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Energy Systems Research Unit

A Feasibility Study on Use of Alternative Fuels at Construction Site Activities

By

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Declaration of author's rights

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Executive Summary

The overall purpose of the project is to study the existing energy consumption on construction equipments and to analyze the effects on using alternative fuels.
After making a through site analysis and studying the various aspects involved in energy consumption pattern in transportation and building sector. A detailed analysis has been done with respect to the type of available alternative fuels their properties, government policies, equipments modification requirements, its advantage and disadvantages and the feasibility for real time implementation.

The rising fuel prices has necessitated the search for alternative energy resource usage. A few alternative energy sources are bio-diesel, ethanol, and fuel cell and hybrid vehicles are fast developing technology; each has its own advantage and disadvantage. As Fuel cell technology and hybrid vehicle technology is at its infant stage it is difficult to incorporate them into the existing systems due to their cost implications, hence the next available technology for the existing situation with less or no modifications on the application of bio-fuels such as ethanol and biodiesel, which upon replacing to a considerable portion will reduce the fuel price inflations and the protects the environment there giving the company a good corporate image and stressing its role towards energy conservation and environmental protection.

The methodology will involve a detailed study about the current situation and then comparing it with the literature study on the alternative fuels which include analyzing the existing conditions in UK and the scope for alternative fuel security in future. A basic reflection to the above proposal will be the collection of the existing

energy consumption patterns and hence after the data collection stage the available data are segregated and analyzed and time frame for each activity are set. Necessary contingency measures are taken to prevent the deviation of the focus of the topic area.

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Chapter 1

Biomass Energy Basics

Biomass energy or "Bioenergy" is the energy obtained from plants and plant-derived materials—since people began burning wood to cook food and keep warm. Wood is still the largest biomass energy resource today, but other sources of biomass can also be used. These include food crops, grassy and woody plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills (which are methane, a natural gas) can be used as a biomass energy source.

Biomass can be used for fuels, power production, and products that would otherwise be made from fossil fuels. In such cases, biomass can provide an array of benefits. For example:

- The use of biomass energy has the potential to greatly reduce greenhouse gas emissions. Burning biomass releases about the same amount of carbon dioxide as burning fossil fuels. However, fossil fuels release carbon dioxide captured by photosynthesis in plants, millions of years ago—an essentially "new" greenhouse gas. Biomass, on the other hand, releases carbon dioxide that is largely balanced by the carbon dioxide captured in its own growth (depending on how much energy was used to grow, harvest, and process the fuel).

- The use of biomass can reduce dependence on foreign oil because biofuels are the only renewable liquid transportation fuels available.

- Biomass energy supports agriculture and forest-product industries. The main biomass feed stocks for power is the paper mill residue, lumber mill scrap, and municipal waste. For biomass fuels, the feed stocks are corn, (for ethanol) and soybeans, rapeseed, and jathropa (for biodiesel).

Classification of Biomass

Biomass could be broadly classified into the following as

- Biofuels
- Biopower
- Bioproducts

Biofuels

Unlike other renewable energy sources, biomass can be converted directly into liquid fuels, called "biofuels," to help meet transportation fuel needs. The two most common types of biofuels are ethanol and biodiesel.

Ethanol is an alcohol, the same as in beer and wine. It is made by fermenting any biomass high in carbohydrates through a process similar to beer brewing. Today, ethanol is made from starches and sugars. Ethanol is mostly used as a fuel additive for vehicles to increase octane and cut down carbon monoxide and other smog-causing emissions.

Biodiesel is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking oil. It can be used as an additive (typically 20%) to reduce vehicle emissions or in its pure form as a renewable alternative fuel for diesel engines.

Conversion Processes

Biochemical Conversion Process

Enzymes and microorganisms are frequently used as biocatalysts to convert biomass or biomass derived compounds into desirable products. Cellulase and hemicellulase enzymes break down the carbohydrate fractions of biomass to five or six carbon sugars, a process known as hydrolysis. Yeast and bacteria ferment the sugars into products such as ethanol. Biotechnology advances are expected to lead to dramatic biochemical conversion improvements.

Photobiological Conversion Processes

Photobiological processes use the natural photosynthetic activity of organisms to produce biofuels directly from sunlight. For example, the photosynthetic activities of bacteria and green algae have been used to produce hydrogen from water and sunlight.

Thermo chemical Conversion Process

Heat energy and chemical catalysts are used to break down biomass into intermediate compounds or products. In gasification, biomass is heated in an oxygen-starved environment to produce a gas composed primarily of hydrogen and carbon monoxide. In pyrolysis, biomass is exposed to high temperatures in the absence of air, causing it to decompose. Solvents, acids and bases can be used to fractionate biomass into an array of products including sugars, cellulosic fibers and lignin.

Biopower

Biopower or Biomass power is used to generate electricity. Biopower system technologies include direct-firing/direct combustion, co-firing, gasification, pyrolysis, and anaerobic digestion.

Technologies

Direct Combustion

Direct combustion involves the burning of biomass with excess air, producing hot fuel gases that are used to produce steam in the heat exchanger sections of boilers. The steam is used to produce electricity in steam turbine generators.

Co-firing

Co-firing refers to the practice of introducing biomass in high-efficiency coal fired boilers as a supplementary energy source. Co-firing has been evaluated for a variety of boiler technologies including pulverized coal, cyclone, fluidized bed and spreader stokers. For utilities and power generating companies with coal-fired capacity, co-firing with biomass may represent one of the least-cost renewable energy options.

Gasification

Biomass gasification for power production involves heating biomass in an oxygen-starved environment to produce a medium or low calorific gas. This "biogas" is then used as fuel in a combined cycle power generation plant that includes a gas turbine topping cycle and a steam turbine bottoming cycle.

Pyrolysis

Biomass pyrolysis refers to a process where biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide).

Anaerobic Digestion

Anaerobic digestion is a process by which organic matter is decomposed by bacteria in the absence of oxygen to produce methane and other byproducts. The primary energy product is a low to medium calorific gas, normally consisting of 50 to 60 percent methane.

Biobased Chemicals and Materials

Biobased chemicals and materials are commercial or industrial products, other than food and feed, derived from biomass feed stocks. Biobased products include green chemicals, renewable plastics, natural fibers and natural structural materials. Many of these products can replace products and materials traditionally derived from petrochemicals, but new and improved processing technologies will be required.

Products and Applications
Green Chemicals

Many organic commodity chemicals, fine chemicals, and chemical intermediates can be made from biomass resources. Commodity chemicals include solvents, fuel additives, lubricants, surfactants, adhesives, and inks. Major fine chemical groups include enzymes, and pharmaceuticals.

Renewable Plastics

Plastics produced from biomass resources shows great scope for replacing plastics derived from petrochemicals. General categories include plant-based degradable polymers, carbohydrate (cellulose, starch and chitin) polymers, and lignin polymers. Examples include starch esters, cellulose acetate blends, polylactide (PLA), polyhydroxybutyric acid (PHB), and thermoplastic proteins.

Natural Fibers

Paper products, some textile products, and many types of rope, twine and string are all made from biomass fibers. Pulp and paper processes are being improved and new processes developed to use alternative feed stocks. New products are being developed based on natural fibers including insulation and geo textiles for soil erosion control applications. These fibers are also being used to replace nonrenewable materials as fillers for many products.

Natural Structural Materials

Many building products such as engineered lumber and structural panels are made primarily from wood. New composite structural materials are being made that incorporate biomass fibers as fillers with other organic (e.g. plastic) or inorganic (e.g. cement) components.

Bioremediation

Bioremediation is the application of biological systems to contaminated soils and water to convert or remove the contaminants and thereby improve their quality and restore them to their original state. Enzymes, microorganisms and plants are the major groups of bioremediation catalysts.

Production Technologies
Biomass Processing Systems

New and improved processing technologies are being developed to allow wider use of biomass resources to produce chemicals and materials. Major routes include chemical processing, bioprocessing, thermochemical processing and mechanical processing. Integrated or hybrid processes may offer the best opportunities for commercial success.

Separation Technologies

The ability to separate chemicals, chemical intermediates and materials from unique and complex processed biomass streams is essential to the commercial viability of these new technologies.

Chapter 2

What Is Biodiesel?

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. This process is described in more detail below. The largest possible source of suitable oil comes from oil crops such as rapeseed, palm or soybean. In the UK rapeseed represents the greatest potential for biodiesel production. Most biodiesel produced at present is produced from waste vegetable oil sourced from restaurants, chip shops, industrial food producers. Though oil straight from the agricultural industry represents the greatest potential source it is not being produced commercially simply because the raw oil is too expensive. After the cost of converting it to biodiesel has been added on it is simply too expensive to compete with fossil diesel. Waste vegetable oil can often be sourced for free or sourced already treated for a small price. (The waste oil must be treated before conversion to biodiesel to remove impurities). The result is Biodiesel produced from waste vegetable oil.

What are the benefits of Biodiesel?

Biodiesel has many environmentally beneficial properties. The main benefit of biodiesel is that it can be described as 'carbon neutral'. This means that the fuel produces no net output of carbon in the form of carbon dioxide (CO_2). This effect occurs because when the oil crop grows it absorbs the same amount of CO_2 as is released when the fuel is combusted. In fact this is not completely accurate as CO_2 is released during the production of the fertilizer required to fertilize the fields in which the oil crops are grown.

