BIODIESEL

APPLICATION FOR FREIGHT TRANSPORT

Anders Lehmann Pultz Knudsen, Kent Bentzen, Michael Stie Laugesen

Aalborg | October 2014

Preface

Today's transport sector is heavily dependent on fossil fuels, which causes significant increases in air pollution. This is in particular crucial in urban areas with high density of transportation. The transition towards alternative fuels is a key factor to fight pollution and to achieve decarbonisation, sustainability and competitiveness of the transport sector.

In Denmark, Høje-Taastrup Municipality is especially concerned and proactive in this area. The project Høje-Taastrup Going Green was launched on 1st of January 2014, where one of the main goals is promoting a fossil free transport sector. Particularly the freight sector is targeted due to the high level of pollution it creates.

A main objective of the project is to create a platform for further use and development of alternative fuels in the freight transportation sector. A special focus is therefore on illustrating the possibilities and perspectives of the alternative fuels: electricity, hydrogen, gas (CNG, LNG and biogas) and biodiesel. At the moment, the application of alternative fuels is not competitive with traditional fossil based propellants. Thus, it is important to prospectively set up the framework and establish the infrastructure to integrate and foster alternative fuels in Høje-Taastrup Municipality.

In line with the project, a set of catalogues of different propellants were developed, focusing on the utilisation of electricity, hydrogen, gas and biodiesel for freight vehicles. Each catalogue analyses the propellant in terms of technology, environmental impact, economics and related policy instruments, in order to point out its applicability and hurdles.

The following catalogue will elaborate on biodiesel driven vehicles.

Table of Contents

List of Figures

List of Tables

1 OVERVIEW

1.1 EU and Danish Goals and Targets

The EU's goal is to reduce emissions by 80 to 95% by 2050 compared to 1990 levels. The transport sector is a significant and still growing source of greenhouse gas (GHG) emissions. Therefore, a reduction of at least 60% of GHGs by 2050 with respect to 1990 is required from the transport sector, which is then followed by a comparable reduction in oil dependency. In order to achieve the target, the EU white paper on transport includes these relevant goals:

- "Halve the use of 'conventionally fuelled'[1] cars in urban transport by 2030;
- Phase them out in cities by 2050;
- Achieve essentially CO_2-free city logistics in major urban centres by 2030". [1]

To strengthen this, Denmark has a challenging goal to reach 100% fossil fuel independence within the transport sector by 2050. Regarding this, almost the entire vehicle fleet needs to become zero-emission.

As a fact, EU transport is 95% dependant on oil and its products. Figure 1 illustrates the final energy consumption in the transport sector in 2011 by type of fuel and emphasise the need of taking actions towards greener transport.

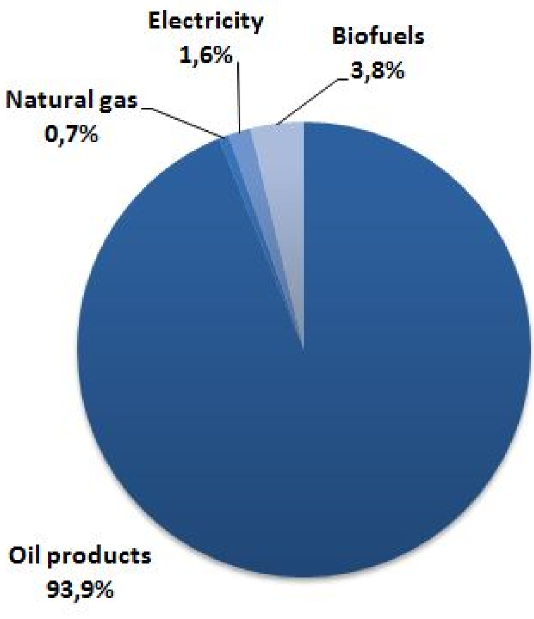

Figure 1: Final energy consumption in EU transport sector by type of fuel

[1] The term refers to vehicles using non-hybrid, internal combustion engines.

