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Feasibility study of CHiP plants in The European Union using pure plant oils

Michal Krzyzaniak

UNIVERSITY OF ICELAND

University of Akureyri

FEASIBILITY STUDY OF CHiP PLANTS IN THE EUROPEAN UNION USING PURE PLANT OILS

Michal Krzyzaniak

A 30 credit units Master's thesis

Supervisor:
Þórhallur Bjarnason

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RES │ the School for Renewable Energy Science
Solborg at Nordurslod
IS600 Akureyri, Iceland
telephone: + 354 464 0100
www.res.is

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ABSTRACT

The purpose of this work is to investigate in which EU member States it is possible to utilize Combined Heat and Intelligent Power technology, which can produce electricity with high efficiency. The paper investigates the Member States' policies and subsidies for renewable electricity production from liquid biomass and additional tax deduction and benefits. The result shows that four Member States are the most promising: Germany, Austria, Portugal and The Netherlands. Research for the sustainability of pure plant oils is also part of this work. The investigation shows that the most common in use plant oils such as palm, rapeseed, jatropha, soybean can contribute to the greenhouse gases reduction. However, incorrect land use and irresponsible deforestation can increase GHG emission more than 20 times. Thus, Blue-NG company must be ready to surmount high opposition for the use of plant oils from developing countries.

PREFACE

The increasing emission of greenhouse gases, especially carbon dioxide, during the fast-paced industrialization in the 20th century increased the average temperature on Earth by 0,74°C in the period 1901-2005. Since 1750 the atmospheric concentration of CO_2 has been rising and in 2000 it increased from 280ppm to 368 ppm. Similarly, the concentration of CH_4 increased from 700 ppb to 1750 ppb and N_2O from 270 to 316 ppb. These changes will have serious ill effects: they increase droughts, corals bleaching and influence the crop productivity. Moreover, they drastically contribute to ice melting in polar zones and, consequently, the rising sea level and cause frequent occurrences of abnormal weather conditions (Watson, Core Writing Team, 2001).

The IPCC Special Report on Emissions Scenarios projects an increase of global greenhouse gases (GHG) emissions by 25 to 90% (CO_2-eq) between 2000 and 2030, with fossil fuels maintaining their dominant position in the global energy mix to 2030 and after (An Assessment of the Intergovernmental Panel on Climate Change, 2007). Therefore, to minimize the greenhouse gases effect 183 countries agreed (under the Kyoto Protocol) to reduce the emission of greenhouse gases below the level of 1991. One of the ways to reduce global warming is the utilization of renewable energy sources. Twenty seven of the countries who agreed to reduce GHG are members of the European Union. The community established a binding target of a 20% of share of renewable energy sources in energy consumption and a 10% binding minimum target for biofuels usage in transport. So to accomplish these targets, great investments into the renewable energy industry have to be made. Yet, renewable energy technologies are still under development and need greater financial support than other business enterprises. Hence, the EU has obliged its members to establish renewable energy programmes and policies to encourage investors to produce energy from renewable and sustainable sources.

Many projects have been launched, under the direction of EU policies,which are designed to help EU countries achieve their targets. One of them is the Combined Heat and intelligent Power (CHiP) plant in Beckton (UK). The plant is a highly efficient cogeneration plant that will produce electricity from renewable fuels (vegetable oils like rapeseed, palm, jatropha and soybean) and from natural gas pressure reduction in the grid.

In this thesis the renewable energy policies of the EU member countries will be studied and the countries with the best potential for future plants will be indicated. Furthermore, various bio-oils will be investigated and those found to be the most suitable will be chosen for the newly designed plant in the United Kingdom.

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1 LITERATURE REVIEW

1.1 Energy use in the World and the European Union

1.1.1 The World

The World energy supply in 2006 (Figure 1-1) was dominated by fossil fuels (81 percent) (IEA, 2008). The highest share of energy supply belongs to oil (34,4 % of Total Primary Energy Supply), coal (26 percent) and gas (20,5 percent). Nuclear energy takes 6,3 percent of the pie chart. Renewable energy in total takes 12,9 percent. Combustible renewable and waste constitutes 10,1 percent of all TPES before hydro (2,2 percent) and other renewables (0,6 percent from geothermal, solar, wind, marine, etc.). While comparing it with the share from 1973 it is possible to observe a decrease in fossil fuels share and a high increase of nuclear energy (by 5,3 percent) and other renewable energy sources (from 0,1 to 0,6 percent).

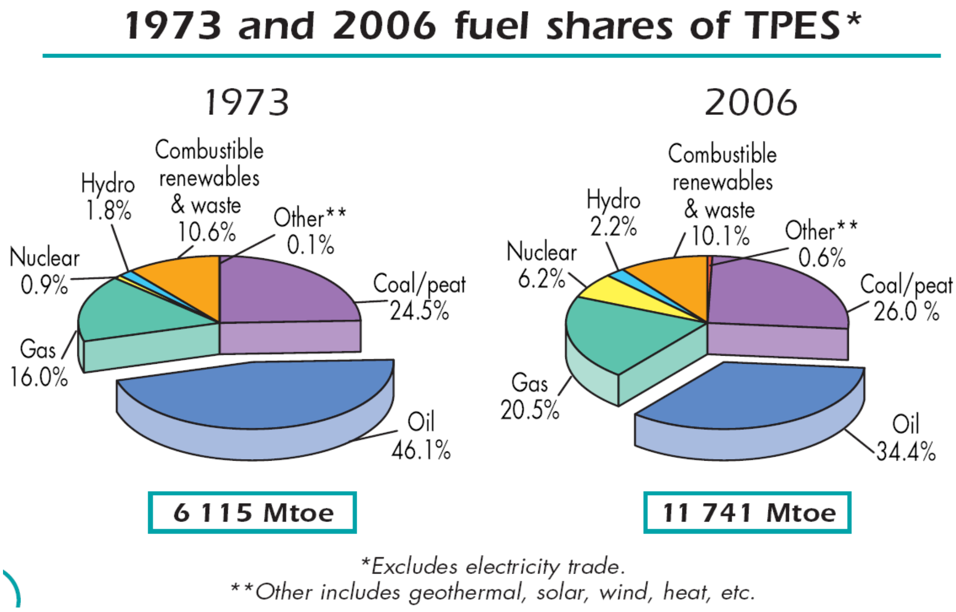


Figure 1-1 Total primary energy supply by fuel in 1973 and 2006 (Source IEA 2008)

World renewable electricity production in 2006 (including pump storage plants) reached 3525,5 TWh, which is 18,6 percent of the total production (Observ'ER, 2007). This share remains higher than in the case of nuclear electricity production (15 percent) but much lower than electricity from fossil sources (67 percent). Hydroelectricity is the biggest source of RES electricity and represents 89 percent of the total production. Biomass, including renewable household waste, remains the second biggest source, amounting to 5,7 percent. It is followed by wind power (3,5 percent), geothermal energy (1,7 percent), solar energy which includes both solar thermal power plants as well as photovoltaic power plants (0,2 percent), and marine energy (0,02 percent). The share of RES electricity generation in the World is presented by Figure 1-2.

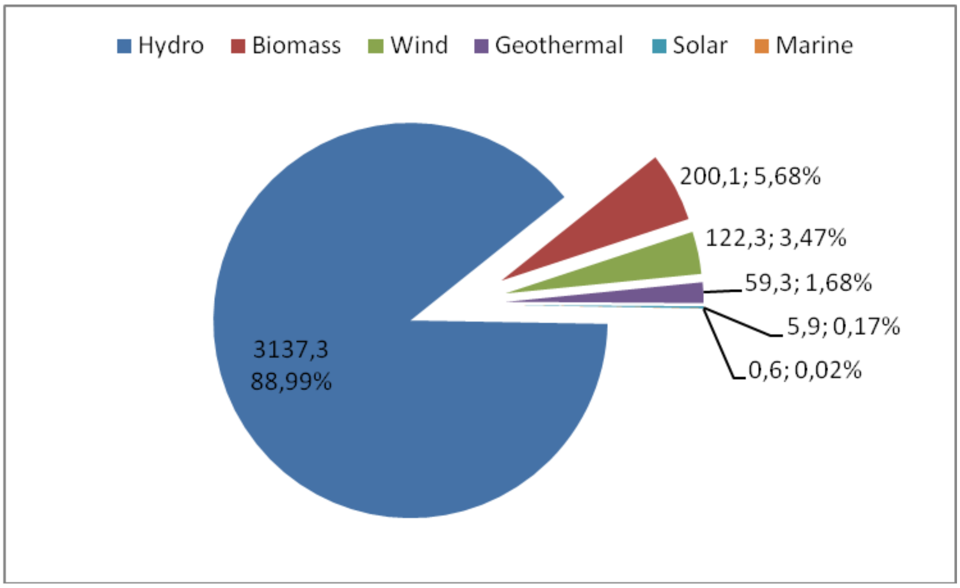


Figure 1-2 The World share of RES electricity generation (TWh) in 2006

1.1.2 The European Union

Since 1995, EU-27 primary energy production has observed a steadily decreasing trend, resulting in a 5,3 percent decrease in 2005 (Eurostat, 2007). Figure 1-3 shows that fuel mixture of primary energy production has changed in favour of nuclear energy and renewable energy sources. The total share has remained rather stable. Fossil fuels' share (lignite, natural gas, oil and hard coal) decreased by 7 percent. In 2005, CO2 "free" sources (renewable energy sources and nuclear energy) had a share of 42 percent while fossil fuels represented the remaining 58 percent of the total primary energy production.

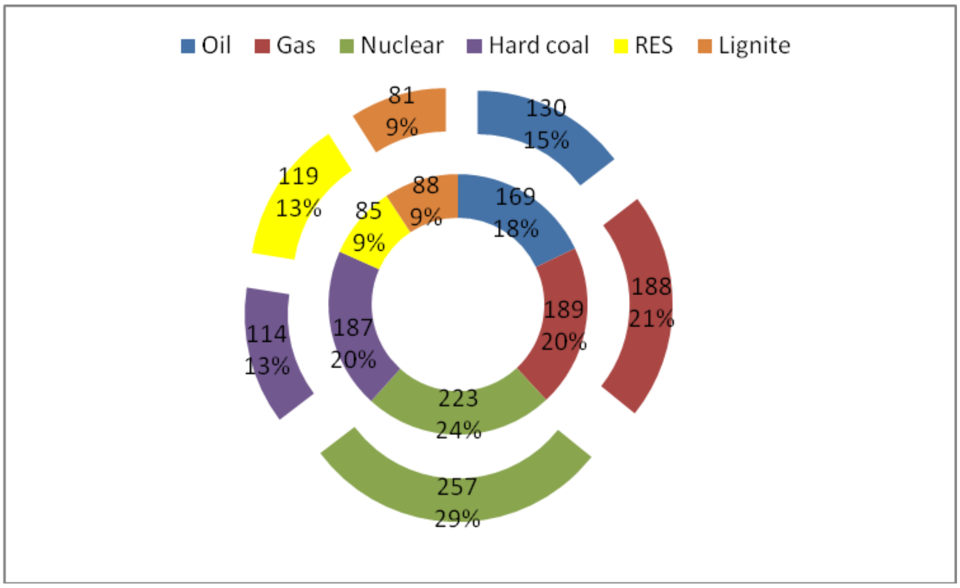


Figure 1-3 EU 27 primary energy production (Mtoe) in 1995 (inner circle) and 2005 (outer circle)

Installed Capacity for Electricity Generation from Renewables

Renewables capacity for electricity generation in the European Union in 2005 amounted to 24 percent (170 GW) of the total installed capacity (712 GW). It increased by almost 40 percent during the last decade mainly due to the development of wind and biomass technologies. The total renewable electricity generated from this capacity in the EU was 451 TWh and the total share of electricity production from RES was 14 percent.

Figure 1-4 shows that hydroelectricity (small and large hydro) generation covers 68 percent of the total RES generation. Hence, due to a large share of hydroelectric power together with the annual variation in its precipitation as well as the role of hydroplants in covering the peak demands, electricity production from renewables and, consequently, their share in the total electricity consumption, fluctuate from year to year. Developing expensive technologies like photovoltaic, offshore wind, tide and wave share only 0,8 percent of RES electricity production.