Fertilizer production is not the only source of pollution associated with the production of biodiesel, other sources include the esterification process, the solvent extraction of the oil, refining, drying and transporting. All these processes require an energy input either in the form of electricity or from a fuel, both of which will generally result in the release of green house gases. To properly assess the impact of all these sources requires use of a technique called life cycle analysis. Biodiesel is rapidly biodegradable and completely non-toxic, meaning spillages represent far less of a risk than fossil diesel spillages. Biodiesel has a higher flash point than fossil diesel and so is safer in the event of a crash.

The Need for Biodiesel

1. The five primary reasons for encouraging the development of biodiesel industry are
2. It provides a market for excess production of vegetable oils and animal fats. There is increasing demand around the world for soybean meal to provide the protein for human and animal consumption. If new markets are not found for the soybean oil, then the price will be low and farmers will have even more difficulty producing a profit. The animal by-products industry also has a problem with more supply than the current market can absorb.
3. It decreases the country's dependence on imported petroleum. Obviously, this reason should not be overemphasized since the percentage of the country's fuel supply that can be replaced with biodiesel will be small. However, petroleum markets tend to be sensitive to small fluctuations in supply so an additional source of fuel can have a surprising impact on keeping fuel prices stable.
4. Biodiesel is renewable and contributes less to global warming than fossil fuels due to its closed carbon cycle. Because the primary feedstock for biodiesel is a biologically-

based oil or fat, which can be grown season after season, biodiesel is renewable. And, since most of the carbon in the fuel was originally removed from the air by plants, there is very little net increase in carbon dioxide levels. However, some fossil carbon is contained in the methanol used to make methyl esters, and some fossil fuel is used during the production process. A life cycle study on biodiesel use in an urban bus conducted by the National Renewable Energy Laboratory[1] found that CO_2 emissions were reduced by 79% for pure biodiesel compared with petroleum diesel fuel.

5. The exhaust emissions from biodiesel are lower than with regular diesel fuel. Biodiesel provides substantial reductions in carbon monoxide, unburned hydrocarbons, and particulate emissions from diesel engines. While the carbon monoxide and unburned hydrocarbons from diesels are already very low compared with gasoline engines, biodiesel reduces them further. Particulate emissions, especially the black soot portion, are greatly reduced with biodiesel. Unfortunately, most emissions tests have shown a slight increase in oxides of nitrogen (NOx) emissions with biodiesel. This increase in NOx can be eliminated with a small adjustment to the engine's injection timing while still retaining a particulate decrease.
6. Biodiesel has excellent lubricating properties. Even when added to regular diesel fuel in an amount equal to 1-2%, it can convert fuel with poor lubricating properties, such as modern ultra-low-sulfur diesel fuel, into an acceptable fuel.[(2.3)]

Biodiesel Production

As mentioned above biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils. There are three basic routes to biodiesel production from oils and fats:

- Base catalyzed transesterification of the oil.
- Direct acid catalyzed transesterification of the oil.
- Conversion of the oil to its fatty acids and then to biodiesel.

Almost all biodiesel is produced using base catalyzed transesterification as it is the most economical process requiring only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report.

The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerine. The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters, ethanol produces ethyl esters) and is base catalyzed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, either base can be used for the methyl ester. A common product of the transesterification process is Rape Methyl Ester (RME) produced from raw rapeseed oil reacted with methanol.

The figure below shows the chemical process for methyl ester biodiesel. The reaction between the fat or oil and the alcohol is a reversible reaction and so the alcohol must be added in excess to drive the reaction towards the right and ensure complete conversion.

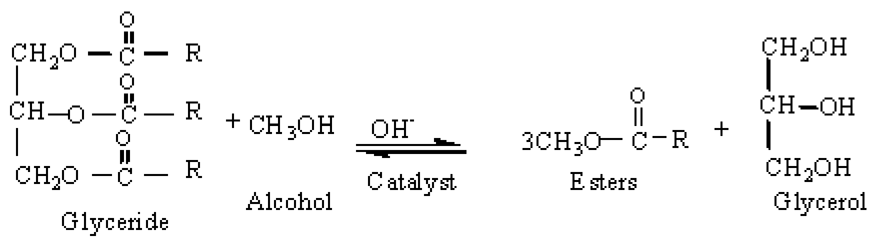

Figure 2.1 Chemical processes for Methyl ester biodiesel

The products of the reaction are the biodiesel itself and glycerol.

A successful transesterification reaction is signified by the separation of the ester and glycerol layers after the reaction time. The heavier, co-product, glycerol settles out and may be sold as it is or it may be purified for use in other industries, e.g. the pharmaceutical, cosmetics etc.

Straight vegetable oil (SVO) can be used directly as a fossil diesel substitute however using this fuel can lead to some fairly serious engine problems. Due to its relatively high viscosity SVO leads to poor atomisation of the fuel, incomplete combustion, coking of the fuel injectors, ring carbonisation, and accumulation of fuel in the lubricating oil. The best method for solving these problems is the transesterification of the oil.

The engine combustion benefits of the transesterification of the oil are:

- Lowered viscosity
- Complete removal of the glycerides
- Lowered boiling point
- Lowered flash point
- Lowered pour point

Production Process

An example of a simple production flow chart is proved below with a brief explanation of each step. [2.2]

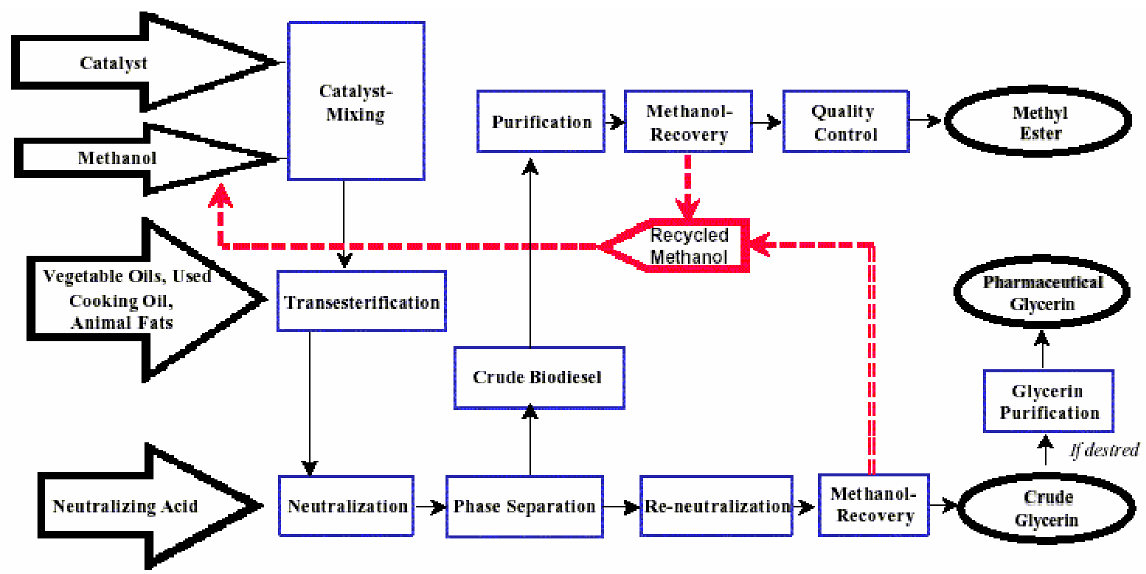

Figure 2.2 Schematic Diagram of a Biodiesel Production Process

Mixing of Alcohol and Catalyst

The catalyst is typically sodium hydroxide (caustic soda) or potassium hydroxide (potash). It is dissolved in the alcohol using a standard agitator or mixer. Reaction. The alcohol/catalyst mix is then charged into a closed reaction vessel and the oil or fat is added. The system from here on is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just above the boiling point of the alcohol (around 160 °F) to speed up the reaction and the reaction takes place. Recommended reaction time varies from 1 to 8 hours, and some systems recommend the reaction take place at room temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. Care must be taken to monitor the amount of water and free fatty acids in the incoming oil or fat. If the free fatty acid level or water level is too high it may cause problems with soap formation and the separation of the glycerin by-product downstream.

Separation

Once the reaction is complete, two major products exist: glycerin and biodiesel. Each has a substantial amount of the excess methanol that was used in the reaction. The reacted mixture is sometimes neutralized at this step if needed. The glycerin phase is much more dense than biodiesel phase and the two can be gravity separated with glycerin simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster.

Alcohol Removal

Once the glycerin and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation. In others systems, the alcohol is removed and the mixture neutralized before the glycerin and esters have been separated. In either case, the alcohol is recovered using distillation equipment and is re-used. Care must be taken to ensure no water accumulates in the recovered alcohol stream.

Glycerin Neutralization

The glycerin by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerin. In some cases the salt formed during this phase is recovered for use as fertilizer. In most cases the salt is left in the glycerin. Water and alcohol are removed to produce 80-88% pure glycerin that is ready to be sold as crude glycerin. In more sophisticated operations, the glycerin is distilled to 99% or higher purity and sold into the cosmetic and pharmaceutical markets.

Methyl Ester Wash

Once separated from the glycerin, the biodiesel is sometimes purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage. In some processes this step is unnecessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to petrodiesel. In some systems the biodiesel is distilled in an additional step to remove small amounts of color bodies to produce a colorless biodiesel.

Product Quality

Prior to use as a commercial fuel, the finished biodiesel must be analyzed using sophisticated analytical equipment to ensure it meets any required specifications. The most important aspects of biodiesel production to ensure trouble free operation in diesel engines are:

- Complete Reaction
- Removal of Glycerin
- Removal of Catalyst
- Removal of Alcohol
- Absence of Free Fatty Acids

Draft Specification for PR EN 14214 - The pure biodiesel standard.