1.2 Application of Alternative Fuels

The transport sector cannot rely only on one single type of alternative fuel. In the long run, it should be based on a mix of several different fuels, with respect to the needs of each transport mode. The coverage of travel range by different alternative fuels is summarised in Table 1 for urban, light-duty and heavy-duty vehicles. Biofuels stand for biodiesel and methane stands for CNG/CBG (compressed natural gas/biogas) and LNG/LBG (liquefied natural gas/biogas). [2]

Vehicle							
Range	Urban	Short	Medium	Long	Short	Medium	Long
Electricity							
Hydrogen							
Biofuels							
Methane							LNG

Table 1: Application of alternative fuels for different transport modes [2]

To conclude, electricity can be applied only for short travel distances, hydrogen and CNG/CBG up to medium distances, and biofuels and LNG/LBG up to long distances. [2]

Electricity, both battery vehicles and fuel cell vehicles, is expected to be applied mainly for the car fleet. Regarding heavy-duty transport, biofuels and methane are prioritised due to the technical reasons. As a result, for the freight transport sector, in particular for long-distance transportation, limited alternative fuels are available. [2]

However, the set of catalogues examines all the different alternative fuels (electricity, hydrogen, biodiesel, CNG/CBG and LNG/LBG) and their possibility to be applied to heavy-duty vehicles.

2 INTRODUCTION

One of the options for the transport sector to meet the EU targets mentioned above is application of biofuels. Today, most vehicles run on either petrol or diesel, which can use biofuels blends of bioethanol or biodiesel respectively. Because most vehicles for distribution operate on diesel, this catalogue will emphasise on biodiesel. The following will elaborate on the production, use and regulations of this type of alternative fuel.

2.1 Fuel Production Method

When talking about biofuel production, including biodiesel, a distinction is often made between 1st, 2nd and 3rd generation biofuels. Biofuels produced from sugar- or starch containing crops or oil seeds are characterized as 1st generation fuels. Some consider 1st generation biofuels as being directly related to a biomass that is generally eatable. [4] 2nd generation bio-fuels is produced from residues such as straw, branches and the like, or is produced from gasified biomass and waste or animal waste products. Another difference between the two is that the supply of materials used in the production of 2nd generation biodiesel is significantly cheaper than for the materials used in 1st generation biodiesel. 3rd generation biofuels are mostly related to algae. Therefore, the major difference between the 2nd and 3rd generations is the feedstock. Algae are known to produce biomass faster and on reduced land surface as compared with lignocellulosic biomass. Nevertheless, production of algal biomass presents technical challenges such as lipid extraction and dewatering, which makes it less widespread as a feedstock for production.

It is possible to use non-modified pure vegetable oil in a diesel engine, but it requires modification of the vehicle's fuel system to make the product thinner by warming it up before injection into the engine. The most widely used vegetable oil is canola oil.

Biodiesel is produced by the chemical modification of animal or vegetable fat or oil to obtain a product with diesel-like properties. This is obtained through the technology seen in Figure 2, thus creating a reaction between oils or fats and methanol to create fatty acid methyl ester (FAME) or biodiesel.

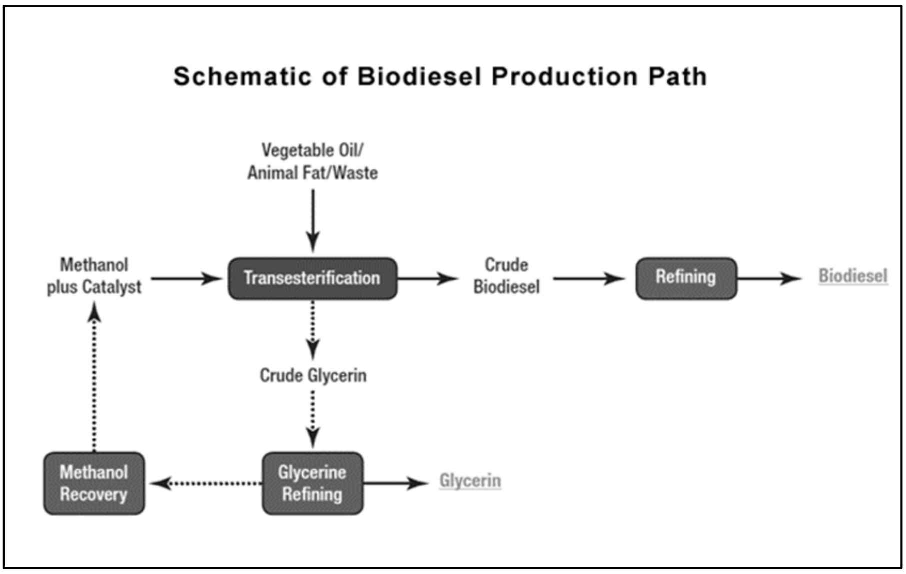

Figure 2: The production process of biodiesel [3]