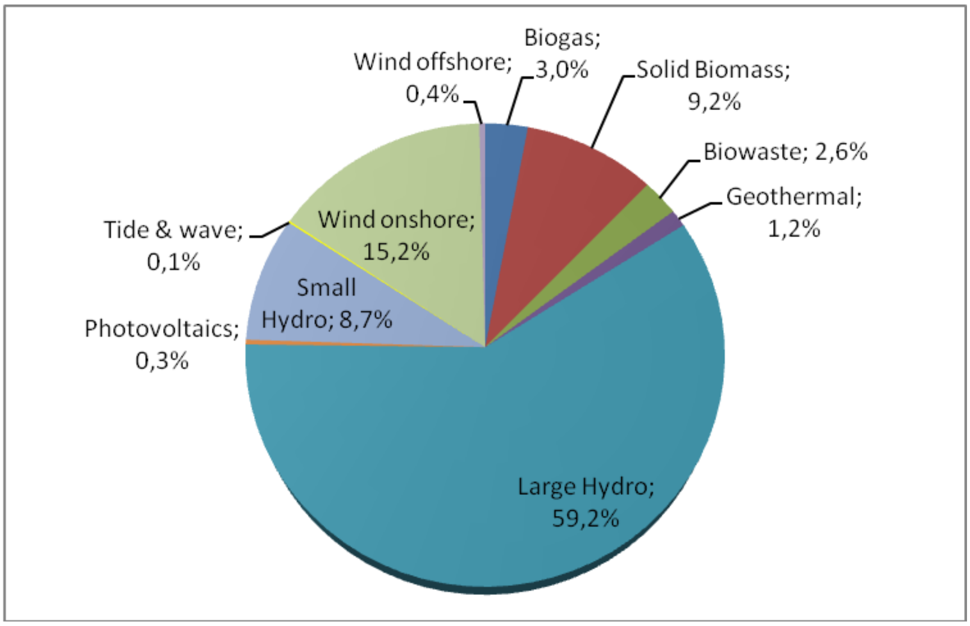


Figure 1-4 The share of renewable electricity production in European Union in 2005

According to Eurostat, approximately 50 percent of the EU energy consumption is imported (Figure 1-5). The European Union is highly dependent on oil (82 percent) and natural gas (58 percent) and the forecasts show the same trend for the next decades. Furthermore, there is an accelerating decline in the resources of fossil fuels which are concentrated in few producing countries. Between 1995-2005 the total energy dependency rate of the 27 EU Member States increased by 9 percent. Eleven countries were less dependent in 2005 than in 1995, and another eleven countries increased their dependency by 0.4 to 9.6 percent. Hungary, Poland, the Netherlands and Ireland increased their energy dependency by 14-20 percent. The United Kingdom's dependency reversed drastically from -16 percent in 1995 to 21,3 percent in 2005. Only Denmark had a negative energy dependency of -51.6 percent while sixteen countries had a higher energy dependency ratio than the EU-27 average.

The European Union is highly dependent on imported oil. In 2007 the energy dependence rate for oil amounted to 82.2 percent as compared to 74.4 percent in 1995. Between 1995 and 2005 the EU production of crude oil decreased by 23 percent while the import increased by 12 percent. Out of all Member States only two remain oil-independent: The United Kingdom was oil independent with only 2 Mtoe net exports in 2005 and Denmark, which was a net oil importing country in 1995, and became an oil exporter with more oil exports in recent years than the gross inland consumption. The remaining EU countries (except for: Romania, Estonia, Hungary, Slovakia and the two net exporting countries mentioned above) have an oil dependency rate greater than 90 percent.

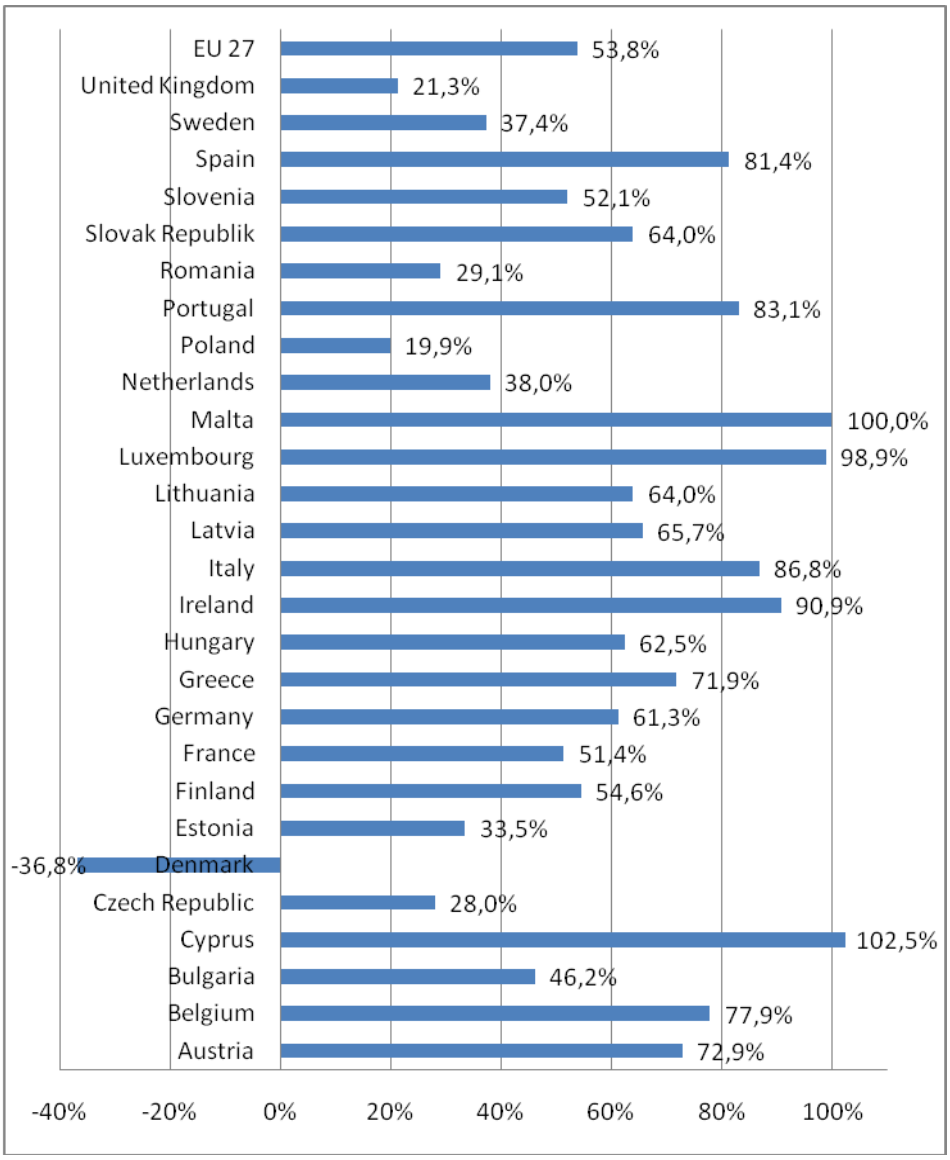


Figure 1-5 The European Union energy dependency by all products in 2005

1.2 Policy of the European Union

1.2.1 The European Union policy overview

Renewable energy policies form an important factor on the way to renewable energy development as these policies are the frame of renewable energy systems. According to the International Energy Agency, proper energy policies shall be built on five fundamental principles (International Energy Agency, 2008):

1. The removal of non-economic barriers, such as administrative obstacles to grid access, poor electricity market design, lack of information and training and the tackling of social acceptance issues - with a view to overcome them – in order to improve the market and policy functioning;
2. The need for a predictable and transparent support framework to attract investments;
3. The introduction of transitional incentives decreasing over time in order to foster and monitor technological innovations and move technologies quickly towards market competitiveness;
4. The development and implementation of appropriate incentives guaranteeing a specific level of support to different technologies based on the degree of their advancement. Its aim is to exploit the potential of the wide range of renewable energy technologies over time; and
5. An evaluation of the impact of a large-scale penetration of renewable energy technologies on the energy system, especially in the liberalized energy markets, with regard to the total cost efficiency and system reliability.

Undoubtedly, the demand for energy in Europe is growing rapidly. Therefore, to meet the growing expectations and to mitigate climate changes the EU should replace the existing ageing infrastructure. To do that, an investment of 1 trillion euro will be needed over the next 20 years. The Commission of the European Communities published three major objectives in the Green Paper that must be fulfilled by the EU energy policy (Commission of the European Communities, 2006):

1. Sustainability:
    a. developing competitive renewable sources of energy and other low carbon energy sources and carriers, particularly alternative transport fuels,
    b. reducing the energy demand within Europe,
    c. leading global efforts to diminish climate changes and improve the quality of local air.
2. Competitiveness:
    a. ensuring that an open energy market is beneficial to consumers and to the economy as a whole as well as stimulating investments in the production of pure energy and its efficiency,
    b. mitigating the impact of higher international energy prices on the EU economy and its citizens and
    c. keeping Europe at the cutting edge of energy technologies.
3. Security of supply:
    a. tackling the EU's rising dependence on the imported energy through an integrated approach – firstly, reducing the energy demand, secondly, diversifying the EU's energy mix with greater use of competitive,

indigenous and renewable energy, and thirdly, diversifying sources and routes of supply of imported energy,

b. creating a framework which will stimulate adequate investments to meet the growing demand for energy,

c. equipping the EU sufficiently so that it is able to better cope with emergencies,

d. improving the market conditions of the European companies seeking access to global resources,

e. making sure that all citizens and businesses have access to energy.

According to the European Strategic Energy Technology Plan, to turn towards security and sustainability, European energy systems ought to rapidly progress on four fronts (Commission of the European Communities, 2007):

1. The efficient conversion and use of energy in all sectors of the market combined with a decreasing energy intensity.
2. The diversification of energy in favour of renewable and low-carbon conversion technologies for electricity, heating and cooling.
3. The decarbonisation of the transport system by switching to alternative fuels.
4. Full liberalisation and interconnection of energy systems.

In the European Commission's view, business as usual is not an option. Putting the EU and the global energy systems onto a sustainable path will require a huge change and certain innovations, from basic research to market integration.

The EU Communication presents an independent overview of the energy technologies that can substantially contribute to achieving these goals (Table 1-1), as well the vision of the European Technology Platforms in the energy field.

Table 1-1 A summary of key future technology options by the FP6 Advisory Group

Time to widespread deployment	Transport technology	Electricity/heat conversion technology
Immediate/ shorterm	Reduction in demand	Low/medium temperature solar thermal applications for hot water, heating, cooling, industrial processes
↓	Advanced high-efficiency ICEs	Combined Cycle Gas Turbine (CCGT)
↓	Improved hybrid electric designs with petrol, diesel, biodiesel	Nuclear fission (Gen III/III+) Wind energy (including offshore/deep offshore)
↓	Bio-diesel, bio-ethanol	System integration (grid issues) Solid biomass
↓	Co-processing of biomass with fossil fuels	Fuel cells (SOFC, MCFC) Geothermal energy (including deep geothermal – HDR/HFR)
↓	Synthetic fuels from gas/coal-Fischer Tropsch	Carbon capture and storage (CCS) Cleaner use of coal (steam/gas turbine, combined cycle) with CCS
↓	Biofuels from lingo-cellulosic feedstocks	Advanced fossil fuel plants (super/ultra-super critical steam), Integrated Gasification CC (IGCC) with CCS
↓	Electic vehicles (EVs) with advanced battery electricity storage	Solar photovoltaic (PV) Solar thermal power plants
↓	Hydrogen with fuel cells	Ocean energy (wave, sea current) Nuclear fission – Generation IV
Longer term	Air transport: Hydrogen/ gas turbine	Nuclear fusion

According to the European Commission, the energy technology landscape could evolve in the following ways:

By 2020 technology advances will enable the target of 20 percent renewable energy market penetration to be met. The Commission forecasts a sharp increase in the share of the lower-cost renewables and the clean coal technologies in the energy system.