Table 2.1 - Generally applicable requirements and test methods.

		Limits		
Property	**Unit**	**Minimum**	**Maximum**	**Test method**
Ester contect	% (m/m)	96.5		prEN 14103
Density at 15°C	kg/m ^{3}	860	900	EN ISO 3675 EN ISO 12185
Viscosity at 40°C	mm^2 /s	3,5	5,0	EN ISO 3104
Flash point	°C	above 101	-	ISO / CD 3679
Sulphur content	mg/kg	-	10	
Carbon residue (on 10% distillation residue)	% (m/m)		0,3	EN ISO 10370
Cetane number		51,0		EN ISO 5165
Sulphated ash content	% (m/m)	-	0,02	ISO 3987
Water Content	mg/kg	-	500	EN ISO 12937
Total contamination	mg/kg		24	EN 12662
Copper strip corrosion (3h at 50 °C)	rating	Class 1	Class 1	EN ISO 2160
Thermal Stability				
Oxidation stability, 110°C	hours	6		pr EN 14112
Acid value	mg KOH/g		0,5	pr EN 14104
Iodine value			120	Pr EN 14111

Linolenic acid methyl ester	% (m/m)		12	pr EN 14103
Polyunsaturated (>= 4 double bonds) methyl esters	% (m/m)		1	
Methanol content	% (m/m)		0,2	pr EN 14110
Monoglyceride content	% (m/m)		0,8	pr EN 14105
Diglyceride content	% (m/m)		0,2	pr EN 14105
Triglyceride content	% (m/m)		0,2	pr EN 14105
Free glycerol	% (m/m)		0,02	pr EN 14105 pr EN 14106
Total glycerol	% (m/m)		0,25	pr EN 14105
Alkaline metals (Na+K)	mg/kg		5	pr EN 14108 pr EN 14109
Phosphorus content	mg/kg		10	pr EN14107 [p]

Source: Rix Biodiesel company, UK

Table 2.2 Specification EN 590 - The current automotive diesel standard.

Parameter	Method	Result	Minimum	Maximum	Unit
Cetane Number	EN ISO 5165	55,0	51	-	-
Cetane Index	EN ISO 4264	52,0	46	-	-
Density at 15°C	EN ISO 12185	828.3	820	845	kg/m^3
Polycyclic aromatic hydrocarbons	IP 391/95	5.5	-	11	mass -%
Sulphur content	EN 24260	50	-	50	mg/kg
Flash point	EN 22719	65	55	-	°C
Carbon residue (on 10% distillation residue)	ISO 10370	0.01	-	0.3	mass -%
Ash content	EN ISO 6245	<0.001		0.01	mass -%
Water Content	pr EN ISO 12937	63	-	200	mg/kg
Total contamination	EN 12662	10	-	24	mg/kg
Corrosivity to copper	EN ISO 2160	1	1	1	Korr.degree
Oxidation stability	EN ISO	18	-	25	g/m^3

	12205				
HFRR at 60°C	ISO CD 12156	210	-	460	Um
Kin. Viscosity at 40°C	EN ISO 3104	2,37	2.0	4.5	mm^2/s
CFPP	EN 116	-16	-10	-	°C
Cloud Point	EN 23015	-5.9	-	-	°C
Distillation	ISO 3405: 1998		-	-	-
% (V/V) distillated at 250 °C	ISO 3405: 1998	45.3	-	65	% (V/V)
% (V/V) distillated at 350 °C	ISO 3405: 1998	96.8	85	-	% (V/V)
95% Point	ISO 3405: 1998	342,2	-	360	°C

Source: A copy from Rix Biodiesels

Existing Diesel Warranties

A growing number of manufacturers endorse the use of biodiesel both in blend with mineral diesel and pure as a 100% biodiesel fuel. The biodiesel is produced to conform to pr EN 14214 the proposed European standard. In a 95%diesel / 5% biodiesel blend the fuel meets the existing EN 590 automotive fuels specification. Numerous engine manufacturers have already endorsed the use of a 95/5 mix.

Table: 2.3 Existing Diesel Vehicle Warranties for 100% Biodiesel Operation

Audi	Personal cars	All TDI models since 1996
BMW	Personal cars	Model 525 tds/1997 onwards, 3 + 5 series diesel since 2001
Case-IH	Tractors	All models since 1971
Caterpillar	MMT, Industrial, marine	All engines except some Perkins
Claas	Combines, Tractors	Warranties exist
Faryman Diesel	Engines	Warranties exist
Fiatagri	Tractors	For new models
Ford	AG Tractors	For new models

Holder	Tractors	Warranties exist
Iseki	Tractors	Series 3000 and 5000
Iveco	Truck	Cursor since 2000
John Deere	Combines, tractors	Warranties since 1987
KHD	Tractors	Warranties exist
Kubota	Tractors	Series OC, Super Mini, 05,03
Lamborghini	Tractors	Series 1000
MAN	Truck	Engine numbers 8953591 to 8953001
Mercedes-Benz	Personal cars Lorry, bus	Series C and E 220, C200 and C220, a.o. Series BR300, 400, Unimog 1988 a.o.
Nissan	Personal car	Type Primera since 2001
PSA	Personal car	All Hdi up to 30% biodiesel Blend, Tractors Since 1990
Seat	Personal cars	All TDI since 1996

Source : Copy from Rix biodiesel Website, UK.

What are Biodiesel's Advantages?

From the above discussion it was noted that biodiesel is renewable, nontoxic, and biodegradable. Biodiesel has its own advantages and disadvantages. While biodiesel is definitely renewable, the fact that it cannot displace a significant fraction of our current petroleum-based fuel consumption means that it does not really allow us to make much progress toward a sustainable energy supply. Non-toxicity and biodegradability are useful characteristics but they are only significant when the fuel is used in its pure form (B100) as is common in Germany and Austria. For the 20% and lower blends that are common in the United States, the diesel fuel portion of the blend determines the toxicity and biodegradability. Biodiesel does provide a reduction in net CO_2 emissions. Although the amount of CO_2 emitted from the exhaust pipe per kilowatt of power is essentially the same as for petroleum diesel fuel, the carbon was originally removed from the atmosphere so there is little net change in atmospheric carbon dioxide. Biodiesel's primary advantages lie in its effect on cetane number, emissions, its flash point, and its lubricity.

Cetane number

The cetane number is an indication of a fuels readiness to auto ignites after it has been injected into the diesel engine. Diesel fuel for use in on-highway engines is required to have a cetane number of 40 or higher. Since higher cetane number translates into higher fuel cost, most refiners keep the cetane number of their diesel fuels between 40 and 45.

Table 2.4 shows the cetane numbers for some typical esters of vegetable oils. The cetane numbers are generally between 46 and 60 depending on the feed stocks used to make the biodiesel. Methyl esters tend to be slightly below ethyl and higher esters. Biodiesel from saturated feed stocks such as animal fat and recycled restaurant greases will be higher than the esters of oils high in polyunsaturates such as soybean oil.

The usual effect of a high cetane number is to shorten the ignition delay period between when the diesel fuel is injected and when it actually ignites. With conventional diesel fuel, the effect of shortening this period is to decrease the amount of fuel that is prepared to burn so that when auto ignition actually occurs, the combustion event will be less severe. This results in a lower rate of pressure rise and less engine noise. Most research indicates that this gradual start of combustion also helps to decrease NOx emissions. The research shows that biodiesel's higher cetane number does shorten the ignition delay and biodiesel's lower volatility also tends to reduce the rate at which fuel is prepared to burn during the ignition delay period. These two factors contribute to a more gradual start of combustion than occurs with diesel fuel. This more gradual start of combustion would be expected to cause a lower level of NOx emissions but, in fact, the opposite occurs. Oxides of nitrogen are generally found to increase with the use of biodiesel. The reasons for this will be discussed in more detail in the section on emissions.

Table 2.4. Cetane Number and Energy Content for Biodiesel Fuels

	Heat of Combustion MJ/kg	Cetane No.
Methyl Soybean	39.8	46.2
Ethyl Soybean	40.0	48.2
Butyl Soybean	40.7	51.7
Methyl Sunflower	39.8	47.0
Methyl Peanut	-	54.0
Methyl Rapeseed	40.1	-
Ethyl Rapeseed	41.4	-
No. 2 Diesel	45.3	47.0

Bagby, M.O. and Freedman, B., "Seed Oils for Diesel Fuels: Sources and Properties," ASAE Paper 871583, 1987.

Wagner, L.E., Clark, S.J. and Schrock, M.D., "Effects of Soybean Oil Esters on the Performance, Lubricating Oil, and Wear of Diesel Engines," Society of Automotive Engineers Paper No. 841385, 1984.

Freedman, B. and Pryde, E.H., "Fatty Esters from Vegetable Oils for Use as A Diesel Fuel," Vegetable Oil Fuels, Proceedings of the International Conference on Plant and Vegetable Oils as Fuels, American Society of Agricultural Engineers, Fargo, North Dakota, Aug. 2-4, 1982.

Emissions

Figure 2.3. Black Smoke from Diesel Exhaust pipe.

Here is the primary reason why we worry about emissions from diesel engines - black smoke. Although modern diesel engines are very clean, older diesels and diesels needing maintenance are notorious for emitting plumes of dense black smoke. Biodiesels' greatest advantage is its ability to reduce this smoke.