This process is called transesterification and only creates glycerine as a bi-product. Roughly speaking, 100 pounds of oil or fat are reacted with 10 pounds of a short-chain alcohol (usually methanol) in the presence of a catalyst (usually sodium hydroxide [NaOH] or rarely potassium hydroxide [KOH]) to form 100 pounds of biodiesel and 10 pounds of glycerine. Glycerine is used in pharmaceuticals and cosmetics among other markets. [3]

All types of vegetable and animal oils and fats can be used for biodiesel production, as all oils and fats have the same fundamental structure. Only the content of specific fatty acids is different, including the content of unsaturated fatty acids relative to saturated. Among other differences, the most important is that a high content of saturated fatty acids increases the solidification point, while a high content of unsaturated fats lowers it. For instance, because of their different composition, biodiesel from animal fats solidifies at a higher temperature than biodiesel made from vegetable oils due to a higher level of saturated fatty acids. This is especially relevant when operating an engine with biodiesel, because it is used in a wide spectrum of temperatures.

2.1.1 Animal Biodiesel – AFME

Animal biodiesel is made from animal fat and provides animal fatty acid methyl ester (AFME). The fat can come from slaughterhouse waste, fish waste, used cooking oil, animal carcasses from agriculture or animal waste. AFME has a relatively high content of saturated fatty acids, and therefore there will be some challenges in substituting conventional diesel in high blends.

2.1.2 Vegetable Biodiesel – RME and others

Vegetable biodiesel can be made from:

- Rapeseed oil that gives rapeseed oil methyl ester, abbreviated RME;
- Sunflower oil, giving sunflower oil methyl ester;
- Soybean oil, giving soybean oil methyl ester;
- Palm oil, providing palm oil methyl ester.

Rapeseed oil methyl ester and sunflower oil methyl ester have the lowest content of saturated fatty acids and can thus relatively easy substitute for regular diesel also in high blends.

2.1.3 Pure Vegetable Oil - Cold Pressed Rapeseed and others

The above oils used for vegetable biodiesel can in principle be used unmodified, i.e. in clean hot or cold pressed form.

Cold-pressed rapeseed oil is made from rapeseed, which is first dried and cleaned, then pressed in a special press. No chemicals or other substances are added, and rapeseed cake remaining after pressing can either be used as protein feed or as fuel instead of wood pellets.

Cold-pressed rapeseed oil can be used as raw material for RME biodiesel and diesel engines. In the latter, the oil is filtered to less than 1 micron, and production requires diligence in terms of cleanliness, so the product can meet the standards of biofuels as motor fuel. The amount of phosphorus and other inorganic compounds in the finished oil is much less compared to an alternative hot pressing of rapeseed oil, and therefore cold-pressed rapeseed oil is attractive when the standard of biofuels must be observed.

Cold-pressed rapeseed oil can in principle be produced in smaller regional facilities, which may reduce transportation costs, and the refining process is less energy intensive than the production of biodiesel. These advantages, however, are limited to some extent by the requirements of the manufacturing process. As for all oils and fats of biological origin, rapeseed oil contains glycerine. The glycerine is removed and replaced with methanol through the conversion to biodiesel, which makes the oil viscous. The oil must be preheated to a temperature of 75-90°C for use as motor fuel.

2.1.4 Properties of Biofuels

As mentioned before, each type of biodiesel has different properties depending on the materials used for production. Especially with regards to temperature, there are unique properties for saturated fats and unsaturated fats, thus increasing and lowering the solidification point respectively. For different types of pure biodiesel, this is illustrated in Figure 3, where a high level of saturated fats increases the solidification temperature. At low temperature the saturates typically precipitate as paraffin, which has a soft solid form. The precipitated paraffin clogs fuel lines and filters and should therefore be avoided. The lowest temperature at which the biodiesel can pass through the standard filter is called cold filter plugging point (CFPP). UCO in the figure stands for the used cooking oil.