1. In 2030, electricity and heat production might be in the course of decarbonisation with fully competitive renewable energy technologies. The Commission would like to see, and concurrently disseminate, fuel diversification in the transport sector, with mass markets of the 2nd generation biofuels and the penetration of hydrogen fuel cells.
2. In 2050 and after, a paradigm shift in the way we produce, distribute and use energy should be completed, with an overall energy mix largely comprising renewable, sustainable coal and gas, sustainable hydrogen, Generation IV fission power and fusion energy.

To help achieve the aforementioned targets, on 27 September 2001 the European Parliament adopted The Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources on the internal electricity market (the European Parliament and The Council, 2001).

The Directive obliges the Member States to enhance a greater consumption of electricity produced from renewable energy sources in accordance with the national targets imposed by this directive (the Community's target is 22 percent by 2010). The Member States are also obligated to adopt the recommended targets for future consumption from RES-E and publish a report illustrating the progress of their implementation. Moreover, the Directive obligated the EU Commission to establish a programme supporting electricity producers. According to the plan, the renewable energy producers will receive direct or indirect support from the Member States.

Another important issue raised in this act is the guarantee of origin of electricity produced from renewable energy sources. The guarantee shall not only specify the source from which the electricity was produced, the dates and places of production, but also demonstrate that the electricity comes from renewable energy sources.

What is more, article 7 of the directive obligates the Member States to ensure that the operators of transmission and distribution systems will guarantee the transmission and distribution of electricity from RES on their territory. The countries may also provide a priority access to the grid system of electricity produced from renewable energy sources. Additionally, the operators, according to the act, are required by the Members States to provide any new producer wishing to be connected with a comprehensive and detailed cost estimate of the connection. The EU members shall also put in place a legal framework or pledge the operators to set up and publish their official regulations relating to the sharing of costs of system installations (grid connections and reinforcements) between all producers benefiting from them. Furthermore, they should ensure that the charging of transmission and distribution fees does not discriminate against electricity from renewable energy sources, especially from remote or rural areas.

Since 2001, renewable energy technologies have been developing rapidly. For the European Commission this development was to establish new goals. In January 2008 a proposal for a new directive was presented. The Directive "On the promotion of use of energy from renewable sources" will concern the Member States whose share of energy from renewable sources in 2020 will amount to at least 20 percent of the Community's total consumption but it cannot not be lower than the share established individually for every country (Table 1-2). Each Member State shall also ensure that the share of energy from RES in transport in 2020 constitutes at least 10 percent of the overall consumption of energy in transport (The Commission of The European Communities, 2008).

What is more, the directive obligates each EU member to adopt a national strategy and set targets for the shares of energy from RES in transport, electricity, heating and cooling in 2020. Moreover, Member States are to develop the already existing national policies so as to fulfil all the requirements of the proposal. The document also regulates the origin of renewable energy sources (not only electricity but heating and cooling as well) by guarantees of origin and enumerates requirements and obligations for operators of systems and distribution systems of grid transmission that have already been mentioned in the Directive 2001/77/EC. Article 15 of the proposal refers to the sustainability of biofuels and bioliquids. Accordingly, all Members States must fulfil sustainability criteria for biofuels and bioliquids:

1. Saving of the greenhouse gas emission shall amount to at least 35 percent.
2. Materials for biofuels and bioliquids shall not be obtained from a land with a high biodiversity value (e.g. forests inviolated by any significant human activity or high biodiverse grassland).
3. Materials for biofuels and bioliquids shall not be obtained from a land with a high carbon stock (e.g. wetlands, continuously forested areas).

Table 1-2 National overall targets for the share of energy from renewable sources in the total consumption of energy in 2020

Country	The share of energy from renewable sources in final consumption of energy, 2005	Target for share of energy from renewable energy sources in final consumption of energy, 2005
Belgium	2,2%	13%
Bulgaria	9,4%	16%
The Czech Republic	6,1%	13%
Denmark	17,0%	30%
Germany	5,8%	18%
Estonia	18,0%	25%
Ireland	3,1%	16%
Greece	6,9%	18%
Spain	8,7%	20%
France	10,3%	23%
Italy	5,2%	17%
Cyprus	2,9%	13%
Latvia	34,9%	42%
Lithuania	15,0%	23%
Luxembourg	0,9%	11%
Hungary	4,3%	13%
Malta	0,0%	10%
The Netherlands	2,4%	14%
Austria	23,3%	34%
Poland	7,2%	15%
Portugal	20,5%	31%
Romania	17,8%	24%
Slovenia	16,%	25%
The Slovak Republic	6,7%	14%
Finland	28,5%	38%
Sweden	39,8%	49%
United Kingdom	1,3%	15%

1.2.2 Support schemes in the Member States

There is a great range of support schemes that EU countries can utilize to subsidise their renewable electricity production. According to the Commission Staff Working Document entitled “The support of electricity from renewable energy sources”, two main types of schemes can be distinguished (the Commission of The Europan Communities, 2008):

1. Quantity-based market instruments:
   a. quota obligations where governments impose an obligation on consumers, suppliers or producers to obtain a certain percentage of their electricity from renewable energy. Suppliers will have to prove that they have discharged the obligation (usually by buying green certificates) or they will have to pay a fine,
   b. legal tenders constituting an announcement of the provision of a certain amount of electricity from a particular technology source (the cheapest offer is accepted).
2. Price-based market instruments:
   a. feed-in tariffs and premiums granted to operators of eligible domestic renewable electricity plants for the electricity delivered to the grid. Feed-in tariffs take the form of the total price per unit of electricity paid to the producer. Premiums are paid to the producer on top of the electricity market price.
   b. fiscal incentives (tax exemption or cuts) encourage producers of renewable electricity by exemptions from certain taxes. The effectiveness of these incentives largely depends on the amount of the tax rate applied in a selected country.

Support schemes applied in Member States are shown in Figure 1-6

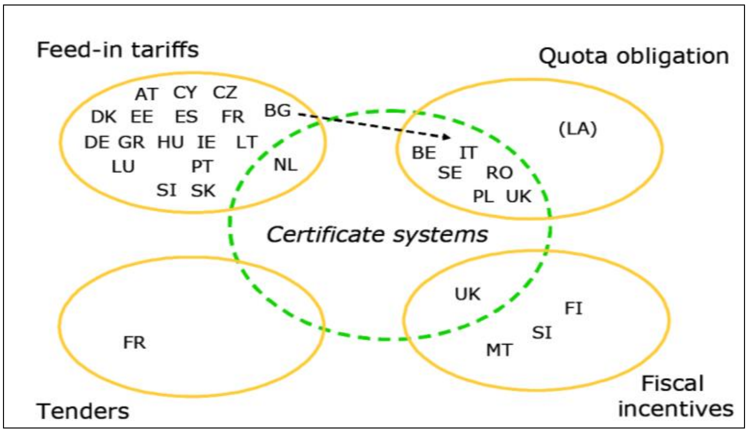


Figure 1-6 An overview of primary renewable electricity support systems in EU 27 (OPTRES, 2007)

The commission’s observations of support schemes in the EU countries suggest that feed-in tariffs achieve a greater renewable energy penetration at lower costs for consumers. The indicators of policies' effectiveness, which show an increase of electricity generation compared to the additional realisable mid-term potential to 2020 for a specific technology, have been higher for photovoltaic technologies in the countries using the feed-in tariffs as their main support scheme. The effectiveness of the low cost options in the renewable electricity portfolio (e.g. sewage gas, some types of biomass) has been particularly high in the countries with non-technology specific support schemes. Feed-in systems in Ireland and France, which have replaced the tendering systems, have shown a moderate effectiveness in Ireland and were more effective in France. Yet a new tendering system for offshore wind in Denmark has been the most effective scheme to support this technology in the European Union.

Below arguments for and against quantity-based market instruments (quota) and price-based market instruments are enumerated (Assmann D, 2006). The advantages of pricing systems are as follows:

- the most successful to date at the developing renewables markets and domestic industries, achieving the associated social, economic, environmental and security benefits,
- designed to take into account changes in technology and in the marketplace,
- flexibility to encourage a steady growth of small and medium producers,
- low costs of transaction,
- easy to finance,
- favourably easy to enter

The disadvantages of price–based market instruments include:

- an unnecessarily high price for renewable power if tariffs are not adjusted over time,
- may involve restraints on renewable energy trade due to domestic production requirements.

The arguments for systems based on quantity-based market instruments are:

- promotion of the less costly projects: the cheapest resources are used first, which minimizes the costs,
- providing certainty regarding future market share for renewables (although this often fails to come true in practice),
- they are perceived as being more compatible with open or traditional power markets,
- more likely to fully integrate renewables into the existing electricity supply infrastructure.

The downsides of quantity–based market instruments are:

- possibility of high risk and low rewards for equipment industry and project developers, which slows innovation,
- fluctuation of prices in thin trading markets, creating instability and gaming,
- favoring large, centralized merchant plants,
- concentration of development in areas with the best recourses, causing opposition to projects and missing many benefits associated with renewable energy (e.g. new jobs, economic development in rural areas, reduction of local pollution),
- quota targets can set upper limits for development because there will be no high profits to serve as incentives to install more than the mandatory levels,
- creation of cycles of stop-and-go-development,
- they are complex to design, administer and enforce,
- high costs of transaction,
- difficult to fine-tune or adjust a changing situation in a short period of time.

1.3 Vegetable oil as a fuel

1.3.1 Definiton

Vegetable oils are triglyceride molecules in which three fatty acid groups are esters attached to one glycerol molecule (Demirbas, 2008). Oils are water-insoluble, hydrophobic substances in the plant that are made up of one mole of glycerol and three moles of fatty acids and are commonly referred to as triglycerides. Most of fatty acids in vegetable oils usually have an even number of carbon atoms (between 12 and 22) (Petursson, 2008). Figure 1-7 shows a general structure of triglyceride.

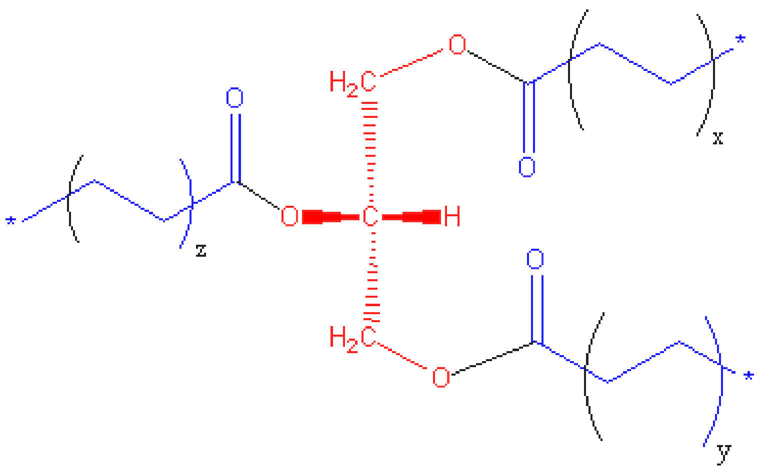


Figure 1-7 A general structure of triglyceride

Plant oils feedstock differs from each other because of proportions of saturated, monounsaturated and polyunsaturated fatty acids. In organic chemistry, a saturated compound has the maximum amount of hydrogen atoms possible: i.e., no double bonds or, in a hydrocarbon chain, every carbon atom is attached to two hydrogen atoms. (NationalMaster.com, 2009). In saturated linear hydrocarbons, every carbon atom is attached to two hydrogen atoms, except for those at the end of the chain bearing three hydrogen atoms.

The degree of unsaturation specifies the amount of hydrogen that a compound can bind. The term is applied similarly to the fatty acid constituents of lipids, where the fat is described as saturated or unsaturated, depending on whether the constituents of fatty acids contain carbon-carbon double bonds. The term unsaturated is used when any carbon structure contains double or occasionally triple bonds. Figure 1-8 presents an unsaturated fat triglyceride with a saturated palmitic acid and an unsaturated oleic and alpha-linolenic acids.

