of the 2nd generation biofuels. The use of 2nd generation bio-fuels needs to be viewed as a means to augment and not to replace the use of 1st generation bio-fuels.

APPENDIX 1: REFERENCES.

1. Øyvind Vessia: Biofuels from lignocellulosic material.
2. Judit Adam: Possibilities for conversion of biomass to liquid fuels in Norway - background information for a roadmap
3. Status and perspectives of biomass-to-liquid fuels in the European Union.
4. Biofuels in the European Union, A Vision for 2030 and beyond.
5. Zero Emission Resource Organisation homepage: www.zero.no
6. Sintef: Bioenergi; ressurser og teknologi (Teknisk rapport)
7. Innovations in the production of Bioethanol and their implications for energy and greenhouse gas balances.
8. Roadmap to Bio-fuels. Roadmap to future Norwegian Solutions. PFI, Zero, NoBio, TØI, SINTEF, KanEnergi, Bioforsk, UMB, Skog og Landskap.
9. Rudloff Matthias: Biomass-to-Liquid Fuels.
10. IEA Bioenergy Task 39: Second generation biofuels, a review from a market barrier perspective.
11. Baitz, Binder, Rudloff et.al.: Comparative life-cycle assessment for SunDiesel (Choren Process) and Conventional Diesel Fuels

APPENDIX 2: NOMENCLATURE.

BTL	Biomass-To-Liquids: denotes processes to convert biomass to liquid fuels
CCGT	Combined Cycle Gas Turbine
CH_2	Compressed hydrogen
CO	Carbon monoxide
CO_2	Carbon dioxide: the principal greenhouse gas
CONCAWE	The oil companies' European association for environment, health and safety in refining and distribution
Atm.CFB	Atmospheric pressure Circulating Fluidized Bed
DICI	An ICE using the Direct Injection Compression Ignition technology
DISI	An ICE using the Direct Injection Spark Ignition technology
DME	Di-Methyl-Ether
DPF	Diesel Particulate Filter
EUCAR	European Council for Automotive Research and Development
ETBE	Ethyl Tertiary Butyl Ether, a gasoline additive to increase octane rating
EHV	Effective heating value
FAME	Fatty Acid Methyl Ester: Scientific name for biodiesel
FC	Fuel Cell
FT	Fischer-Tropsch: the process named after its original inventors that converts syngas to hydrocarbon chains
GHG	Greenhouse gas
GTL	Gas-To-Liquids: denotes processes to convert natural gas to liquid fuels
HHV	Higher Heating Value ('Higher" indicates that the heat of condensation of water is included)
HTU	Hydro Thermal Upgrading
ICE	Internal Combustion Engine
IGCC	Integrated Gasification and Combined Cycle
IPCC	Intergovernmental Panel for Climate Change
LBST	L-B-Systemtechnik GmbH
LHV	Lower Heating Value ('Lower" indicates that the heat of condensation of water is not included)
M	Density of wood
N_2O	Nitrous oxide: a very potent greenhouse gas
NREL	National Renewable Energy Laboratory
NG	Natural Gas
NOx	A mixture of various nitrogen oxides as emitted by combustion sources
PISI	An ICE using the Port Injection Spark Ignition technology
Press.BFB	Pressurized Bubbling Fluidized Bed
RME	Rapeseed Methyl Ester: biodiesel derived from rapeseed oil (colza)
SRF	Short Rotation Forestry
SSCF	Simultaneous Saccharification and Co-Fermentation: a process for converting cellulosic material to ethanol
Syngas	A mixture of CO and hydrogen produced by gasification or steam reforming of various feedstocks and used for the manufacture of synthetic fuels and hydrogen
TTW	Tank-To-Wheels: description of the burning of a fuel in a vehicle
WTT	Well-To-Tank: the cascade of steps required to produce and distribute a fuel (starting from the primary energy resource), including vehicle refuelling
WTW	Well-To-Wheels: the integration of all steps required to produce and distribute a fuel (starting from the primary energy resource) and use it in a vehicle

APPENDIX 3: 10 RULES FOR USING BIO-DIESEL:

1. **Bio-diesel is an ecologic fuel.**
2. **Bio-diesel is produced from renewable materials.**
3. **Bio-diesel contains practically no sulfur. (0.001%)**
4. **Bio-diesel considerably decreases soot emissions. (up to 50%)**
5. **When burnt, bio-diesel emits the same amount of CO_2 as the plants absorb in growth. (closed CO_2 cycle).**
6. **Bio-diesel contains no benzole or other carcinogenic polyaromatic components.**
7. **Bio-diesel easily decomposes biologically and in the case of an accident no harm is done to the soil or ground water.**
8. **Bio-diesel is not considered a hazardous material (flashpoint above110°C).**
9. **Bio-diesel has superior lubrication capabilities and increases engine life.**
10. **Bio-diesel is an ecologically beneficial alternative to conventional diesel fuel.**