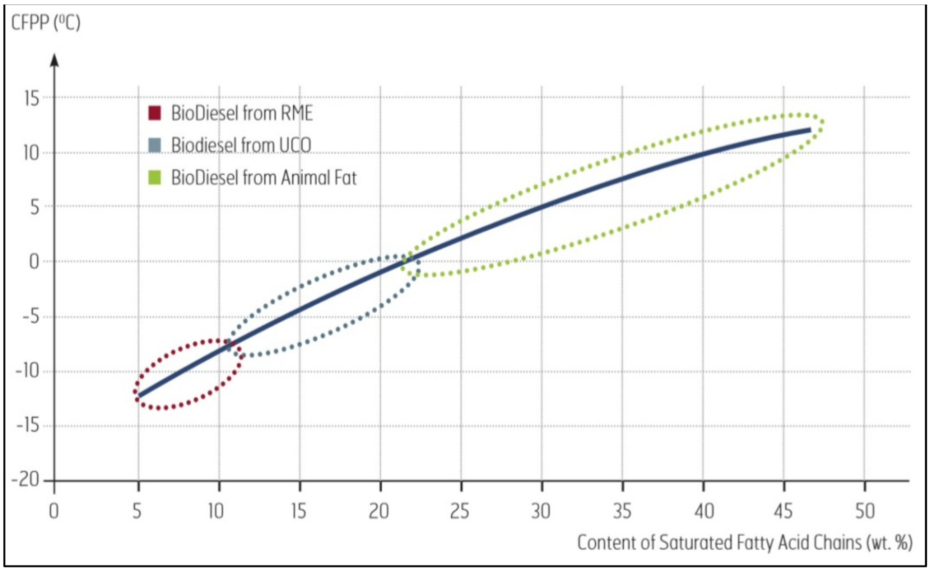

Figure 3: Cold filter plugging point vs. the weight of saturated fatty acid chains [14]

As seen in the figure above, paraffin excretion occurs for pure AFME already at about 10°C, but can vary and depends largely on the raw material originally used in their production. Biodiesel from used cooking oil has a lower solidification point than biodiesel from pure animal fat. Biodiesel made from rapeseed oil (RME) can withstand freezing temperatures better. Table 2 shows paraffin excretion for different blends of biodiesel. For instance, B10 blend consist of 90% regular diesel and 10% biodiesel. Compared to B100, this means that if biodiesel is mixed with regular diesel the excretion temperature is lowered and thus also the CFPP.

Blend	CFPP [°C]
Regular Diesel	-24
B10	-18
B15	-15
B30	-7

Table 2: Cold Properties AFME mixtures [10]

Overall, this information is important when operating vehicles on biofuels. Different properties of the fuels and their blends make them useful in different conditions of operation.

2.1.5 Production of Biodiesel in Denmark

There are several biodiesel producers in Denmark, but most of the production is exported to countries where the framework conditions are better than in Denmark, for example Germany and Sweden. Examples of producers are Emmelev A/S [6] and Daka ecoMotion [7]. Emmelev A/S production is primarily based on rapeseed oil, and has the capacity to produce more than 100 million litres per year. Daka Biodiesels uses animal fat extracted by-products from slaughterhouses and primary agriculture as the primary raw material. Daka plant has a production capacity of 55 million litres of biodiesel annually. [8]

Production of biodiesel is a known and proven process and raw materials are easy to find in Denmark. However, the total cost of the purchase of raw materials and the manufacturing process are still too high to make biodiesel competitive with diesel. Therefore, the widespread use of biodiesel requires tax reductions or government assistance. Alternatively, the use of biodiesel is promoted by the government who claimed a certain percentage mixed in conventional diesel.

Generally, there are standards to follow when producing biodiesels. EU has introduced the following standards (see the full descriptions of the standards in Annex 2):

- The EN 590 norm for auto diesel: i.e. contains a number of technical specifications, including a maximum of 7% blend of biodiesel;
- The EN 14214 norm for biodiesel;
- The DIN 51605 norm for rapeseed oil fuels.