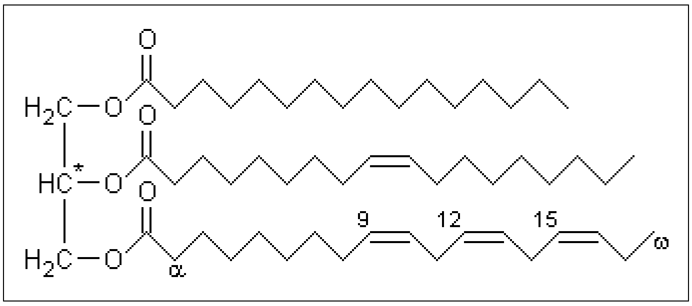


Figure 1-8 An example of unsaturated fat triglyceride

Many vegetable oils contain fatty acids with one (monounsaturated) or more (polyunsaturated) double bonds in them (Figure 1-9). The best vegetable oil for energy use would be made only from monounsaturated fatty acids (the U.S. Department of Energy, Energy Efficiency and Renewable Energy, 2006).

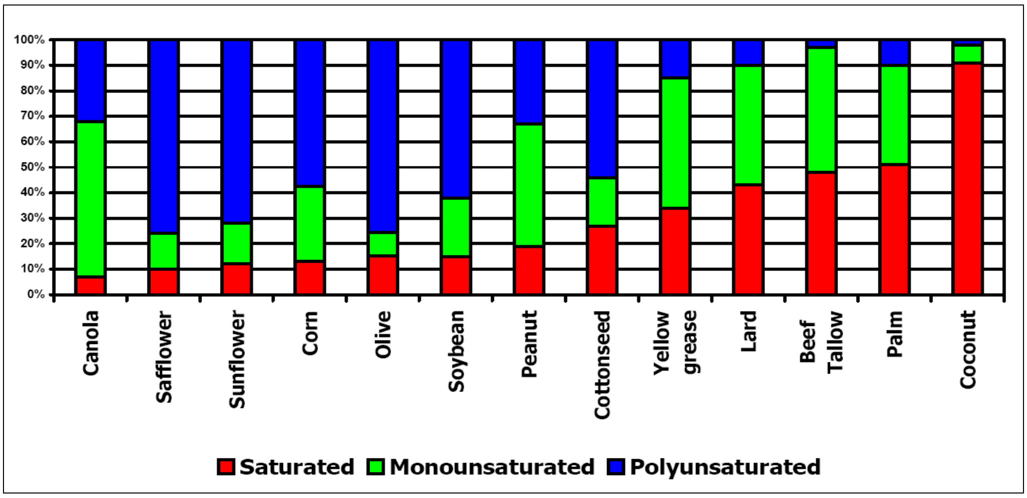


Figure 1-9 A composition of various oils and fats (Biodiesel handling and use guidelines of the US Department of Energy, Energy Efficiency and Renewable Energy 2006)

Generally, more than 350 oil-bearing crops have been identified. Among them only soybean palm, sunflower, safflower, cottonseed, rapeseed and peanut oils (which was the oil used by Rudolf Diesel with his first engine) are considered potential alternative fuels for diesel engines (Demirbas, 2008). These plants have oil yields varying from 446 l/ha for the soybean to 5950 l/ha for the oil palm (Table 1-3) and a good composition of fatty acids that influence the quality of the fuel (Handmade Projects, 2001).

Table 1-3 Vegetable Oil yields of oil plants

Plant	Yield liters oil/ha
Oil palm	5950
Rapeseed	1190
Soybean	446
Jatropha	1892
Sunflower	952
Safflower	779
Cottonseed	325
Peanut	1059

1.3.2 Production and price

The total vegetable oil production in 2007 amounted to 129 374 000 tonnes and the fat production was 24 733 000 tonnes (the Malaysian Palm Oil Board, 2007). The biggest amount was produced from an oil palm (42 643 000 tonnes including the palm kernel oil) before a soybean oil (37 481 000 tonnes) and a rapeseed oil (18 521 000 tonnes). Since 1998 the production of vegatable oils and fats has incresed by 50% from 102 807 000 tonnes to 154 107 000 tonnes (table 1-4).

Table 1-4 The World production of oils and fats: 1998-2007 (´000 tonnes)

Oils/Fats	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Palm Oil	16,920	20,625	21,867	23,984	25,409	28,259	30,987	33,846	37,142	38,246
Palm Kernel Oil	2,191	2,559	2,698	2,947	3,044	3,347	3,581	3,976	4,344	4,397
Soyabean Oil	24,008	24,794	25,563	27,828	29,850	31,241	30,729	33,612	35,278	37,481
Cottonseed Oil	4,059	3,893	3,850	4,052	4,221	3,987	4,367	4,978	4,903	5,119
Groundnut Oil	4,498	4,697	4,539	5,141	5,178	4,508	4,706	4,506	4,382	4,156
Sunflower Oil	8,407	9,308	9,745	8,200	7,610	8,917	9,423	9,785	11,191	10,997
Rapeseed Oil	12,290	13,247	14,502	13,730	13,343	12,698	15,088	16,294	18,510	18,521
Corn Oil	1,874	1,935	1,966	1,962	2,016	2,017	2,025	2,133	2,264	2,337
Coconut Oil	3,153	2,399	3,261	3,499	3,098	3,270	3,040	3,237	3,083	3,033
Olive Oil	2,588	2,475	2,540	2,761	2,773	2,904	3,110	2,965	2,798	2,993
Castor Oil	441	435	497	515	438	425	500	540	535	529
Sesame Oil	709	686	705	747	807	810	831	868	860	863
Linseed Oil	692	734	705	648	581	594	635	626	695	702
Total Vegetable Oils	**81,830**	**87,787**	**92,438**	**96,014**	**98,368**	**102,977**	**109,022**	**117,366**	**125,985**	**129,374**
Butter	5,765	5,885	5,967	6,010	6,331	6,394	6,476	6,666	6,730	6,911
Tallow	7,806	8,171	8,202	7,693	8,062	8,018	8,230	8,386	8,548	8,686
Fish Oil	886	1,413	1,411	1,131	946	1,005	1,129	988	1,001	1,069
Lard	6,520	6,619	6,739	6,780	7,016	7,228	7,367	7,577	7,855	8,067
Total Animal Oils/Fats	**20,977**	**22,088**	**22,319**	**21,614**	**22,355**	**22,645**	**23,202**	**23,617**	**24,134**	**24,733**
GRAND TOTAL	**102,807**	**109,875**	**114,757**	**117,628**	**120,723**	**125,622**	**132,224**	**140,983**	**150,119**	**154,107**

The main producers of vegetable oils and fat in 2007 were China, the EU and Indonesia with more than 19 000 000 tonnes each, followed by the USA with approximately 17 000 000 tonnes.

The price of vegetable oils depends mostly on the feedstock. Raw materials often constitute 80 to 95 percent of the production cost of biodiesel fuels. The International Food Policy Research Institute (Braun, 2008) claims that production costs also differ widely among countries. For instance, Brazil produces ethanol at about half the cost of Australia and one-third of the cost of Germany.

The price of raw materials usually fluctuates and very often follows the world market price of crude fossil oil or the price of food. Figure 1-10 shows how the price of palm oil followed the price of fossil oil at the end of 2007 and in 2008 (the Malaysian Palm Oil Board, 2008; the International Energy Agency, 2008). The World Agricultural Outlook Board shows that during the last two years prices of crude oil and soybean oil were correlated in 91 percent (Menzie, 2008).

Figure 1-10 Crude and palm oil prices between 10-2007 and 10-2008

According to the Economics & Industry Development Division of Malaysian Palm Oil Board, a governmental agency within the purview of the Malaysian Ministry of Plantation Industries and Commodities, the cheapest vegetable oil at the European market is palm oil (1041 US$/tonne) which makes it more competitive than rapeseed oil produced in Europe (1415 US$/tonne). This fact clearly indicates that even when the cost of transport from Asia is included, the palm oil is still 36 percent cheaper than the rapeseed oil (table 1-5) (the Malaysian Palm Oil Board, 2008).

Table 1-5 The price of vegetable oils at north-west European Market

Oil	2007 (US $/tonne)	Average January – October 2008r (US $/tonne)
Palm (crude)	780	1041
Palm (refined)	800	1096
Rapeseed	969	1415
Soybean	881	1356
Sunflower	1022	1638
Tallow	710	970

1.3.3 Vegetable oil performance in diesel engines

Many investigations during the last decade have shown that vegetable oils can be used as a fuel for compressing ignition engines, especially in medium speed engines (de Almeida et al, 2002; Carranca, 2005). Notwithstanding, there are important differences when using vegetable oils instead of fossil diesel or even fatty acid methyl esters in diesel engines:

- extremely high viscosity of vegetable oils (9 to 17 times higher than in the case of fossil diesel) in the same temperature causes fuel transfer problems and poor atomisation in the injectors which might result in a higher soot deposition, clogging of filters and injection system,
- deposition of coke on the injection pump and piston rings if the fuel contains a substantial amount of multiple bonds or glycerine/glycerides,
- necessity to use lubricant oil with higher detergency due to the alteration of its required physical specifications and contamination after about 100 h of engine's operation,
- more deposits on the cylinder head when the vegetable oil is not preheated
- the constituents of some vegetable oils react with copper piping existing in the engines when their temperature exceeds $50^{o}C$,
- higher fuel consumption because of a lower net calorific value compared to diesel fuel,
- problems with engine starting in lower temperature, (CFPP - filtration limit) caused by crystallization of fuel in the pipes and the fuel filter in low temperatures,
- damage because of the ash content to exhaust-gas retreatment systems,
- corrosion because of water content and high acidity,
- possibility of injection pump damage as a result of insufficient lubrication / cooling by the circulating fuel,

- fuel tank corrosion and gum formation as a result of reactivity of unsaturated hydrocarbon chains (higher iodine number) (Carranca, 2005; de Almeida, 2002; Morimitsu, 2007; Ayhan, 2007).

Some of differences are presented in table 1-6.

Table 1-6 A comparison between properties of bio-diesel, rapeseed-oil fuel and fossil diesel

	Diesel according to EN 590	**Bio-diesel (FAME) according to DIN EN 14214**	**Rapeseed-oil fuel according to E DIN V 51605**
Density	820 to 845 mg/kg	860 to 900 mg/kg	900 to 930 kg/m³
Viscosity at 40 °C	2,00 mm²/s to 4,50 mm²/s	3.50 mm²/s to 5.00 mm²/s	36 mm²/s
Flash point	Min. 55 °C	Min. 120 °C	Min. 220 °C
Lower calorific value	43 000 kJ/kg	Typical: 38 000 kJ/kg	Min. 36 000 kJ/kg (typically around 37 500 kJ/kg)
Proportion of alkaline elements (N+K)	-	Max. 5.0 mg/kg	Not specified
Proportion of alkaline earth elements (Mg + Ca)	-	Max. 5.0 mg/kg	Max. 20 mg/kg
Phosphorous content	-	Max. 10.0 mg/kg	Max. 12.0 mg/kg
Ash content	Max. 0.01 %	Max. 0.02 %	Max. 0.01 %
Total contamination	24 mg/kg	Max. 24 mg/kg	Max. 24 mg/kg
Acid value	-	Max. 0.5 mg KOH/g	Max. 2.0 mg KOH/g
Cetane value	Min. 51	Min. 51	Min. 39

MAN B&W Diesel group research on vegetable oils utilization in compressed ignition engines have shown that the best-suited for their burning are larger bore medium-speed engines (Carranca, 2005). Yet there were no significant changes in the efficiency of the tested engine. However, some differences in the biofuels presented above indicate that several changes in internal combustion engines are required.

Biodiesel requires different materials compared with petroleum diesel. All parts coming into contact with media (hoses, seals) should be resistant to biodiesel. As the combustion process differs from petroleum diesel, which influences the emissions composition, the engine and exhaust-gas treatment system must be ideally matched by the fuel parameters.

Because bio-diesel is very difficult to evaporate, it can accumulate in the engine oil, mainly during a low-load operation. Consequently, oil changes are needed more frequently in order to avoid damage by diluted engine oil. High viscosity of vegetable oils in stationary engines can be lowered by preheating with hot exhaust gases or cooling water. Some studies also recommend turbo-charged installation so as to increase the temperature and pressure inside the cylinders which can improve fuel atomisation and lower its viscosity (de Almeida, 2002). The problem of oxidation stability can be solved by adding anti-oxidation agents to the fuel (Morimitsu, 2007).