Table 2.5 Emissions on 3 engines with biodiesel

Test Engine	Test Fuel	Transient Emissions, g/hp-hr			
		HC	CO	NOx	PM
Cummins N-14	B100	0.01	0.41	5.17	0.076
Cummins N-14	B20	0.19	0.64	4.76	0.102
Cummins N-14	2-D	0.23	0.75	4.57	0.106
DDC Series 50	B100	0.01	0.92	5.01	0.052
DDC Series 50	B20	0.06	1.38	4.66	0.088
DDC Series 50	2-D	0.06	1.49	4.50	0.102
Cummins B5.9	B100	0.08	1.27	4.90	0.081
Cummins B5.9	B20	0.21	1.61	4.79	0.109
Cummins B5.9	2-D	0.31	2.05	4.70	0.128

From: Sharp, C.A., S.A. Howell, and J. Jobe, "The Effect of Biodiesel Fuels on Transient Emissions from Modern Diesel Engines, Part I Regulated Emissions and Performance," SAE Paper 2000-01-1967, 2000.

Table 2.5 shows that biodiesel can dramatically reduce particulate matter emissions. Unburned hydrocarbons and carbon monoxide are also reduced although they are not usually a problem with diesel engines. The above table also shows how NO_x can increase with the use of biodiesel. The reason for the NO_x increase is still an area of active research, but it is at least partially due to injection timing advances associated with property differences between biodiesel and petroleum.

Flashpoint

The flashpoint of a fuel is the temperature at which the vapors above the fuel become flammable. Petroleum based diesel fuels have flash points of 50^{o}C to 80^{o}C so they are considered to be intrinsically safe. Biodiesel has a flash point that is considerably higher than petroleum-based diesel fuel (above 160°C). This means that the fire hazard associated with transportation, storage, and utilization of biodiesel is much less than with other commonly used fuels. Flashpoint can also be used as a measure of whether the production process has been successful in removing the residual alcohol from the fuel. Figure 2.6 shows how the flashpoint decreases rapidly when a small amount of alcohol is left in the biodiesel. As 1% methanol in the biodiesel will drop the flashpoint below ambient where the fuel needs to be considered as hazardous as gasoline.

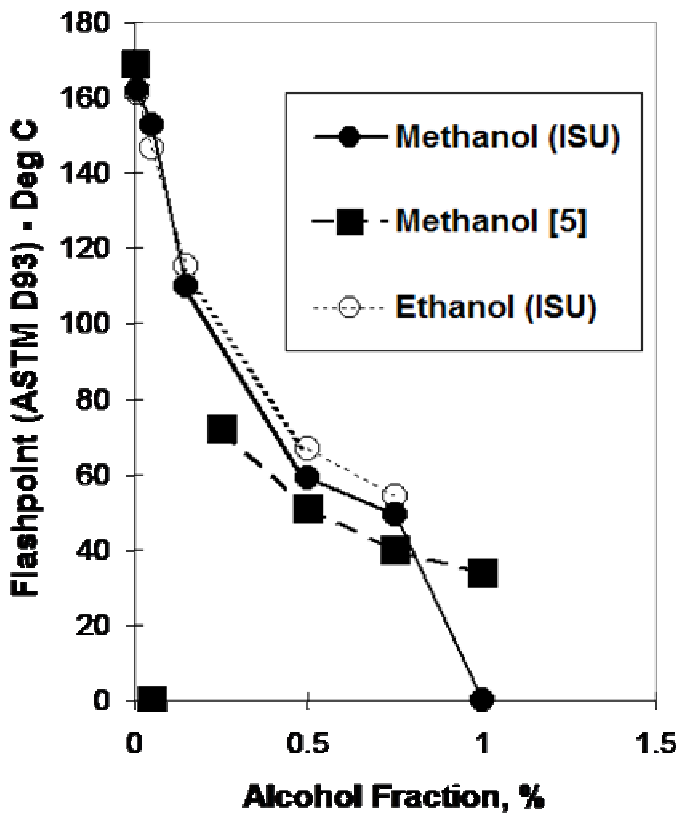

Figure 2.4 The effect of alcohol on the flashpoint of biodiesel
Howell, S., Research Director for the National Biodiesel Board, personal communication, June 1996.

Lubricity

Lubricity can be defined as: "The property of a lubricant that causes a difference in friction under conditions of boundary lubrication when all the known factors except the lubricant itself are the same. The lower the friction the higher the lubricity[2.4]

How is Biodiesel Used?

There are many ways to use alkyl esters including as solvents and as chemical intermediates for the formation of detergents. However, the application of most interest to us is as fuel. Fuel applications can be divided into 3 categories.

1. Pure fuel (B100)

Biodiesel can be used in its pure form, also known as neat biodiesel, or B100. This is the approach that provides the most reduction in exhaust particulates, unburned hydrocarbons, and carbon monoxide. It is also the best way to use biodiesel when its non-toxicity and biodegradability are important. Marine applications may be important for B100. Although neat biodiesel would not be expected to cause any operational problems, its solvent properties will be at their highest intensity and may cause problems with loosening of varnish deposits in fuel tanks and lines, degradation of fuel lines because some elastomers are not compatible with biodiesel (such as BUNA rubbers), and paint removal near fuel fill ports.

2. Blends (typically 20-50%)

Biodiesel will blend with petroleum-based diesel fuel in any proportion so it is common to use blends of 20 to 50% biodiesel in 80 to 50% No. 2 diesel fuel. Blends reduce the cost impact of biodiesel while retaining some of the emissions reduction. Most of the emissions reductions appear to be proportional to the percentage of biodiesel used. The cold flow and solvency problems noted with B100 are less of a concern when blends are used.

3. As an additive, 1-2% (B02)

Tests for lubricity have shown that biodiesel is a very effective lubricity enhancer. Even as little as 0.25% can have a measurable impact and 1-2% is enough to convert a very poor lubricity fuel into an acceptable fuel. Although these levels are too low to have any impact on the cetane number of the fuel or the emissions from the engine, the lubricity provides a significant advantage at a modest cost.

Other applications:

All three of the applications described above relate to diesel engines. Biodiesel has also been considered for use in spark-ignited engines , but without much success. Biodiesel is being used in a variety of non-engine applications such as solvents and paint remover.

Reference:

2.1) National Renewable Energy

2.2) Biodiesel Production and Quality, 1/03/02

http://www.biodiesel.org/pdf_files/prod_quality.pdf

2.3) Reference: Sheehan, J., V. Camobreco, J. Duffield, M. Graboski, and H. Shapouri, Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus," Report from the National Renewable Energy Laboratory for the U.S. Department of Energy's Office of Fuels Development and for the U.S. Department of Agriculture's Office of Energy, NREL/SR-580-24089, May 1998.

2.4) ." [Kajdas, C., S.S.K. Harvey, and E. Wilusz, *Encyclopedia of Tribology*, Elsevier, New York, 1990.]

Chapter 3

Introduction

Road transport is a vital element of the UK economy, and the freedom it brings is a highly valued commodity. But the growth of transport - fuelled almost exclusively from finite reserves of fossil fuels - has significant environmental consequences, particularly with respect to greenhouse gas emissions.

As the Government is committed to tackling climate change, and has set in place policies to move towards a 20 percent reduction in overall UK CO_2 emissions by 2010. In 2003 the Energy White Paper it is said that the UK should put itself on a path towards a reduction in CO_2 emissions of some 60% from current levels by 2050. It also stated that transport, currently responsible for some 25 percent of the UK's emissions, would need to play a key role in helping to deliver reductions in emissions of CO_2. Improving the efficiency of vehicles and reducing the need to travel will both form an essential part of this strategy, but in order to deliver deep cuts in emissions of carbon from the transport sector, there will need at some point to be a shift to low carbon fuels.

In the longer term, biofuels - fuels made from a variety of sources of biomass - offer the prospect of truly low carbon transport. The White Paper highlighted that biofuels were an important potential route for achieving the goal of zero carbon transport, and suggested that biofuels could account for some 5 percent of road transport fuels by 2020.

Biofuels have also risen to prominence in the wider EU context. In May 2003 the EU's Biofuels Directive came into force, requiring Member States to set indicative targets for biofuels sales in 2005 and 2010. The Directive also included 'reference values' for Member States to take into account in setting their own targets; 2 percent by energy content in 2005, and 5.75 percent by 2010.

The EU Biofuels Directive

As part of a wide range of measures to promote sustainable development, and in particular to tackle rising greenhouse gas emissions from transport, Directive 2003/30/EC "the Biofuels Directive" was agreed by the European Council and Parliament on 8 May 2003. The main objectives of the Directive are to reduce life-cycle emissions of carbon dioxide from transport across Europe, and to reduce the European Unions future reliance on external energy sources (in this case, oil).

The Directive aims to promote the use of biofuels or other renewable fuels as a substitute for petrol or diesel in the transport sector. It requires Member States to set indicative targets for biofuels sales for 2005 and 2010, and to introduce a specific labelling requirement at sales points for biofuel blends in excess of 5 percent.

The Directive requires Member States to take account of the reference values prescribed in setting their national indicative targets.

These reference values are:

- 2 percent, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005.
- 5.75 percent, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2010.

Member States must also report to the Commission each year on measures taken to promote the use of biofuels and on levels of biofuel sales. Although the Directive is clear that Member States are free to set their own indicative targets, it specifies that the annual reports to the Commission should justify any differentiation between the proposed national targets and the Directive's reference values.

To avoid unnecessary confusion, targets are considered on a volume of sales basis only. As a result, the costs and carbon savings quoted are somewhat lower than they would be if the sums had been done on the basis of energy content.

Broader policy context - Government climate change policy

Biofuels need to be considered within the context of the UK Climate Change Programme and the Government's broader policy to create a low carbon economy, as set out in the Energy White Paper (EWP). As both of these documents note, the transport sector has a key role to play in delivering carbon reductions.