In June 2009 the Danish government agreed on a regulative that imposes every company to ensure that biofuels account for at least 5,75% of its total annual sales of fuels for ground transportation. This law has been active since June 2011 and it ensures a certain amount of biofuels in the supply of fuels consumed for ground transportation, thus influencing the production in- and outside Denmark. [9]

2.2 Availability

Because of law enforcements, all fuels for ground transportation in Denmark are blends with 5,75% biodiesel, thus making the availability high. However, most gasoline stations do not provide biofuels with higher blends than the EN 590 norm. This means that users who desire higher blends need to be provided directly from the biodiesel producers, such as Emmelev A/S or Daka ecoMotion. In order to do so, the customer needs to have storage capacity for the biodiesel, which is delivered by truck. [8] Aside from storage capacity, the customer may also need to acquire assets that can mix a blend that matches their specific need. [10]

3 TECHNOLOGY

3.1 Technology Description

Biodiesel can be mixed with fossil fuels or used as a pure product. Biodiesel in low blends are directly interchangeable with fossil fuels for use in ordinary diesel engines without operational problems as long as it complies with the blend requirements of EN 590. Use of biodiesel in high blends, as a clean product (b100) or running on cold-pressed rapeseed oil may however require minor modifications of the engine and/or fuel system.

Common for driving with biodiesel and cold-pressed rapeseed oil is that the engine oil is required to be changed in intervals that are more frequent. The engine's oil can be affected because a small amount of fuel can pass the engine pistons and get into the engine oil. Biodiesel and especially rapeseed oil do not evaporate as fast as ordinary diesel and can therefore accumulate in the oil, which loses its properties, making it necessary to change the oil. According to the car manufacturers, it is necessary to change oil twice as frequently as when driving on conventional diesel. Furthermore, it is advised to change rubber hoses and gaskets. [10]

Regarding vehicles fuelled with cold-pressed rapeseed oil, the plant oil's higher viscosity is a particular challenge and it is necessary to install equipment so that the oil is preheated to at least 75°C. To avoid problems with cold and thick flowing rapeseed oil in the fuel system during start-up, it is necessary either to start and heat the engine with ordinary diesel from a separate tank, the so-called two-tank system, or to install electric heater equipment, so that the rapeseed oil can be heated to the desired temperature before starting. In the former, when the engine is started and heated with conventional diesel, the system automatically switches to rapeseed oil, which has been preheated to 75°C using the engine cooling water. Before the engine is stopped, the injection system must be flushed with regular diesel, thus the system shifts to diesel. The flushing process flushes the system with approximately 10-15 litres of diesel and consumes 0,5 litres of diesel in the process. The flushing takes 4-5 minutes. If the driver forgets to switch to diesel before the engine is stopped, the control system emits an alarm and you should start the engine again to perform the complete rinsing process. A flushing should be made if the car is stationary for more than six hours in winter and a few hours in summer, or it may find it difficult to start. [10]

3.2 Operation and Maintenance

Trafikstyrelsen has made several tests with biodiesels and rapeseed oil in the period 2008-2010, thus gaining experience in operation and maintenance of vehicles. The types of vehicles in the experiments were trucks, busses, vans and personal vehicles. [10]

3.2.1 Diesel with a Maximum 7% Blend of Biodiesel

The experience with this mixture of fuel shows no problems in the operations of the vehicle. This is also to be expected since it is the maximum blend level the manufacturers recommend.

3.2.2 Blends Higher than 7% AFME and RME

Operations of vehicles with the blend of more than 7% biodiesel provide no unexpected service needs or breakdowns. Experiences were made with operations of various blends of up to B30, but also a test of B100 was performed. The result of B100 is dependent on the vehicle, as newer vehicles have adopted combustion technologies that make them incapable of running entirely on B100. Operating on B100 was without any further problems than lower blends, but was run on a rather old engine, which tend to be better capable of running on high biodiesel blends. Running with blends up to B30 showed no operational problems and is also compatible with most engines. To ensure operations during the winter period, a B30 was replaced by B10 in the period from December to February. In the test period, the temperature was as low as -15°C not creating any operational problems for the vehicle.