1.3.4 Emissions

The emission realised from the burning of vegetable oils in compressing ignition engines is similar to the one from fossil diesel. Generally, the combustion of vegetable oil realised less carbon monoxide (CO), particulate matters (PM) and polycyclic aromatic hydrocarbons (PAH). The emissions of sulphuric oxides (SO_x) are lower as well because of a lower sulphur content in vegetable oils (Ivarsson, 2008).

The biggest problem is the emission of oxides of nitrogen (NO_x). Usually they are slightly higher from vegetable oils than from fossil diesel. The higher emission is caused by a quantity of double and triple bonds in fatty acids compositions. The chemical composition of the fuel affects how much NO_x will be produced from an engine. Usually, emissions from biodiesel are 10 percent higher compared to fossil diesel (Hansen, 2006). Figure 1-11 below shows the percentage increase in NO_x from biodiesel made from saturated fatty acids (C12:0, C16:0 C18:0) monosaturated fatty acids (C18:1) and polisaturated fatty acids (C18:2, C18:3) compared to diesel fuel (the U.S. Department of Energy, Energy Efficiency and Renewable Energy, 2006). Certain kinds of biodiesel, such as those which are high in polyunsaturated fatty acids (for example soybean oil) produce more NO_x than fuels which are high in saturated fatty acids (like palm oil).

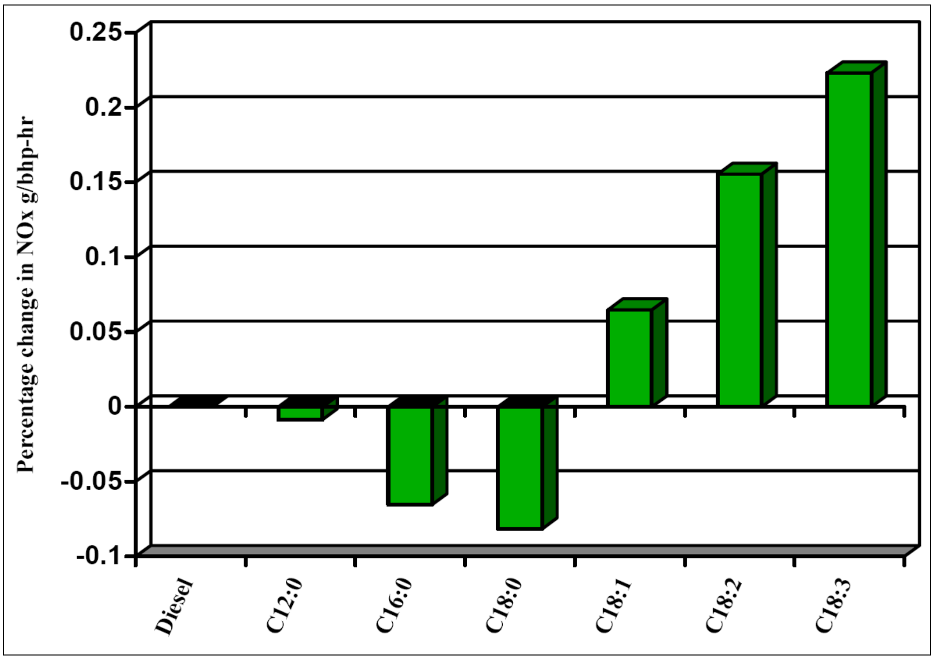


Figure 1-11 NO_x emissions of biodiesel made from single types of fatty acids (source Biodiesel handling and use guidelines of the US Department of Energy, Energy Efficiency and Renewable Energy 2006

The emission quality also depends on the load and purity of fuels. Kalam and Masjuki (2003) found that when a diesel engine operates on a preheated crude palm oil with water content, emissions of PAH, CO and PM might be higher and NO_x lower than from fossil diesel.

1.3.1 The energy balance and reduction of greenhouse gases

The target of vegetable oils use in energy production and transport is to reduce the greenhouse gases emission. Vegetable oils are derived from different feedstock e.g. oil palm, rapeseed or jatropha. They are cultivated in different places around the world, have different climate, nutrients, water requirements, land use and collecting techniques. In most cases, GHG balance for plant oils is positive but it varies from plant to plant.

An assessment of Folkecenter for Renewable Energy (2000) for rapeseed oil in Denmark presents that the direct CO_2 reduction from the rapeseed oil as a substitute for diesel is 2,78 kg/l or 3019 kg/ha. A gross CO_2 reduction factor from cultivation is 9,3:1 when excluding rapeseed cake utilization, and 14,41:1 when rapeseed cake is utilized.

The Life Cycle Assessment of different biodiesel fuels in Australia done by CSIRO (2007) shows that if vegetable oil originates from cultivation without land use change, the greenhouse gases emissions can be 2 to 5 times lower than the Ultra Low Sulphur Diesel depending on the type of feedstock used. Notwithstanding, if e.g. oil palm plantations are established on a cleared rainforest or a peat swamp forest, the greenhouse gas equivalent might be 10 times higher for plantations on the cleared rainforest and 22 times higher for plantations on the peat swamp forest (table 1-7).

Table 1-7 Greenhouse gas emission equivalent (gram CO_2) for biodiesels from different feedstock

Biodiesel (FAME)	Canola oil	Palm oil (existing plantations)	Palm oil (cleared rainforest)	Palm oil (cleared peat swamp forest)	Used cooking oil	Ultra Low Sulphur Diesel (fossil)
Equivalent of gram CO_2/kg of fuel	433	175	8075	18108	109	834
Emission reduction*	-1,9	-4,8	9,7	21,7	-7,6	1
*negative values mean GHG reduction comparing to ULSD, positive emissions higher than from ULSD						

Also, German research (the Institute for Energy and Environment, 2008) shows that land use may significantly affect the overall results. Cultivation of soybean in Latin America emits 323,5 kg CO_2-Eq. per GJ of soybean oil and only 84,7 kg CO_2-Eq. per GJ in North America. Moreover, production of palm oil from Southeast Asia emits 136,2 kg CO_2-Eq. per GJ but rapeseed oil production in Europe only 72,9 kg CO2-Eq. per GJ. Figure 1-12 shows that the emission change resulting directly from land use change in Latin America for soybean oil amounts to 92 percent of whole CO_2 equivalent emission when in North

America it constitutes 66 percent. The direct land use change in Southeast Asia responds to 86 percent of greenhouse gas emission from palm oil while for rapeseed in Europe, which produces five times less oil per hectare, it is 47 percent. These vast differences are caused by the land use change in the developing countries. While in Europe and North America plants are cultivated on an existing, arable land, in the developing countries savannahs and rain forests are converted into arable fields.

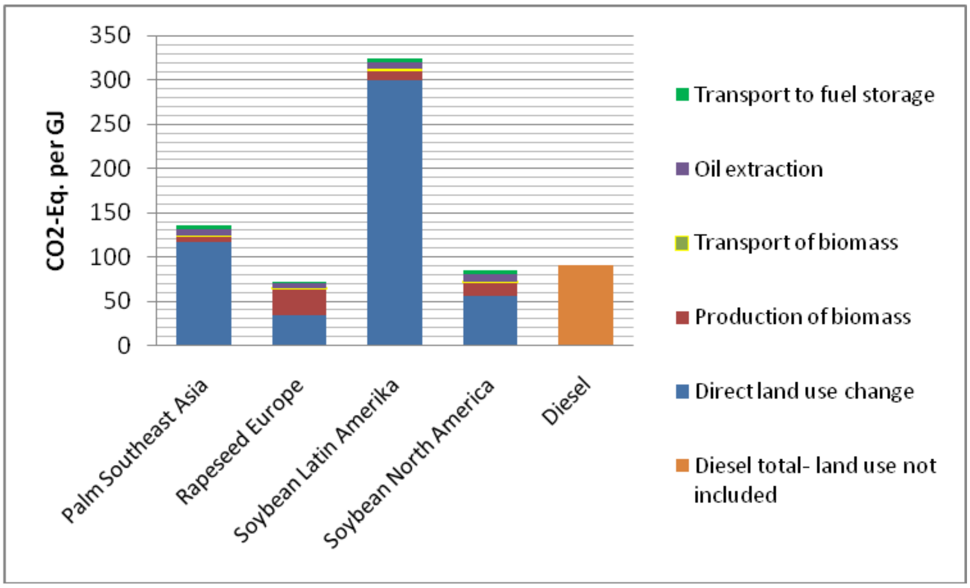


Figure 1-12 Greenhouse gases emission from different vegetable oils (kg CO_2-Eq. per GJ)

2 METHODOLOGY

1. Methodology used in this research has been based on the Internet database. The investigation has included the Member States' policies and subsidies in renewable energy. The method of gathering of RES policies has been as follow:

    - From the official European Union energy web sites (e.g. http://www.managenergy.net, http://www.energy.eu/).
    - From the Member States' government and cooperation reports (e.g. german-spanish-slovenian national energy agencies cooperation in feed-in tariff systems: "International Feed-in Cooperation"; from ministries responsible for renewable energy development).
    - From the national energy agencies in the UE countries (e.g. researches of the Energy Research Centre of the Netherlands (ECN), the Austrian Energy Agency (eA), the German Energy Agency (DENA)).
    - From scientific and research centers which cooperate with governments and the EU authorities (e.g. ECOFYS).

    However fast this method is, and even though it offers advantages for collecting data about policies and subsidies, there are also great disadvantages. There is always some concern about the topicality of the data. Collection of material is also a bit of a struggle because of weak, or lack of, response from sources, i.e. national energy agencies. Sometimes there can be a lack of data in English. Many materials about Member States policies have not been translated and analysis in native languages must be done. Another problem is categorisation of bioliquids to RES-E technologies. In this research it has been assumed that bioliquids are the biomass technologies that received the biggest subsidies in the Member States.

2. The method of selecting countries for the future CHiP location has been based on the gathered material. The elimination process included:

    - Discarding the countries in the development phase where CHiP technology will be too expensive. Most of them are post-communist countries which will promote cheaper local renewable sources i.e. hydroelectricity in Romania and Slovakia, biomass in Slovenia, Czech Republic and Poland.
    - Rejecting the countries with quota systems. It is assumed that this technology would not be chosen by obligated RES-E buyers because some quota systems promote the cheapest and the most developed technologies in electricity production. An example of such a country can be Poland. Polish green certificate's policies promote the cheapest renewable energy technologies, which are usually biomass firing and biomass-coal co-firing. The co-firing

technology is the cheapest but there are great concerns about sustainability of it. The investigations have shown that GHG emissions from biomass co-firing can be higher than from single burning of coal. Except co-firing, the cheapest RES-E technologies that are promoted by quota systems are hydro electricity, biomass and waste combustion.

- Natural gas systems, especially pressure reduction stations, are an indispensable part of CHiP plants. Thus countries with a small or complete lack of natural gas infrastructure have been rejected as well.

3. The best countries for a CHiP plant have been chosen from a list of the most promising Member States. The countries selected are characterized by:

   - Stable policies for renewable electricity production.
   - Promoting subsidies for renewable electricity from biomass.
   - The price of renewable electricity production from biomass is higher than the cost of electricity generation from CHiP plant.
   - Additional subsidies and support for CHP systems, investment support and tax deductions are available.

4. The comparison of the electricity production costs was based on the data from Vattenfall, which is one of the leading European energy companies, and VDI GmbH and VDE (the Association for Electrical, Electronic & Information Technologies in Germany).
5. The calculation of vegetable oil and biodiesel stock has been done as follows:
   - An average rapeseed production from period 2003-2007 has been taken from the UK's Department for Environment and Rural Affairs (DEFRA) statistics,
   - The rapeseed cultivation area from 2007 (DEFRA statistics) has been taken into account in the calculations,

6. Rapeseed oil yield was calculated using the data below:

   - An average oil content in the rapeseed has been estimated at 42 percent,
   - The solvent extraction with hexane has been accepted as the method of oil extraction with the efficiency of 99,5 percent,

7. The data used for biodiesel stock conversion to rapeseed oil equivalent:

   - 1 toe is equal to 41,87 GJ per tonne,

- 1 tonne of rapeseed is equal to 37,5 GJ per tonne,
- Rapseed oil to biodiesel ratio is equal to 0,89.