The UK Climate Change Programme, which will be reviewed later this year, sets out the Government's plans for reducing emissions of greenhouse gases from all sectors in the period to 2010. It takes a balanced approach, with all sectors and all parts of the UK playing a part. It lists the measures that the Government has put in place to help deliver not only the UK's target under the Kyoto Protocol to reduce its greenhouse gas emissions by 12.5 percent below 1990 levels by 2008-2012, but also the UK's domestic goal of moving towards a 20% reduction in carbon dioxide emissions by 2010.

These measures include:

- The climate change levy package
- A UK-wide emissions trading scheme
- A target that 10 percent of sales from licensed electricity suppliers will be generated from renewable sources by 2010, subject to the cost to the consumer being acceptable
- A target to at least double the capacity of combined heat and power by 2010.
- European-level agreements with car manufacturers to improve the fuel efficiency of new cars by at least 25 percent on 1995 levels by 2008-2009
- A number of transport policy measures as set out in the 10 Year Plan for Transport.
- Better energy efficiency in the residential sector
- Improvements to the Building Regulations.

The Energy White Paper sets out the challenges we face - for the environment as global carbon emissions continue to rise, and for security of supply as the UK's indigenous energy supplies decline. And it set out the main routes to achieving the goals of the Government's energy policy. The transport chapter of the Energy White Paper suggests that the carbon efficiency of transport could be improved by up to 10% by 2020, as a result of further vehicle efficiency improvements and increasing use of biofuels.

The Government's "Powering Future Vehicles" strategy, published in July 2002, brings together many of the key policy measures which will help deliver a shift to clean, low-carbon transport and fuels. It provides a framework for future decisions and action, aimed at promoting the development, introduction and take-up of low-carbon vehicles and fuels; and at ensuring the full involvement of the UK automotive industries in the new technologies.

Biofuels Background

Biofuels offer a number of benefits over conventional mineral fuels, which make them attractive as alternatives for the transport sector. The benefits include greenhouse gas reductions which will contribute to domestic and international targets, potential air quality benefits (albeit limited), the diversification of the fuel sector and an additional market for agricultural products.

The Energy White Paper (EWP) identifies liquid biofuels and hydrogen as the most promising candidates for tomorrow's low carbon transport fuels. In the longer term, significant use of biofuels could offer large carbon savings. Biofuels also have the advantage that, unlike other potential future low-carbon transport fuels such as hydrogen, they can be used as direct substitutes for conventional fuels without the need for new vehicles or refueling infrastructures. They can be used neat in some circumstances, but are more commonly used as a blend (usually up to 5 percent) with conventional fossil fuels.

There are a variety of biofuels potentially available, but the main ones are outlined below.

Biodiesel is the only type of biofuel currently on sale in the UK. It can be used neat, but is generally used as a blend in conventional diesel. It can be produced from a number of sources, including recycled waste vegetable oil and oil crops such as rapeseed and palm.

Bioethanol can be blended into petrol, where it offers air quality as well as carbon benefits. Bioethanol can be produced from a number of crops including sugar beet. Future technologies may allow bioethanol to be produced from a variety of source materials including wood, grass, straw and green waste.

Current policy and the UK Market for Biofuels

The UK has already taken a number of steps to promote the uptake of biofuels. The main support to date has been through fuel duty incentives. 20 pence per litre duty incentive on biodiesel has been in place since July 2002, and a similar duty incentive for bioethanol will be introduced from 1 January 2005. This policy has seen sales of biodiesel increase rapidly, and sales are currently running at some 2 million liters a month.[3.1] To a large extent, production is from waste vegetable oil (WVO), since this is currently the cheapest way of producing biodiesel.

Biodiesel is currently available at over 100 filling stations in the UK, including a number of major supermarket sites[3.2]. As a percentage of total diesel sales, however, biodiesel sales currently make up less than 0.1 percent, and as a percentage of total petrol and diesel sales, biodiesel sales make up less than 0.05 percent. At the present time no bioethanol is sold in the UK, but there are considerable changes after 1 January 2005 when the 20 pence per liter fuel duty incentive for bioethanol comes into effect.

Whilst large scale production of bioethanol looks unlikely in the short term, UK biodiesel sales are forecast to increase steadily through 2004 and more rapidly in 2005. Much of this growth is predicted to be as a direct result of increasing UK biodiesel production.

Environmental Performance

A number of studies have considered the environmental benefits of biofuels, with particular focus on their carbon savings potential. There is broad agreement that they can deliver substantial carbon reduction compared to fossil fuels, but figures vary quite widely according to feed stocks, processes and methodologies used.

The Government has used a range of between 40 and 57 percent in this paper to reflect this, though it is important to note that the range is potentially far wider [3.3]. For illustrative purposes, this would mean that if biofuels contributed 5 percent of the road transport fuel used today, the UK would be saving as much as 1 million tonnes of carbon (mt/c) per annum - up to 3 percent of overall road transport CO_2 emissions.

Biofuels potentially have some air quality benefits, provided the fuel is of appropriate quality (studies have shown that use of unprocessed vegetable oil can actually lead to considerable increases in emissions).[3.4] However, advances in engine and fuel technologies in the last decade - in response to strict EU regulations - mean that these benefits are fairly limited in effect.

Whilst biofuels clearly offer a number of environmental benefits, the possible expansion of biomass production could also have other effects that need to be taken into account. These include possible impacts on land-use, landscape, biodiversity and soil structure.

Research to date into some of these impacts has shown that increased biofuel production from a broad mix of arable crop feed stocks would have a broadly neutral effect on the farmed environment.[3.5] Direct replacement of cereal crops with oilseed rape would have no significant effect. However, replacement of spring grown break crops by an expanding winter oilseed rape or cereal area could have a negative effect on crops diversity and farmland birds. Growing biofuel crops on un-cropped land or replacement of natural-regeneration set-aside with biofuel crops would, on balance, be environmentally detrimental due to increased use of nitrogen and pesticide use and reduction in biodiversity. Environmental damage could be minimized by avoiding large-scale block-cropping and introducing a percentage of non-crops habitats, for example on headlands. As technology improves and sources of feed stocks widens for bioethanol production there would be no significant effect on the farmed environment.

Agricultural and Rural Development Issues

The production and transportation of biofuels could potentially provide employment opportunities for UK farmers and other rural businesses. Research has suggested that about 2-5 farming jobs could be created (or sustained where crops substitute for other cultivation) for each 1000 tonnes of biofuel produced. A 100,000 tones processing plant could therefore create/sustain around 60-80 jobs directly and as many as 550 jobs in agriculture[3.6].

On the one hand a number of companies have expressed a strong interest in making major investments in production plants, subject to greater levels of Government support. Against this, world market prices for biofuel feed stocks suggest that cheaper imports from abroad would predominate, unless some support could be directed towards UK producers.

Fuel Security and Diversity of Supply

As a substitute for conventional fossil fuels, biofuels also offer benefits in terms of the UK's fuel security and diversity of supply, issues that will become increasingly important as the UK becomes a net importer of energy over the coming decades. As set out in the EWP, a mix of energy sources is desirable, to ensure that the UK is able to maintain an uninterrupted supply of energy to end users.

Production Costs

Today's biofuels are more expensive to produce than conventional fossil fuel, although costs vary considerably according to the different feed stocks and production methods used.

Waste vegetable oil (WVO) bio-diesel production benefits from low feedstock prices, making it economic to manufacture in the UK with the current duty incentive. However, limited supplies and fuel quality issues limit the contribution WVO can make.

Areas of Concern

The current incentive has also enabled some limited production of biodiesel from imported palm and Soya bean oils, which are generally cheaper than production from domestic crops such as rapeseed. Some biodiesel produced from rape is imported from the continent, though the extra costs (UK prices fluctuate between £350-600 per ton for virgin rape-seed oil) require the final blended product to be sold at a premium to conventional diesel, which limits demand. A further issue which adds to the cost of biofuels is their hydroscopic (water-attracting) properties, which can cause problems with storage and distribution.

For ethanol in particular, blends with gasoline cannot be stored in conventional floating roof storage tanks, and it is difficult to distribute through the existing pipeline infrastructure due to the potential for contamination of jet fuel. As a consequence, blending tends to be done at the distribution terminals (so called "splash" or "rack" blending). This approach is thought to add at least 1 penny per liter to the effective cost of production of the fuel. Problems with meeting fuel vapor pressure specifications when using biofuels also add costs to the producer.

Other European countries, including France, have mitigated some of the problems associated with bioethanol by using it in ethyl tertiary-butyl ether (ETBE), a petrol extender. This is potentially a promising route, but the Government is carrying out further work to ensure that the environmental, health and safety implications of the use of bio-ETBE as a road fuel have been fully addressed.

Longer-term outlook

Looking ahead to 2050 and beyond, the Government's Energy White Paper, published in February 2003, identified the two major possibilities for non-fossil transport energy as renewably-generated hydrogen used in fuel cells, and biomass-based fuels. The White Paper noted that each had major implications for both fuel production and fuel distribution and indicated that the Government would make *'an assessment of the overall* *energy implications of both a hydrogen economy, and of large scale use of biomass-based fuels...'*

The Government is currently finalizing this assessment. Interim results and technical analysis are available via the DTI's website[3.8]. Among the emerging conclusions are that:

- In the long term, the large-scale use of biofuels could reduce CO_2 emissions from transport to very low levels. To reach these low levels, very high penetration of the fuel market would have to be achieved.
- Assuming a maximum growing area of 4Mha, indigenous resources could supply a maximum of around 500 peta joules (PJ) of energy; total energy consumption by road transport was around 1700PJ in 2002.
- By 2050, complete substitution of petrol and diesel could require approximately two thirds of total biofuel demand to be met by imports.
- The availability of biomass for transport energy is likely to be limited by competing resource demands from heat and power generation.
- Lowest projected biofuel costs, excluding co-products, are for processes using lignocellulosic crops. It is likely therefore, that these technologies will dominate in the future.