The following practical experiences were made:

- Firstly, switching to using biofuels, the fuel filters in some cases became clogged. This is because biodiesel has a cleansing effect on a lightly soiled tank, from which the dirt is collected by the filter;
- Secondly, visual inspection of fuel nozzles showed no visible differences after driving ordinary diesel and B15 biodiesel;
- Thirdly, it is necessary to change the engine oil almost twice as often as compared to what vehicle manufactures normally prescribes;
- Fourthly, the vehicle's oil-fired boilers are operating without problems at temperatures above -5 °C. However, B30 AFME may face a problem below this temperature. A solution to this is, for instance, to use a lower blend, i.e. B10 AFME, or biodiesel blends with RME in it;
- Fifthly, there may arise problems of getting insurances of the vehicle and there is no guarantee that the car manufacturer allows warranty with higher blends.

3.2.3 Cold-Pressed Rapeseed Oil

The biggest challenge for this type of fuelling is to heat the fuel sufficiently enough in order to use it in the engine. Especially during the winter months, Trafikstyrelsen has experienced this as a challenge due to the low temperatures during these months. Other experiences were:

- The engine oil should be changed twice as often than what the vehicle manufacturer usually prescribes. Even more frequent oil changes are necessary for cars with many starts and stops;
- If the abovementioned rules are followed, the engine and emission control equipment is not affected negatively by driving on rapeseed oil;
- When using the two-tank system, the vehicles may have trouble switching between regular diesel and rapeseed oil in winter;
- Vehicles can get problems to be started, especially in winter, if the engine is not turned off correctly after the previous use;
- The car's oil burner is not expected to work optimally with cold-pressed rapeseed oil, but it is not tested.

3.3 Safety

Due to the similar characteristics of conventional diesel and biodiesel it is perceived as equally safe. Biodiesels have a higher flash point temperature, which may suggest that it is slightly safer than conventional diesel.

4 ENVIRONMENTAL IMPACT

One of the major greenhouse gasses is carbon dioxide. When combusted in an engine, biodiesel has roughly the same environmental impact as conventional diesel but emissions are calculated differently. [10] The overall performance of biofuels regarding emissions varies when considering the lifecycle of the fuel, from production to transport use, including the type of feedstock used, the production process and the amount of fossil energy needed in the process. [11] Plants used as feedstock in the production absorb carbon dioxide through photosynthesis from the atmosphere while growing. When the biodiesel produced from this particular feedstock is used, the carbon dioxide is released back again. As opposed to fossil fuels, this creates an isolated ecosystem where a relatively fixed amount of carbon dioxide is linked to the lifecycle of the biodiesel. [11] Furthermore, 2nd generation production does not follow the same ecosystem, but instead uses waste products in the biodiesel production.

It is hard to measure the precise environmental impact of biodiesel fuels. However, it is important to consider the production process and what indirect effects it may have. Here, it is significant to look at the production method and the type of feedstock used. Other factors to include in the calculation of environmental effects are emissions from growing the feedstock (incl. fertilizers), transporting the feedstock to the production facility and processing the feedstock into biodiesel. [11]

Production material (100% biodiesel, B100)	Typical savings in GHG emissions	Default savings in GHG emissions
Pure vegetable oil from rape seeds	58%	57%
Biodiesel from rapeseed oil	45%	38%
Biodiesel from sunflower	58%	51%
Palm oil biodiesel (non-specified process)	36%	19%
Biodiesel from vegetable or animal oil waste	88%	83%
Biogas from municipal organic waste	80%	73%
Biogas from manure, compressed	86%	82%
Wheat ethanol (energy from CHP[2] plant)	53%	47%

Table 3: Typical and default emissions for biofuels if it is produced with no net carbon emissions [16]

The European Parliament and the Council's Directive of 2009/28/EF has estimated the "*typical and default emissions for biofuels if it is produced with no net carbon emissions*". Part of the estimations is shown in Table 3. [12]

According to this information, a higher level of emission savings is linked to the use of 2nd generation biodiesels compared to 1st generation. However, materials used for production of 2nd generation biodiesels are a limited resource, thus making it necessary to vary in the production methods.