3 RESULTS

3.1 Blue-NG CHiP

In September 2007, 2OC Limited and National Grid plc, the UK's largest energy transporter and the owner of most of the UK's Pressure Reduction Stations (PRS), formed Blue-NG Limited. The companies agreed to construct and operate a new type of a highly efficient power station. The power station is known as the Combined Heat and intelligent Power unit (CHiP). The plant is called "intelligent" because the maximum output from the plant at periods of the maximum consumer demand during a day coincides with the time when the plant is operating with its maximum efficiency, i.e. early in the morning and early in the evening the demand increases.

In the first phase of the project two power plants shall be constructed (of a planned total of eight). Both will be located in the London area, one in Beckton and the other in Southall, close to Heathrow Airport. The Beckton plant will produce electricity and domestic heat for the area where the Olympics of 2012 will take place. The second plant (Southall) will supply electricity and domestic heat to a new district which is now being designed. The construction work in Beckton has already been started and the power production is expected to start in the year 2010. The Southall plant is scheduled to be open about a year later. Each power station is designed to produce 20MWe of electricity; of which 12MWe will be generated by diesel engines powered by bio-liquids (vegetable oils in this case), 6MWe will be derived from pressure reduction of natural gas and 2MWe from cooling water and exhaust heat from diesel engines (the Organic Rankine Cycle). Additionally, the thermal heat generated in the system will be utilized for district and domestic heating or cooling. Figure 3-1 presents the scheme of CHiP plant in Beckton

The innovation element of the project lies within the integration of diesel engines, natural gas pressure and thermal heat. Future plans are to expand this concept and project similar power plants in European countries as well as in the USA.

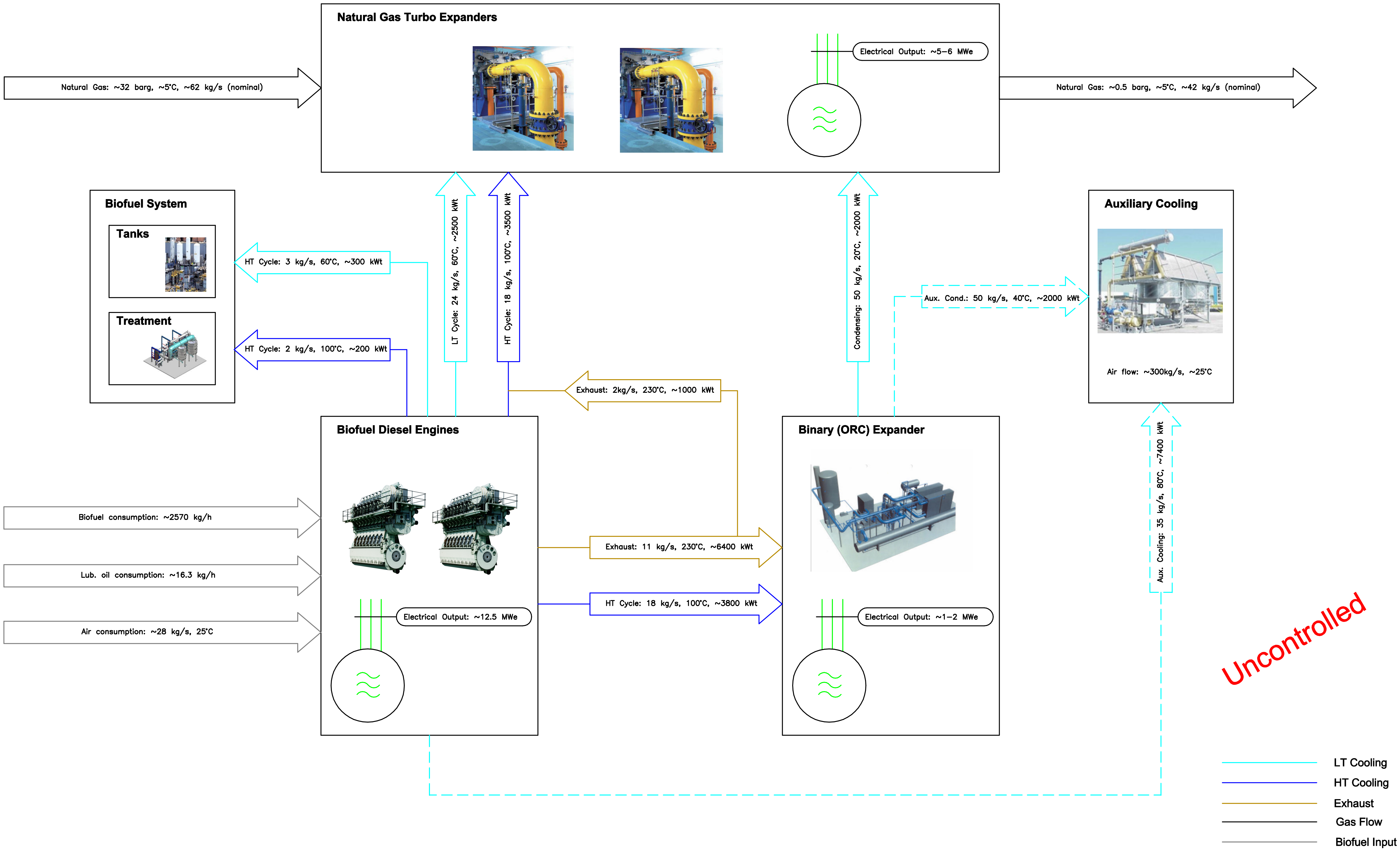
3.1.1 Pressure reduction stations and expansion turbines

Natural gas is transported long distances through transit pipelines at high pressures (5 - 7 MPa) (Pozivil, 2004). When being used for consumption or when passing into a lower pressure pipeline the pressure of the gas must be reduced. It is reduced from 5-7 MPa to 1.5-4.0 MPa (usually to 2.5 MPa) into high pressure intrastate pipeline and then to approximately 0.3 MPa into medium pressure intrastate pipeline.

Gas pressure reduction is accomplished in throttle-valves where the isenthalpic expansion takes place without any energy production. In fact, most gases cool during expansion (the Joule-Thompson effect). The temperature drop in natural gas is approx. 4.5-6°C per 1 MPa, depending on a gas's composition and state. Thus gas must be preheated before expansion so as to ensure that no liquid or solid phase condenses in the output temperature.

In order to preheat gas, a small portion of the gas stream is diverted from the main flow and its pressure is reduced so that it can be combusted (Maddaloni, Rowe, 2006). The exhaust from the burnt fuel gas is then vented to the atmosphere. The remaining majority of gas flow is heated using the thermal energy obtained from combusting the small slipstream of fuel gas. Natural gas, high in pressure and temperature, is then expanded using an isenthalpic J–T valve to low the pressure and ambient temperature. After expansion, the gas leaves the let-down facility and enters a local distribution network at an appropriate pressure.

When an expansion turbine is used in place of the throttle valve, the energy in the gas can be used to produce electricity (Pozivil, 2004). The activity the gas performs is gained from its internal energy (enthalpy) and the gas cools rapidly in the turbine. Slovak research shows that the temperature drop in the expansion turbine is approx. 15-20°C per 1 MPa of pressure drop in transmitting stations from the transit pipeline, depending on a gas's composition, state and turbine's isentropic efficiency. When using an expansion turbine, the gas outlet temperature must remain above the hydrate zone and dew point. Before it enters the turbine, the gas also must be pre-heated to temperatures higher than when using throttle valves, usually to 55-85°C. The reliability of the pressure regulating and reduction stations must be assured, and, therefore, the expansion turbines are installed parallel to the existing conventional pressure-reducing valves. Expansion turbines are relatively small and compact. What is more, they are usually coupled with a generator in one power pack. The power output might reach hundreds of kW to several MW.



Útrás
Consulting Engineers
Furuvellir 13, Pósthólf 37, 602 Akureyri
S: 461 2920, 461 2921 Fax: 461 2922

Name:	Beckton CCBG Power Plant	Draw. no:	08105
Project:	Thermal - Power - Performance	Date:	Oct. 08
		Design:	ÞSB
		Scale:	~

3.1.2 Diesel engine

Blue-NG has ordered a series of MAN B&W type 10L35MC-S diesel engines (MAN Diesel, 2008). The first four engines will be installed at sites in Beckton and Southall. The two-stroke, low-speed engines will run on bio-liquids and will be built by MAN Diesel's Polish licensee, H. Cegielski – Poznan S.A. Each engine develops 6,450 kW at 214,3 rpm and has an ISO 3046 efficiency of 48,9 percent. Their high thermal efficiency is one of the major contributory reasons for the choice of this particular type of engine. In the segment of 6 MW, a typical efficiency of diesel engines varies between 42-47 percent. To improve the overall efficiency, useful heat will be recovered from the high temperature gas in the engine exhaust and from the cooling water that will be circulated through the engine to ensure it can continue to operate within its originally designed parameters.

In the CHiP plant, the thermal efficiency will be improved by including two additional heat recovery cycles. Consequently, the heat transported by the engine coolant will be transferred into a working fluid from which, by reducing its pressure when expanding it through a turbine, an additional shaft power can be extracted. During this process the temperature of the working fluid will be reduced – this describes the heat recovery process. The rotating shaft from each turbine is connected to a generator to produce additional electricity. These two distinct heat recovery cycles increase the overall thermal efficiency of the CHiP plant to over 80 percent (Blue-NG, 2008).

3.1.3 The first heat recovery cycle with ORC

The first heat recovery cycle involves the use of an Organic Rankine Cycle. This system will contain a working fluid which is a mixture of hydrocarbons. In the ORC, the working fluid will be pressurised and heated by the heat extracted from the engine passing through a heat exchanger.

To achieve a constant mass flow rate, the fluid's velocity increases as it passes through a nozzle connecting the high pressure reservoir with the lower pressure one. The jet of fluid exiting the nozzle will run the turbine. As a result, mechanical power will be produced and converted into electricity in a generator. The extraction of mechanical work from the fluid causes its temperature drop. The working fluid still needs to be cooled further to turn it back to a liquid state prior to it being compressed to a higher pressure where it will be ready to repeat the cycle again.

The cooling of the working fluid will be done by transferring the residual heat in the fluid to the natural gas flowing through the pipeline system operated by the National Grid through a heat exchanger. The thermal energy of the natural gas will be increased before its pressure reduction in the PRS (pressure reduction station). If no useful flow of natural gas in the system exists, the ORC and engine cannot run without an additional cooling. Therefore CHiP will have additional forced-air-fan configured heat sinks so as to enable its continuous operation (Blue-NG, 2008).

3.1.4 The second heat recovery cycle

The second heat recovery cycle generates power, as in the ORC, by expanding the working fluid through a turbine to create shaft power. The working fluid in this cycle is a natural gas transported by the pipeline system. The heat will be transferred to the natural gas to increase its temperature:

1. Initially by transferring heat from the ORC working fluid to the natural gas stream through a heat exchanger.
2. By heating the natural gas stream directly with the heat from the engine (via a heat exchanger).

The National Grid requires the pressure of the natural gas to be reduced at certain points of its network. Locating CHiP plants at those points where favourable site and flow conditions exist enables more renewable power to be generated from a unit of bioliquid than could otherwise be the case. Accordingly, it may contribute to the UK Government's renewable electricity target. The turbine placed in the natural gas flow will only extract heat from the natural gas so that the outlet temperature of the natural gas exiting the turbine remains greater or equal to the temperature of the natural gas that existed immediately before the introduction of heat to it. Consequently, the only source of energy that will be used in the production of electricity is the heat introduced from processes that consume liquid biomass (Blue-NG, 2008).

3.1.5 Cost of electricity generation

The expected cost of electricity generation for CHiP plant in Beckton is 76 £/MWh (84 €/Wh) where electricity costs for each module are as follows:

1. Diesel engine – 102 £/MWh or 112 €/MWh.
2. Organic Rankine Cycle – 6,12 £/MWh or 6,7 €/MWh.
3. Natural gas turbo expander 2,96 £/MWh or 3,3 €/MWh.