Policy options for promoting biofuels

The Government is already supporting biofuels by means of fuel duty incentives. There are a number of ways in which the Government could, in theory, offer further support to biofuels in order to deliver future targets, and this consultation paper seeks views on a number of possible support mechanisms.

The two major options are through either fuel duty (as the Government uses presently), or through some form of regulatory mandate or obligation. There are a number of other support mechanisms that could contribute to the policy framework, and these are also discussed briefly, but they do not of themselves appear adequate to bridge the financing gap.

Fuel Duty

This is perhaps the most widely used method of incentivisation, and many other Member States have taken this option. When set at an appropriate level, experience has shown (e.g. introduction of low-sulphur fuel) that the industry can be very responsive to this economic signal in introducing new fuels.

A substantial increase in the current fuel duty incentive of 20 pence per litre could certainly be expected to boost sales of biofuels in the UK, and could have a rapid impact.

One disadvantage of this approach is that the Government would have little certainty over the amount of its revenue losses to supporting biofuels - which could potentially be very high. As indicated in table two below, if the duty incentive were increased to 30 pence per litre, and if sales of biofuels increased to 5 percent of all road fuel sales, the total annual costs to the Exchequer would be well over half a billion pounds. A further disadvantage is that increasing the duty incentive further would potentially over-compensate current producers using cheaper WVO inputs.

In addition, the fuel duty regime is fairly indiscriminate in terms of the source or quality of the fuel; imports are as eligible for the duty incentive as domestically produced fuels; and fuels produced to poor environmental standards are just as eligible as those produced to a high standard (provided they meet the necessary fiscal specification). In the shorter-term in particular, higher levels of fuel duty differentials could simply result in cheaper imports.

One option the Government could explore with a view to reducing the long-term costs would be to announce a period of higher duty incentives followed by a period of gradually lowering incentives - a 'stepped approach'. This could potentially provide a helpful boost to the sector, whilst limiting the ultimate cost to the Exchequer. The three-year rolling certainty on fuel duty differentials announced in the PBR 2003 would support such an approach.

A Renewable Fuels Obligation

It might be possible for the Government to introduce an obligation for the road fuel sector drawing on the experience of the Renewables Obligation that applies in the electricity generation sector.

The obligation might, for example, be placed upon refiners, blenders and importers, and would in essence require them to ensure that over a given period of time a certain percentage of their aggregate fuel sales were bio-fuel. This would allow them to distribute fuels containing higher levels of bio-material at certain times and lower (or zero) levels at other times, depending on availability.

There may be a number of options for operating such a system - from a relatively straight-forward obligation with penalties for non-compliance, to a more complex one providing for trading of certificates. The operation of the Renewables Obligation in the electricity generation sector may provide a useful model for the latter option.

The concept of an obligation has a number of appealing features. For the Government, it would provide a mechanism to deliver a higher level of certainty over meeting any target it sets, both for 2010 and into the future. For industry, an obligation would demonstrate the Government's long-term commitment to biofuels, increasing investor confidence and providing a greater level of long-term market certainty.

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Table 3.1: Estimates of the cost implications at the pump of implementing an obligation[3.10]

	With 20 ppl duty differential		**Without duty differential**	
	Pump price ppl	**Difference in price from conventional fuel ppl**	**Pump price ppl**	**Difference in price from conventional fuel ppl**
1% blend				
Biodiesel	78.85	0.1	79.09	0.24
Bioethanol	77.68	0.1	77.91	0.24

2% blend				
Biodiesel	78.86	0.2	79.33	0.49
Bioethanol	77.69	0.2	78.16	0.49
3% blend				
Biodiesel	78.87	0.3	79.58	0.73
Bioethanol	77.69	0.3	78.40	0.73
4% blend				
Biodiesel	78.88	0.4	79.82	0.98
Bioethanol	77.70	0.4	78.64	0.98
5% blend				
Biodiesel	78.89	0.5	80.07	1.22
Bioethanol	77.71	0.4	78.89	1.22

Note: These prices include all taxes and subsidies, profit and distribution.

Voluntary Agreement

It is possible that the complexities of a regulatory obligation could be mitigated if it were done on a voluntary basis, with the oil companies entering into a "voluntary agreement" to sell certain amounts of biofuels each year. However, due to the extra costs involved in producing biofuels, including substantial investment in production and distribution, a voluntary agreement may not provide adequate certainty for industry. Early consultation with the oil industry has indicated that they do not favour a voluntary approach.

Supporting Measures

Regional Capital Grants

Regional Capital Grants offer one of the few methods of direct support for industry allowable under the EU's single market rules. Biofuels processing plants would qualify under the terms of the support framework and could therefore be used to help establish a UK-based biofuels industry. However, there are limitations in terms of the geographical areas eligible for support and in the grant amounts that could be provided.

Enhanced Capital Allowances.

Capital allowances allow the costs of capital assets to be written off against a business's taxable profits. Enhanced capital allowances (ECAs) can allow a greater proportion of an investment to qualify for tax relief against a business's profits of the period during which the investment is made. Enhanced Capital Allowances ECAs have been introduced for energy-saving technologies (2001) and water-saving technologies (2003) and are intended to help address the higher up-front costs that new and nascent technologies can experience before they achieve market penetration. The qualifying technologies are kept under review to ensure that the support is targeted on equipment until it achieves market penetration.

Budget 2004 announced that the Government would hold stakeholder discussions on the possibility of introducing enhanced capital allowances for clean biofuels production processes

Research and Development

All of the approaches outlined above are focused on the promotion of commercially applicable projects. However, a number of the technologies that offer the highest carbon savings (e.g. Fischer-Tropsch biodiesel and gasification-based bioethanol) are still relatively unproven. The uncertainty surrounding these technologies means that they face difficulties raising the necessary finance to develop their ideas further.

Encouraging Best Environmental Practice

As highlighted throughout, a draw-back of further stimulating biofuels sales beyond mainly WVO production is that the environmental and carbon benefits are uncertain and can vary quite widely. Ideally therefore, policies aimed at stimulating the industry would include or be supported by measures to ensure that the greatest environmental benefits are derived.

It has been suggested that some form of environmental certification system could fulfil this brief, providing a mechanism through which minimum standards of environmental benefit (including carbon) would qualify for fiscal support and/or regulatory obligations. In theory, it might even be possible to reward greater carbon saving performance on a sliding scale.

Against this, there are questions about the practical feasibility of creating such a system; the bureaucracy and costs involved in running it; and the potential for conflict with international trade rules. The Government is not, therefore, currently minded to set up a mandatory carbon certification system.

Reference:

3.1) Details of monthly sales figures are available at UK Trade Information Website at www.uktradeinfo.com.

3.2) Details of these are available UK energy for transport sector at the Website www.transportenergy.org.uk.

3.3) The lower number reflects the findings of the recent EUCAR, CONCAWE & JRC report, which is available at http://ies.jrc.cec.eu.int. The higher figure is from the Government-sponsored Sheffield Hallam study. Both numbers reflect conventional biodiesel production. It is possible to achieve much higher savings using modified production methods.

3.4) Details of the report are available on the DfT website at http://www.dft.gov.uk/stellent/groups/dft_roads/documents/page/dft_roads_027622.pdf

3.5) These are the conclusions of Defra's Central Science Laboratory in the report 'Liquid biofuels – industry suppport, cost of carbon savings and agricultural implications, Turley, D. Ceddia, G. Central Science Laboratory. Bullard, M. ADAS. and Martin, D. Ecofys, August 2003.

3.6) Research carried out on behalf of the East of England Development Agency (EEDA). Further information available via www.eastofenglandobservatory.org.uk/.

3.7) Data derived from modeling by Teeside Biofuel Consortium.

3.8) Liquid biofuels and hydrogen from renewable resources in the UK to 2050: a technical analysis, 2003, E4tech (UK) Ltd. www.dti.gov.uk/energy/sepn/futuretransport.shtml

3.9) Given the limited time between now and the end of 2005, the 2% reference value does not appearsa realistic for the UK even with higher duty differentials. For UK production, for example, it would take at least 18 months to build additional production facilities.

3.10) The modeling is based on the mid-resource cost of biofuels.

Chapter 4

Overview

The UK construction industry consists of over 250 000 firms employing 2.1 million people[4.1] in a multitude of roles. The sector is defined as one which embraces the construction materials and products; suppliers and producers; building services manufacturers, providers and installers; contractors, sub-contractors, professionals, advisors and construction clients and those organizations that are relevant to the design, build, operation and refurbishment of buildings.

The UK construction industry output is the second largest in terms of the Gross Value Added to the economy among the EU nations[4.1]. UK designers, civil engineers, contractors, component & product manufacturers have a worldwide reputation for working overseas, providing high-tech solutions to environmental, transport & building projects.