[2] Combined heat and power

5 ECONOMICS

The economical perspectives of running on biodiesel are the following: [10]

- *Commodity price*: biodiesel and rapeseed oil are more expensive than regular diesel, i.e. the price can vary from just a little more expensive than regular diesel to twice as expensive.
- *Consumption*: Biofuels have slightly lower calorific value than regular diesel, which can give a few percent increase in fuel consumption.
- *Infrastructure*: Since there are only few supplier depots from where biofuels can be delivered, there may occur an expense in transporting the fuel to the user. Furthermore, expenses could arose for the establishment of local storage tanks, fuel dispensers and possibly heated mixing tanks for AFME, if the depot cannot deliver the mix. These tanks need to be cleaned up more often than conventional diesel.
- *Maintenance and repairs*: Engine oil needs to be changed twice as often when driving on blends of more than 7% biodiesel and driving on cold-pressed rapeseed oil compared to driving on regular diesel and blends of biodiesel up to 7%. There may be increased repair costs, especially in connection with the operation of cold-pressed rapeseed oil.
- *Conversion of vehicle*: Driving with a cold-pressed rapeseed oil requires modification of the vehicle fuel system. Driving with biodiesel may require replacement of hoses and gaskets.

6 POLICY INSTRUMENTS

Initially, requirements of a minimum blend of 5,75% biodiesel in all Danish fuels for ground transportation was adopted in 2009 and applicable from 2011. In March 2012, the government made an energy policy agreement with several other parties for the period 2012-2020. This means that the agreement is secured by broad political support for an ambitious green transformation. It focuses on energy conservation throughout society and integration of more renewable energy in the form of wind turbines, biogas and more biomass. An important factor in this matter is that the blending requirement for biofuels in petrol and diesel will be increased to a minimum of 10% in 2020. [13]

7 SUMMARY

Table 4 summarises the main findings about biodiesel as an alternative fuel for the transport sector. Strengths and weaknesses are found in terms of technology, environment, economics and policy instruments.

	Strengths	Weaknesses & Improvements needed
Technology	Easy to implement: biodiesel and rapeseed oil can be run on a conventional internal combustion engine	Modification needed for running rapeseed oil (additional tank) Characteristics of biodiesel make it vulnerable to cold weather Poor biodiesel infrastructure
Environment	2nd generation biodiesel has the highest emission impact. The production includes waste products	Emission reduction is highly dependent on production method and blend
Economics	No need to invest in entirely new vehicles	Biodiesel and rapeseed oil are more expensive than regular diesel Few supplier depots may result in infrastructural expenses Increased need for maintenance, i.e. change of engine oil Driving with a cold-pressed rapeseed oil requires vehicle modification
Policy	Regulations already enforced: blend of 5,75% biodiesel In 2020, a minimum of 10% biodiesel blend is required	

Table 4: Strengths and weaknesses of biodiesel and biodiesel driven vehicles

REFERENCES

[1] http://ec.europa.eu/transport/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf

[2] http://ec.europa.eu/transport/themes/urban/cts/doc/2011-01-25-future-transport-fuels-report.pdf

[3] http://www.afdc.energy.gov/fuels/biodiesel.html

[4] http://www.animalfrontiers.org/content/3/2/6.full.pdf+html

[5] http://www.afdc.energy.gov/fuels/biodiesel_production.html

[6] http://www.emmelev.dk/

[7] http://www.dakaecomotion.dk/fileadmin/user_upload/ecomotion_dk/downloads/6130_Biodiesel_-_transport_DK.pdf

[8] https://www.landbrugsinfo.dk/energi/andre-teknologier/sider/Biodiesel.aspx

[9] http://www.ens.dk/klima-co2/transport/biobraendstoffer/iblandingskrav-reduktion-braendstoffers-drivhusgasintensitet

[10] http://www.trafikstyrelsen.dk/DA/Gr%C3%B8n-Transport/Gron-vejtransport/Forsoeg-med-biodiesel.aspx

[11] http://www.greenfacts.org/

[12] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:DA:PDF

[13] http://www.ens.dk/sites/ens.dk/files/politik/dansk-klima-energipolitik/politiske-aftaler-paa-energiomraadet/energiaftalen-22-marts-2012/Faktaark%201%20Energiaftalen%20kort%20fortalt.pdf

[14] Hilber, Mittelbach & Schmidt (2006), Animal Fats perform well in Biodiesel, Render Magazine February 2006

[15] http://www.engineeringtoolbox.com/

[16] The European Parliament and the Council's Directive of 2009/28/EF

ANNEX 1: FUEL PROPERTIES COMPARISON

Table 5 gives an overview of the main properties of different alternative fuels, which can then be compared to conventional fuels. These are the following:

- **Physical state**.
- **Feedstock**.
- **Composition**.
- **Gasoline gallon equivalent** is the amount of alternative fuel, which has the same energy content as one gallon of gasoline. This factor is used to compare the energy content of different competing alternative fuels to the conventional fuels. As a note, 1 US gallon is equal to 3,8 litres.
- **Density** is mass of certain substance per unit volume.
- **Calorific value** of the fuel shows the amount of energy released as heat by the complete combustion of fuel (unit of mass or volume).
- **The flash point** of a volatile liquid is the lowest temperature where the fluid evaporates to form a combustible concentration of gas. It indicates how easy a chemical may burn. Chemicals with higher flash points are less flammable or hazardous, making the fuel safer to handle and transport. [15]
- **The autoignition temperature** is the minimum temperature at which gas or vapour spontaneously self-ignites in air without external source of ignition (spark or flame). Higher autoignition temperature typically indicates a safer substance. [15]

The values of the properties are approximate and can differ depending on the fuel composition.

Characteristics	Units	Conventional fuels		Alternative fuels				
		Petrol (gasoline)	Diesel	Electricity	Hydrogen	Biodiesel	CNG/CBG	LNG/LBG
Physical state	-	Liquid	Liquid	Electricity	Compressed gas or liquid	Liquid	Compressed gas	Cryogenic liquid
Fuel material (feedstock)	-	Crude oil	Crude oil	Coal, nuclear, natural gas, hydro, wind and solar	Natural gas, methanol, electrolysis of water	Fats and oils from sources such as soy beans, waste cooking oil, animal fats, and rapeseed	NG: Underground reserves BG: Biomass, sewage, agricultural waste, certain industrial wastes, municipal waste, energy crops	
Composition	-	C_4 to C_{12}	C_8 to C_{25}	N/A	H_2	Methyl esters of C_{12} to C_{22} fatty acids	CH_4 (83-99%), C_2H_6 (1-13%)[3]	CH_4
Gasoline gallon equivalent	-	100%	1 gallon of diesel has 113% of the energy of 1 gallon of gasoline	33,7 kWh has 100% of the energy of 1 gallon of gasoline	1 kg of H2 has 100% of the energy of 1 gallon of gasoline	0,96 gallon of B100 or 0,90 gallon of B20 has 100% of the energy of 1 gallon of gasoline	3,9 gallons (2,6 kg) of CNG has 100% of the energy of 1 gallon of gasoline	1,56 gallons of LNG has 100% of the energy of 1 gallon of gasoline
Density (average)	**kg/m3**	749	851	N/A	40	860-890	175	455
Lower calorific value	**MJ/l**	32,4	35,8	3,6 (MJ/kWh)	4,8	33,4 (B100)	8,2	20,8
	MJ/kg	43,3	42,1		121	38,2	47,1	45,7
Flash point	**°C**	-45	126	N/A	N/A	min. 120	-184	-188
Autoignition temperature	**°C**	257	210	N/A	500	373-448 (B100)	580	580

Table 5: Comparison of different alternative and conventional fuels

[3] Composition of row biogas: CH4 (50-80%), CO2 (20-50%)

ANNEX 2: SUMMARY OF STANDARDS FOR BIODIESEL

		EN 590 norm for autodiesel	EN 14214 norm for biodiesel			DIN 51605 norm for rapeseed oil fuels	
Property	**Unit**	**Specs**	**Specs**	**Typical value AFME**	**Typical value RME**	**Specs**	**Typical value cold-pressed oils**
Cetane Number	min.	min. 51	min. 51	61	> 51	min. 39	49.3
Density, 15°C	kg/m³	820-845	860-900	876	883	900-930	920
Sulphur Content	mg/kg	max. 10	max. 10	8	5	max. 10	5.2
Flash Point	°C	min. 55	min. 120	> 140	160	min. 220	240
Water	mg/kg	max. 200	max. 500	150	150	max. 750	582
Dirt	mg/kg	max. 24	max .24	5	< 24	max. 24	6
Viscosity	mm²/s	2.0-4.5	3.5-5.0	4.53	4.4	max. 36	34.39
Calorific value	m/kg	-	-	37	38	min. 36	37.7
Ester Content	% (V/V)	max. 7	min. 96.5	97	> 96.5	-	-

Table 6: Summary of standards for different types of biodiesel