An average electricity generation price, as compared to plants that utilize other renewable energy sources, is high. According to Vattenfall 2006 annual report, only electricity generated from wind that costs between 73 and 91 €/MWh and PV (between 330 and 480 €/MWh (Thomas, 2008)) is more expensive. A CHiP unit using bioliquids (30 MW electricity and 80 MW heat) costs between 6,0 and 6,6 €/MWh (Vattenfall, 2007). The full comparison of electricity generation cost from different sources is presented in Table 3-1.

The calculations for electricity generation costs for CHiP in Beckton assumed 500 £ per tonne of bioliquids. However, this price depends on the price of fossil oil. At the beginning of 2009 the price of oil went down to approximately 42 $ per barrel which automatically lowered the price of palm oil to 380 £/tonne and about 300 £/tonne for jatropha. Yet the price of rapeseed oil, which is the UK's domestic oil, was still above 700 £/tonne, which showed that the cost of electricity generation can be lower when oils from Asia and South America or a blend of these oils with rapeseed oil are used.

3-1 A comparison of electricity generation cost from CHiP and other technologies

Technology	Cost of electricity generation €/MWh
CHiP average CHiP Diesel CHiP ORC CHiP NG turbo expander	84 112 6,72 3,25
Nuclear	37-44
Hydro	44-66
Windpower	73-91
Bioliquid CHP	60-66
PV	330-480
NGCC	56-65
Coal condensing	49-56

3.2 The UK rapeseed oil and biodiesel stock

Combined Heat and Intelligent Power plant in Beckton will be a large recipient of vegetable oil in the United Kingdom. The plant will burn 2,5 tonnes of vegetable oil per hour. Assuming that the plant will operate 8000 hours per year, 20 000 tonnes of vegetable oil will be burnt per year.

Rapeseed cultivation area in the UK in 2007 covered 681 000 hectares (Department for Environment and Rural Affairs, 2009). This area is able to produce approximately 2 160 000 tonne of rapeseed. Assuming that all this rapeseed is used to extract oil with hexane, 902 000 tonnes of oil can be produced. Thus it is possible to asses that one 20 MWe plant can burn 2,2 percent of the UK's rapeseed oil production and the eight planned plants can burn almost 18 percent. Data are presented in Table 3-2.

On the other hand, the United Kingdom's biodiesel production in 2006 amounted to 128 000 toe (PROGRESS, 2008), which corresponds to approximately 143 000 tonnes of rapeseed oil. This indicates that only one CHiP plant is able to burn 14 percent of the UK's biodiesel production per year (Table Table 3-3).

Table 3-2 The capacity of rapeseed oil production in United Kingdom

Cultivation area (2007)	681 000 ha
Avarage production (2003-2007)	3,17 t/ha
Avarage oil content in rapeseed	42 %
Maximum extraction yield with hexane	99,50 %
Rapessed producion	2 158 770 t/year
max oil yield (hexan extraction)	1,32 t/ha
total oil yield UK (hexan extraction)	902 149,98 t/year
CHiP consumption share of UK oil	2,2 %

Table 3-3 The consumption of UK biodiesel production by CHiP in Beckton

UK Biodiesel production	128 000 toe
Rapseed oil equivalent	142909 tonnes
Share of UK´s Biodiesel consumption	14%

3.3 Renewable Energy Policies and tariffs for electricity production in the Member States of the European Union

This chapter presents the most promising tariffs and policies in the EU countries for renewable electricity production. Only two countries, out of fourteen chosen, introduced the quota obligation. The rest of the countries use the feed-in tariff system for subsiding green electricity. The list below also includes the United Kingdom as the country where the CHiP project is starting first.

3.3.1 The United Kingdom

1. The Renewables Obligation Order came into force in April 2002. The order requires the licensed electricity suppliers to generate at least part of their electricity from a renewable generation. The amount of the Renewables Obligation starts at 3 percent of the total electricity supplied to customers in Great Britain in 2002/2003 and is to reach 12,4% in 2012/2013.
2. All licensed suppliers have to produce evidence that they have supplied a specified proportion of their electricity supplies to customers in Great Britain from eligible renewable sources. The relevant percentages were set to 3 percent of the total supplies in 2002/2003, the second was 4.3 percent in 2003/2004 and these are to rise to 12,4 percent in 2012/2013.

3. In order for ROC's to be issued, the station generating electricity must be accredited by Ofgem (an electricity regulator) as capable of generating electricity from eligible renewable sources. The participation of a generating station in the scheme is voluntary, yet such stations have to fulfill certain criteria before they can be accredited.
4. The suppliers are allowed to make buy-out payments instead of producing ROCs for all or part of its obligation.
5. The total buy-out payments received by Ofgem together with any interest earned, known as the buy-out fund, are to be distributed back to those suppliers who have correctly produced ROCs in proportion to the total number of correctly produced ROCs for the obligation period.
6. An exemption from the Climate Change Levy (tax for electricity) of 6,26 €.
7. The total amount (including interest) due to be redistributed for 2007-08, the sixth year of the obligation, was £307 180 739, which equates to £18.65 for each ROC presented. The non-compliance buy-out price was 49,74 €/MWh.
8. The non-compliance buy-out price in 2008/2009 has been set by Ofgem at £35.76/MWh (39,67 €/MWh in January 2009). Table 3-4 presents ROCs targets and prices for period 2002-2009.

Table 3-4 Renewables Obligation targets, buy-out price and amount recycled to producers 2002- 2009

Year	**Targets - % of supply**	**Non-compliance buy-out price***		**Amount recycled**
		£/MWh	**€/MWh**	**£/MWh**
2002-03	3	30	43,50	15,94
2003-04	4,3	30,51	44,24	22,92
2004-05	4,9	31,39	45,52	13,66
2005-06	5,5	32,33	46,88	10,21
2006-07	6,7	33,24	48,2	-
2007-08	7,9	34,30	49,74	18,65
2008-09	9,1	35,76	39,67	-
*Exchange rate used £1:1,45 except year 2008-09 which is 1:1,11				

3.3.2 Austria

1. Fixed budget for RES-E 21 million €/year up to 2011 (30 percent for biomass).
2. Must apply for the permission "first come, first served" - granted as long as there is a sufficient budget. The application is kept for one year, after which companies must re-apply and join the bottom of the list.

3. FITs are guaranteed for 10 years, but the Minister of Economics may extend it in individual cases to 13 years for fuel independent technologies and 15 years for fuel dependent technologies. For the period thereafter (until the age of 24 years is reached) a purchase obligation at the market price for electricity (minus the cost of balancing power) is applied.
4. Feed-in tariffs (for new RES-E plants). Solid biomass and waste tariff in 2008 was between 113 and 157 €/MWh.
5. CHP plants receive investment support of up to 10 percent of the direct investment costs, though maximal 400 €/kW.
6. Biofuels – 95 percent exemption from the fossil fuel taxes, introduced in 1995.

3.3.3 Belgium

1. Renewable electricity obligation on suppliers, combined with a tradable green certificate system (different green certificates for different Belgian regions).
2. Companies which fail to reach their target by the end of the certificate accounting period must pay a fine.
3. A minimum price is guaranteed (fall-back prices) for the sale of RES-E to give security to RES-E investors (Table 3-5).
4. The income from trading green certificates is additional to the price of electricity.

Table 3-5 Prices of Green Certificates for biomass in Belgium

Region		**Flanders**	**Wallon**	**Brussels**	**Federal**
Target	%	6% by 2010	7% by 2007	2,5% by 2006	
Duration	years	10	10		
Min price (fixed)	€/MWh	80	65		20
Penalty	€/MWh	125 (2005-10)	100 (2005-07)	100 (2007-10)	

3.3.4 Germany

1. The main promotion scheme is Renewable Energy Act 2004. Regulations which are important for the CHiP project include:

- the fees paid for electricity produced in plants with capacity of up to and including 20 MW using biomass exclusively,
- minimum fees shall be increased,
- The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is authorised to issue, in agreement with the Federal Ministry of Consumer Protection, Food and Agriculture and the Federal Ministry of

Economics and Labour and with the consent of the Bundestag, an ordinance with provisions as to which substances shall be deemed to be biomass within the meaning of this provision, which technical processes may be used to produce electricity and which environmental standards must be complied with.

2. Feed-in tariffs for biomass installations 80,3 or 100 for CHP €/MWh (2006).
3. 20-40 €/MW possible bonus for innovation.
4. An annual reduction of tariff 1,5 percent.
5. The duration of payment - 20 years.

3.3.5 The Netherlands

1. A new subsidy scheme has been in force since April 2004.
2. Feed-in tariff for biomass smaller than 50 MWe is 120 €/MWh.
3. The contract duration is 12 years.
4. A maximum subsidy in contract period is 289 million Euros.
5. Because of the "fresh" changes introduced in RES policies (transition of RES-E policy), access to data in English is very limited.

3.3.6 Spain

1. Biomass and cogeneration technologies development was insufficient. Consequently, the tariff for biomass has been increased.
2. A higher disaggregation of tariff categories for biomass has been implemented.
3. Two kinds of tariffs are in use: fixed tariff and premium.
4. Introduction of cap and floor price for premium tariffs.
5. Liquid biofuels: premium and FITs for a period of 1-15 years and FITs only for the period longer than 15 years (Table 3-5).
6. The tariffs for biomass cogeneration and for liquid biomass are the same as for the electricity production.

Table 3-5 Fixed and premium tariffs for liquid biomass in Spain

Category	**Period (years)**	**Fixed price (fixed tariff) €/MWh**	**Market option (€/MWh)**		
			Reference premium	**Cap**	**Floor**
Liquid biomass	1-15	53,6	30,8	83,3	51,0
	> 15	53,6	0	0	0

3.3.7 Slovenia

1. According to the Law on Energy, the network operators are obliged to purchase electricity from "qualified producers" either for fixed feed-in tariffs or premium feed-in tariffs (Table 3-6).
2. The RES-E producer chooses between the fixed and premium tariff.
3. The tariff reduction by 5 percent after 5 years and by 10 percent after 10 years.
4. The network operator and the qualified producer sign a Purchase Agreement covering the purchase of electricity from the qualified producer for a period of 10 years.
5. Subsidies or loans with reduced interest-rates are also available. These financial incentives aim at using RES for heating, electricity and highly efficient cogeneration plants.
6. Two different soft loans are normally offered every year by the "Environmental fund of the Republic of Slovenia" – the loan can cover up to 90 percent of investment, with a fixed annual interest rate of 3M-Euribor+0,3 percent for maximum duration of 15 years with moratorium of interest up to 2 years.

Table 3-6 The level of feed-in tariffs for biomass 2006- present

Technology	Capacity	Tariff (€/MWh)	
		Fixed	Premium
Biomass	Up to 1 MW	94	57
	More than 1MW	91	54

7. Tariffs can be adjusted within the double tariff system, if RES-E producers choose the option to get variable tariffs depending on load categories defined within the FIT-system. Three different seasons and two daily categories are distinguished in Table 3-7.

Table 3-7 Factors in the double-tariff-system in Slovenia

	Higher daily tariff item (HDT)	Lower daily tariff item (LDT)
High season (Jan, Feb, Dec)	1,4	1,0
Middle season (Mar, Apr Oct, Nov)	1,2	0,85
Low season (May-Sept)	1,0	0,7

3.3.8 Czech Republic

1. A feed-in system for electricity from RES and cogeneration is implemented.

2. Fixed tariffs or premium tariffs are available.
3. Producers can choose between fixed or premium tariffs each year.
4. Feed-in tariffs are guaranteed for 15 years and cannot be reduced more than 5 percent per year.
5. The premium tariff‘s duration time is set annually.
6. In 2008 fixed tariff was set between 93 and 161 €/MWh for biomass combustion and depended on the technology used. The premium tariff was set between 44 and 112 €/MWh.
7. The act on the promotion of electricity and heat produced from RES (2005) allows producers of electricity in combined heat and power plants to receive a bonus to the electricity price depending on the installed capacity of the plant and the fuel.
8. The State Environmental Fund, supervised by the Minister of the Environment, offers investment support for selected projects, from 30 to 80 percent of the investment costs, depending on the status of the applicant, which, in general, should represent a non-profit enterprise.