The role of Construction Industry towards Sustainable Development

Key Issues or Current Scenario

The construction industry plays a major role in improving the quality of the built environment, but it also impacts on the wider environment in a number of ways. The construction business in the UK is responsible for nearly a third of all industry-related pollution incidents.[4.2] Construction and demolition waste alone represent 19% of total UK waste. Too many buildings are environmentally inefficient and do not make best use of limited resources such as energy and water. The energy used in constructing, occupying and operating buildings represents approximately 50% of greenhouse gas emissions in the UK.[4.2]

Sustainable construction techniques have been successfully used to deliver projects such as the Great Western Hospital in Swindon and the Millennium Village in Greenwich [4.3] Yet take up of sustainability principles varies significantly, with some leading firms following recognized good practice, but others still making little effort. The environmental efficiency of buildings in the UK remains lower than in many other European countries. An increase in the number of single person households, together with rising domestic waste production and water consumption, means that increases in environmental efficiency are needed just to limit the impact of existing buildings.

Promoting sustainable construction is difficult because of the industry's size and fragmentation. The industry provides a tenth of the UK's gross domestic product and employs 1.4 million people in many types of business.[4.3] The rate of construction in the UK is set to increase. The Government's "Sustainable Communities Plan" seeks to accelerate the current house-building programme and increase the house-building target by about 200,000 on top of the 900,000 new homes planned between 1996 and 2016 in the South East. This new emphasis on growth represents an opportunity to shift development towards delivering more sustainable homes and construction.

The Need for an Environment Agency

As the principal environmental advisor to the Government, the Environment Agency has a broad interest in construction and would like to see its environmental impacts reduced. More specifically:

- As consultees on land use planning, they advise on where buildings and infrastructure should be located to reduce environmental impacts and flood risk.
- As regulators of waste and discharges their role is to ensure construction waste is managed safely and to drive a reduction in construction pollution and waste volume.
- As an organization with a statutory duty for strategic water resources planning, their role is to ensure homes and other buildings are built in places that have the capacity to support them, and to standards that encourage efficient water use.
- As a construction client our projected spending on construction in 2005/06 is £250 million and our role is to lead by example and demonstrate what sustainable construction means in practice.

The Recommended Solutions are:

- Government, industry and the Agency all have a role to play in promoting environmental improvements and reducing the environmental impacts of the built environment, both in terms of construction and during the life of buildings.
- Development to be located in the right place and in the right way.
- Local authorities should comply with Government planning policy and advice relating to development and flood risk and consult the Agency on planning applications where there is a risk from flooding.
- Local authorities should always consider the environmental capacity of an area, particularly its water resources and waste management options, to support new built

development. These issues should be reflected in all strategic planning and individual development control decisions.

- The Government has a target to locate 60% of new development on previously developed 'brownfield' land. This land is often potentially contaminated by previous use. The Agency will work with local authorities to encourage the redevelopment of such land to include appropriate site investigations and remediation to reduce risk to human health and the environment, especially controlled waters.
- The environmental agency will discourage development that harms habitats and species and encourage developments that include improvements to biodiversity.

Current Scenario of construction pollution and waste managements requirements

The environmental agency will work with others to address pollution incidents caused by construction sites, construction waste and industry-related fly-tipping. Their broader work on waste reduction will contribute to reducing waste streams and better segregation for recovery from construction, particularly hazardous waste and will encourage more construction firms to actively manage their environmental impact, ideally through a recognized Environmental Management System. Such as Large-scale developers should produce and implement a written 'site waste management plan'. They should identify the volume and type of construction and demolition waste, and demonstrate how off-site disposal of wastes will be minimized and managed.

- The Government should amend the Duty of Care provisions so that developers and others are not allowed to avoid responsibility for waste materials through simply using contracted waste carriers.

- The Government should also extend to building inspectors the powers to examine and enforce sustainability issues *during their routine site checks*.
- Targets on recycling construction waste should be increased and there should be a requirement to use a fixed percentage of reclaimed materials in construction. This would help make construction and demolition waste more valuable and hence less likely to be disposed of in a careless way.
- Government should continue to use revenue from the Landfill Tax to help industry improve its environmental performance.

Improved environmental efficiency of buildings

Government should review the scope of the building regulations and expand them to cover water efficiency. In the longer term Government should introduce a sustainable development duty within building regulations so they apply to construction waste and the wiser use of materials, including packaging.

- Voluntary schemes such as the EcoHomes Standard should be improved over time and be increasingly used to guide higher construction standards.
- Commercial house builders should be encouraged to follow the example of English Partnerships and the Housing Corporation and aim for a ‘very good’ or ‘excellent’ standard of EcoHomes.
- Government should explore how the town and country planning system can be used to drive forward environmental efficiencies during refurbishment and in new homes and buildings.

- Government should ensure homebuyers are provided with a wide range of information on the environmental efficiency of homes through expanding the scope of the Home Information Pack.

Increased skills development and training

The lack of relevant skills and knowledge is a hurdle to sustainable construction. Hence various Environmental agencies are working along with Government, professional institutions and both further and higher education to influence and support skills development and training in the industry. This will include work with sector bodies such as the Construction Industry Training Board.

The Agency to lead by example

The agencies have made progress as a public sector client adopting the principles of sustainable construction. Further they will identify sustainable construction targets when developing capital projects, such as reducing waste and pollution incidents, setting targets for recycling aggregates or enhancing biodiversity. The Agency will acknowledge sustainable construction as a priority for the Agency when setting policy, and will adjust the appraisal framework and procurement practice so that sustainable construction objectives are taken into account. And promote the principles of sustainable construction through the procurement policy and chain of suppliers. Further encourage other public sector clients and industry to achieve similar approaches to more sustainable construction.

Overview of the Xscape Project

The Xscape project is the construction site used for this study. It is a state of the art building project being developed near Braehead shopping complex, located on the south bank of the River Clyde in Glasgow, Scotland. When finally completed, it would comprise a ski-centre with a dry ski slope, a cinema and shopping malls with car parking and gardens and has a total estimated project value of £50million. The on-site workers are mainly building contractors, technicians, supervising engineers and company 39 management staff. A two-storey accommodation cabin has been provided on site for staff use.

Related Work Done to Date

Laing O'Rourke as a company is aware and constantly putting together plans to control and manage energy consumption on its construction sites. It is in line with this desire that the company is working with the Carbon Trust to find methods of reducing energy consumption. To effectively management and monitor energy consumption on site, it has assigned one mechanical and electrical (M&E) engineer to be in charge of energy management. The M&E engineer has been using the Xscape project site to try out many energy efficiency measures and as it stands the Xscape project site has the best energy efficiency practices witnessed on four sites visited by David Palmer of Campbell Palmer Partnership Ltd in a related work done by him. In Mr Palmer's recommendations he emphasised that the Xscape project site should be as the basis of a Laing O'Rourke procedural document for energy conservation on current and future Laing O'Rourke construction sites. He however further recommended training in energy management and energy technologies to allow the M&E manager to build on his knowledge of the subject, and to develop appraisal skills for investment opportunities [4.4]

On the actual work done by Mr. Palmer, he [4.4]

- Identified key energy efficiency issues for Laing O'Rourke
- Undertook energy audits for four Laing O'Rourke construction sites including

the Xscape project site

- Provided an outline specification for energy efficiency prefabricated cabins.

Although his work centred on energy efficiency, he was quick to point out the implication of using diesel generators which produce up to twice as much CO_2 as compared with electricity drawn from the grid. With the CO_2 emissions from the national grid in the UK estimated to be 0.43 kg/kWh, diesel generators operating at maximum efficiency of 35% liberate 0.71 kg/kWh and are even worse off when operating at mean load of 20% and 27% efficiency. The four sites Mr Palmer audited were all operating around the mean load implying that they were each liberating 0.93 kg of CO_2 per kWh of electricity generated.

This project basically deals with a feasibility study on various aspects required for the use of biodiesel for equipments used in various construction activities.

Reference:

4.1) http://www.dti.gov.uk/sectors/construction/index.html

4.2) http://www.environment-agency.gov.uk/aboutus/512398/289428/654938/?version=1&lang=_e&lang=_e

4.3) UK Regulations http://www.environment-agency.gov.uk/commondata/acrobat/ippc_rgs7_v3_0606_509888.pdf

4.4) Palmer, D., Restricted – Commercial Partnership Report for Laing O'Rourke Scotland, Document Reference SRV 13892.1, Pg 3, April 2004.

Chapter 5

Different types of Construction Equipments

A normal construction activity uses various types of machines for quicker and efficient completion of the project, and it uses various construction equipments such as the

Excavator

The excavator is mainly used for digging the soil and transferring it on to the dumpers. They are the most commonly used machines in the construction industry. Like most of the construction equipment the excavators uses a diesel engine to transform the energy into useful work. The capacity of the machine is determined by capacity of the engine.

Figure 5.1 Picture of a CAT Model Tracked Excavator

The design of excavator is like an arm which is powered by the base. The base contains the diesel engine and hydraulic system for the movement of the arm. The work carried out by the equipment is digging the soil, carrying in bucket and unloading in the dumper.

One thing is to be noted in the operation of this type of machine is that the useful work is being done in only half of the cycle of the arm i.e. when it carries the load. The return is empty hence the consumption of the fuel in the first cycle will be more than the second cycle, and between two different jobs the machine running but not doing any work. The different parameters that are to be considered in the calculation of the fuel use by the excavator are the efficiency of the engine, the power rating of the machine and the diversity factor.

In case of the excavator the efficiency is taken as 25 % (constant for a diesel engine) this efficiency includes the transmission losses. The other parameter is the capacity of the machine i.e. the rating of the diesel engine which can be easily noted from the specifications of engine. The diversity factor is taken as 0.60 which includes the losses in the arms, the losses due to improper usage and the account of operating the machine but not doing the useful work.

The main movements of the excavator are the movement of the arm, the movement of the whole machine, rotation of the arm and the bucket attached to the arm.