3.3.9 France

1. Feed-in tariffs system implemented – Law 2000-08 modified by Law 2005-781.
2. For renewable energy installations up to 12 MW (except for wind which has no longer this maximum limit) tariffs depend on source type and may include a bonus for some sources).
3. Biomass tariff is 49 €/MWh + 12 €/MWh bonus for efficiency.
4. Tariff duration is 15 years.
5. The disadvantage of French RES-E is national tender system for installation with capacity bigger than 12 MW (rule: the cheapest win).

3.3.10 Denmark

1. Fixed feed-in tariffs for biomass plants have been used.
2. The subsidy together with the market price will ensure a tariff of 60 øre (0,08€) /kWh for 10 years and 40 øre (0,05 €)/kWh for the following 10 years.
3. CHP plants above 10MW are operating under market conditions. However, they can apply for an individual, non-production related subsidy paid for up to 20 years.

3.3.11 Greece

1. The main promotion schemes for RES-E in Greece are based on Law 2244/94 (feed in tariff), Law 2773/1999 (liberalisation) and on the recently approved feed-in law.
2. The tariffs are guaranteed for 12 years with a possibility of extension up to 20 years.
3. The tariff for biomass & biogas is 73 €/MWh on mainland and 84,6 €/MWh on the autonomous islands.
4. Biofuels are exempted from fossil fuel taxes (Law 3423/2005).

5. Law 3299/2004 supports investment activities (including energy investments) of private companies (investment subsidy of about 30-40 percent depending on the geographical region or 100 percent tax deduction on all RES-investments cost for a 10-year period).

3.3.12 Hungary

1. A new electricity act came into force on 1st January 2008. This act (Act number LXXXVI of 2007 on electricity) and its related decrees have set the new feed-in tariffs for renewable electricity. Subsidies are available from certain funds (the central environment protection fund and the regional development fund) that operate under the Action Programme for Energy Saving.
2. The main objective of Electricity Act is to create a comprehensive promotion system on the basis of a green certificate scheme.
3. According to the Act, the Government will define the start date of the scheme's implementation. Until the date of the implementation has been set, a feed-in system operates. In 2005 a regulation with technology-specific feed-in tariffs has been adopted (Decree 78/2005).
4. The tariffs have been changed by the electricity act of 2007. The tariffs are guaranteed for the lifetime of the RES-E plant. The Table 3-8 contains feed-in tariffs for 2008.

Table 3-8 Fixed feed-in tariffs for biomass technology in Hungary

Technology		**Fixed tariff (€/MWh)**
Biomass power plant smaller than 20 MW	Peak time	117,3
	Off peak time	105
	"Deep" off peak time	42,9
20 – 50 MW power plant, which received its licensee after Jan 2008	Peak time	93,8
	Off peak time	84
	"Deep" off peak time	34,24

3.3.13 Ireland

1. The feed in tariff (REFIT) is the main support instrument for new renewable electricity projects.
2. 119 million Euros' support will be available through the feed-in tariff scheme over 15 years starting from 2006 (guaranteed for 15 years).
3. The fixed feed-in tariff for biomass has been 72 €/MWh since 2006.
4. However, the support cannot extend beyond 2024, meaning that the guaranteed REFIT payments should start no later than in 2009.

3.3.14 Italy

1. An obligation system with green certificates for producers and importers is used in Italy.
2. The obligation target in 2008 was 3,8 percent and is to increase by 0,75 percent per year till 2012.
3. The 2008 budget law (Law 244/2007) established that new installations (defined as those which started operating after 1 January 2008) will be granted green certificates for the duration of 15 years.
4. Green certificates are issued to plants with production of more than 1 MWh, changing the default energy value of certificates from 50 MWh to 1 MWh.
5. The quantity of green certificates granted to renewable power producers with installations larger than 1 MW is calculated by multiplying the real power production and a coefficient, which varies for different RE technologies.
6. The electricity production of plants fuelled by biomass or biogas, either agricultural or animal with a short chain supply, i.e. supplied within the range of 70 km from the site plant, having a capacity higher than 1MW is granted the issuance of Green Certificates, for a period of 15 years.
7. The plants mentioned above shall be entitled to receive Green Certificates equal to the net output multiplied by 1.8.
8. The Green Certificates issued by GSE are sold at a price equal to the difference between the reference value – 180 €/MWh for the first year and the annual average price for electricity sale defined by the AEEG (Italian Regulatory Authority for Electricity and Gas)(Watson, Farley and Wiliams, 2008).
9. An average free market price of electricity in 2008 was 74,14 €/MWh
10. A reference green certificate price set up by GME (the Power Service Administrator) in 2008 was 135,46 €/MWh. However, the market price was 87,97 €/MWh (Autorità per l'energia elettrica e il gas, 2008).
11. The legislation concerning non-compliance and legal sanctions (the Regulatory of Electricity and Gas can suspend or terminate the electricity license) for those that do not comply with the obligations is currently ineffective.
12. There are concerns about the uncertainty of the Italian law at the beginning of 2008 due to its changes.

3.3.15 Portugal

1. Fixed feed-in tariff system is guaranteed for 15 years.
2. The tariffs depend on the monthly inflation's correction, time of feed-in (peak or off-peak), technology used and the characteristics of resource.
3. Fixed feed in tariffs for biomass (limited only to forest and animal) are presented in Table 3-9.

4. The investment subsidies up to 40percent and tax deductions are available.

Table 3-9 Fixed feed-in tariffs for electricity from biomass in Portugal

Technology		2007 (€/ MWh)
Forest biomass	< 5 MW	109
	> 5 MW	107
Animal Biomass	< 5 MW	104
	> 5 MW	102

3.4 Non-governmental organizations' views on the Blue-NG's project

Non-Governmental Organisations have started to have a big influence on the renewable energy projects. They represent an active group of citizens that have a great contribution in the public consultations. It is common knowledge that due to their lobbying and public protests, a lot of the projects must be cancelled or changed so as to be more sustainable and environment-friendly. The Blue-NG's project in Beckton has both supporters and opponents in Non-Governmental Organizations. One of the opponents is Biofuelwatch, the principles of which are:

- they campaign against the use of bioenergy from unsustainable sources,
- provide support for organizations which campaign for substantial cuts in greenhouse gas emissions in all sectors based on an overall demand reduction,
- work closely with those adversely affected by the emerging global agrofuels market, and biofuel targets and incentives in industrialised countries, including the EU. Moreover, they create links and supportive networks with organisations in the global South whose environment, livelihood, food sovereignty, food security and human rights are threatened by the large-scale agrofuel monocultures,
- highlight the environmental and social impact of the global agrofuels market,
- call for a moratorium on the research and development of biomass-to-liquids agrofuels,
- lobby governments, international bodies, institutions, NGOs and industries (Biofuelwatch, 2006).

The Biofuelwatch have been campaigning against the plans for vegetable oil combined heat and power plants in the UK. They are also against plans for building a CHiP plant at Beckton which "will be the first such CHP plant in the UK and could pave the way not just for seven similar plants by Blue-NG but potentially for similar investment by other companies" (Biofuelwatch, 2008). In their opinion, the plant would largely be fuelled by palm oil and, in the future, possibly by jatropha oil because of the tense situation in the world‘s vegetable oil markets and the high price of rapeseed oil. What is more, the organisation believes that vegetable oil use for CHP in the UK will have an impact on the rain and peat forests in Asia and South America. They also think that it could have a negative impact on air pollution, as experienced by communities living close to CHP palm oil plants in Germany.

The concerns of NGOs were also placed in an open letter written to UK government and local authorities, which has been signed by about 90 organisations. They claim that there is no evidence that large-scale truly ‘sustainable’ sourcing of agrofuels is possible. In their opinion, the UK government must abandon all incentives and subsidies for industrial agrofuels. They also believe that decentralised energy can play an important role in reducing greenhouse gas emissions (An open letter to the UK government and local authorities and other relevant organisations, 2008).

Notwithstanding, not all NGOs are against Blue-NG project. The company has a strong supporter in Greenpeace UK. The organisation’s goal is to guarantee the Earth’s ability to nurture life in all its diversity. Accordingly, they organise campaigns:

- for preventing climate change by ending the global addiction to polluting fuels and promoting clean, renewable and efficient energy,
- for the protection of oceans and ancient forests,
- for the elimination of toxic chemicals,
- against the release of genetically modified organisms into nature,
- for nuclear disarmament and an end to nuclear contamination (Greenpeace).

Greenpeace endorses the plans of constructing combined heat and power plants using the energy from natural gas pressure reduction stations around the UK to produce electricity. Greenpeace UK also believes that CHP units “should play a pivotal role in this strategy” (Greenpeace UK, 2008). Despite supporting the project, Greenpeace UK is however concerned about the sustainability of biofuels and bioliquids, especially in transport. Greenpeace is also against the use of palm oil that is usually shipped to Europe by companies that destroy forests to set up plantations, for example in Indonesia. The Greenpeace investigation also shows that the certified sustainable palm oil, which is shipped to Rotterdam, is unsustainable. Therefore the companies failed the certificates by:

- clearing peatlands,
- intruding into the buffer zones around the Runtu lake complex,
- developing plantations without an approved Environmental Impact Assessment,
- having triggered significant land conflicts without a mutually agreed resolution process in place (Greenpeace, 2008).

4 CONCLUSIONS

A Combined Heat and intelligent Power plant constitutes an innovative technological enterprise which uses Organic Rankine Cycle and natural gas turbo expanders to produce electricity from waste heat and natural gas pressure in the grid. The use of these technologies and highly efficient diesel engines guarantees a 62 percent efficiency in the electricity production (82 percent input energy efficiency), which is an excellent result for power plants. However, these innovations result in high costs of renewable electricity generation. Also the cost of the fuel is very unstable and difficult to assess. The price of vegetable oils fluctuates strongly depending on oil yields (weather, plant diseases etc.) and fossil oil prices, which will influence the costs of electricity generation. Yet the utilization of the surplus heat and the natural gas geopressure will stabilize the electricity generating cost.

Research in renewable energy policies in the EU countries has shown that the CHiP project can be utilized. Four Member States are the most promising: Austria, Germany, the Netherlands and Portugal. These countries have the highest subsidies for electricity generation and cogeneration from biomass and also additional support programs (Table 4-1). Portugal and the Netherlands have increased subsidies for electricity generation to enlarge the share of biomass, which was recently insufficient. Austria and Germany have already had much experience in RES-E production and the use of vegetable oils in electricity generation. They guarantee additional subsidies for cogeneration and innovations (Germany) and investment support (Austria). However, though these countries look promising, a thorough analysis of the policies is needed, especially for the Netherlands where RES policies have been changed recently. There can be several problems with the allocation of natural gas pressure as a renewable source, which has been solved in the United Kingdom.

The research has shown that the United Kingdom's rapeseed oil and biodiesel production can be insufficient for Blue-NG projects. One planned CHiP plant can consume approximately 2,2 percent of UK's potential for rapeseed oil production and about 14 percent of biodiesel production. Also the price of rapeseed oil producers in the UK and Europe is higher than assumed in the project and it is very likely that they will be higher in the future because of the rising demand for biofuels in the EU.

The company will be forced to import high amounts of vegetable oils (in the worst case 20 000 tonnes per year) from Asia and South America. These oils (especially palm and jatropha) can have a strong green house gases reduction potential if they are produced in a sustainable way. Moreover, they can increase the emission of CO2 equivalent more than 20 times if they are cultivated on clear peat and in rain forests. The plantation owners are also accused by many organizations of depraving natives of lands, lowering their living standards and forcing them to change their traditional habits. These examples constitute strong arguments against biofuel projects and Blue-NG will have to deal with them in the near future.

Table 4-1 The Member States chosen as the best for further place of investment

Country	Feed-in tariff (€/MWh)		Premium tariff (€/MWh)	Duration for FIT	Reduction rate per year	Additional subsidies and support
Austria	min	113	-	10	-	Investment support up 10%, maximum 400 €/kW
	max	157		15	-	
Germany	min	80	-	20	1,50%	20- 40 €/MWh for innovative systems
	max	100				
Netherlands	120		-	12	nd	nd
Portugal	min	107	-	15	-	Investments up to 40% and tax deductions
	max	102				

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