Backhoe Loaders

The backhoe loader is mainly used for transporting the soil for short distances and digging the trenches. Backhoe loader is also an essential machine in the construction industry. Like most of the equipment the backhoe loader use the diesel engine as prime source of energy. The capacity of the machine is determined by the capacity of the engine.

Figure 5.2 Picture of a JCB make Backhoe Loader

The construction of the backhoe loader has two attachments for two different types of work one at the front and one at the rear end. The front attachment is the bucket which is used to carry loads for short distances and dump them where required. The rear end is provided with an arm which can dig small trenches where required. Both the attachments are powered by the engine in front of the machine and hydraulic system for the movement of the arm. The machine works by filling the bucket with load and carrying it to shorter distances, one thing is to be noted in the operation of this type of machine that the useful work is being done in only half of the cycle of the bucket or arm i.e. when it carries the load or digs by the arm. The return is empty hence the consumption of fuel in the first cycle will be more than the second cycle.

The efficiency is taken as 25 % (constant for a diesel engine) this efficiency includes the transmission losses, the other parameter is the capacity of the machine i.e. the rating of the diesel engine this can be easily noted from the specification of the engine attached to the machine and the diversity factor taken as 0.6.

Dumpers

The dumpers are the machines that carry load to longer distances and dump where ever required. The construction and operation of a dumper is very simple. The dumper is like a load carrying truck which has a load carrying bucket attached at the rear and the engine and drivers seat in the front of the machine.

Figure 5.3 Picture of CAT model make Dumper Truck

The main purpose of the dumper is to carry loads and dump them where ever required. These types of machine are used in the initial stage of the construction activity, where excavation is carried out on the construction site. The working of this machine can be described as it is filled with the load, and the load is carried by the machine then with the hydraulics the buck is lifted to empty the load wherever desired and then the dumper is ready for another lift.

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Compressors

The compressors are used in the construction activity by the power tools such as the hammers, drill, punching equipment and the equipment used for digging. The compressor consists of an IC engine or electric motor to run an air pump to compress air and store it in a pressure vessel or an accumulator which can be used for operation of different machines. The operation of this machine is simple as it operates according to the requirement of the compressed air in the accumulator.

A typical energy flow on compressor system will like, for 100% energy provided by diesel engine only 41 % is utilized to compress the air in the compressor. The other forms in which energy is wasted are through radiant energy – 8 %, cooling water – 22 %, and exhaust heat 38 %.

Plant And Fuel Analysis

ANALYSIS OF PLANT HIRE

The data of the plant hire for the Xscape project consist of all the equipments hired from the start of the project in August 04 to July 05. By analyzing the data, the different plants which use the diesel as fuel can be separated from the other equipment. A graph is plotted from the plant hire data which shows the use of the diesel using equipment for the months of August 04 to July 05.

Table 5.1 Plant Hire Analysis Data

S. No	Description	Sep 04	Oct 04	Nov 04	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Jun 05
1.	Excavator	9	7	11	10	15	10	11	8	7	14
2	Compressor	2	2	0	0	1	1	1	0	0	0
3	Crusher	3	0	0	1	1	0	2	0	0	0
4	Generator	4	10	5	6	5	8	5	4	8	4
5	Dozer	0	0	1	1	1	1	1	1	0	0
6	Dumper	6	6	7	4	5	6	7	4	6	4
7	Roller	1	1	1	0	0	0	0	0	0	0
8	Lighting Tower	0	10	24	11	17	16	0	0	2	8
9	Mobile Crane	0	0	1	0	0	0	0	0	0	0
10	Bunyan Striker	0	0	0	1	0	0	4	3	3	0
11	Concrete Pump	0	0	0	0	0	0	3	4	4	3

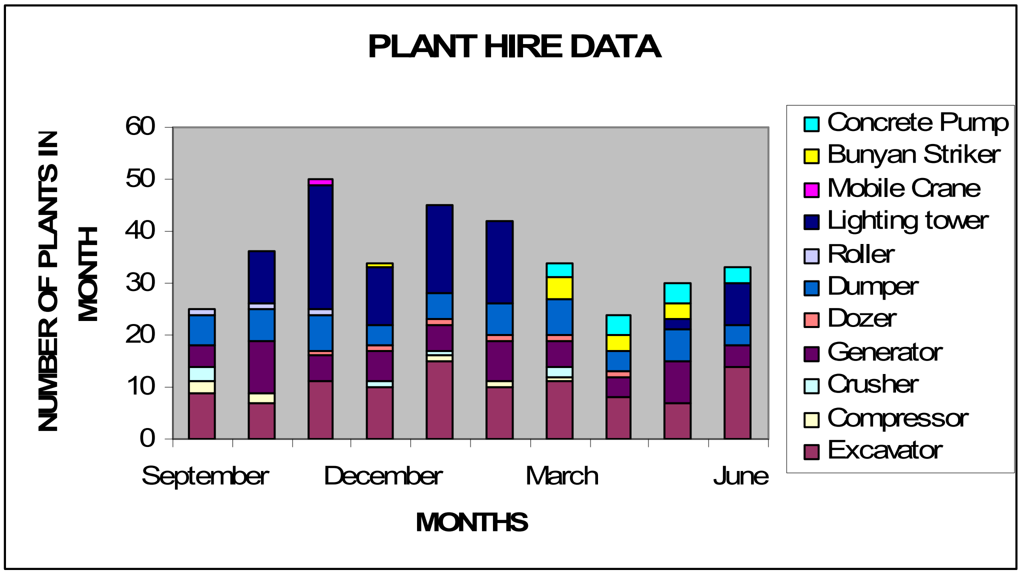

Figure 5.4 Schematic views of Plant Hire Data

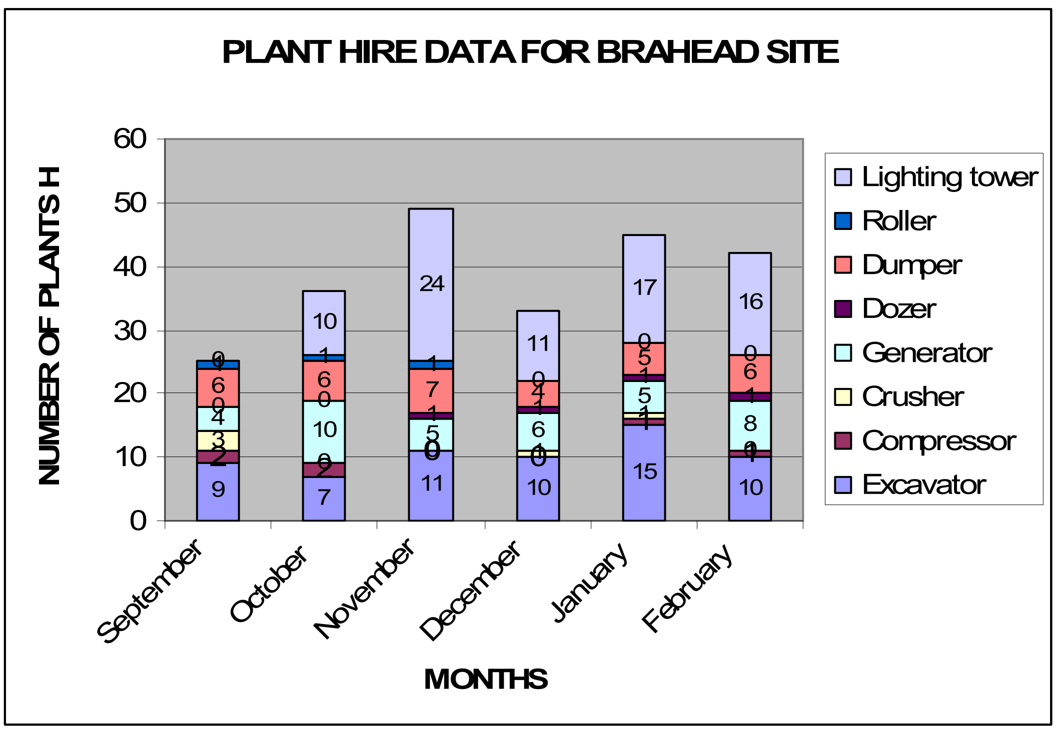

Figure 5.5 Distribution Graphs of Plant Hire Data for Xscape Site (@ Brahead)

From the above graph we are able to observe that the Bunyan striker and Mobile Crane are not included as they are hired only once in the month of November and December '04

From the above Plant hire distribution graph we can see that in the month of September 04 the plant hire distribution indicates that the hire of all the fuel using equipments. By interpreting the graph it can be noted that the use of two machines is most prominent in the month of September 04 i.e. Excavator and the Dumper. These two machines are extensively used in the first stage of the construction process i.e. excavation.

Further in the month of October 04 the distribution indicates that use of the excavator and dumpers as usual but the use of lighting tower and the generators are increased as compared to the moth of September 04. The lighting tower has been hired in October 04 for the provision of lights on the construction site when the sun sets early in the months from October to February. This indicates that the use of the lighting tower and the increase use of the generator is the result of poor light on the sites in the late afternoon for the stated months. The use of the excavator and the dumper is same as the month before which indicates the continuation of the excavation process in the month of October.

From the graph we can notice that the major plant used in the month of November is excavator. The lighting tower is not considered as the plant as the used of the lighting tower will be relatively less because they will operate to supplement the natural light in the late afternoon. The second most used plant is the dumper, 7 of them are used in this month. In the months from December 04 to February 05 the excavator, generator and dumpers are prominent fuel users as indicated in the graph.

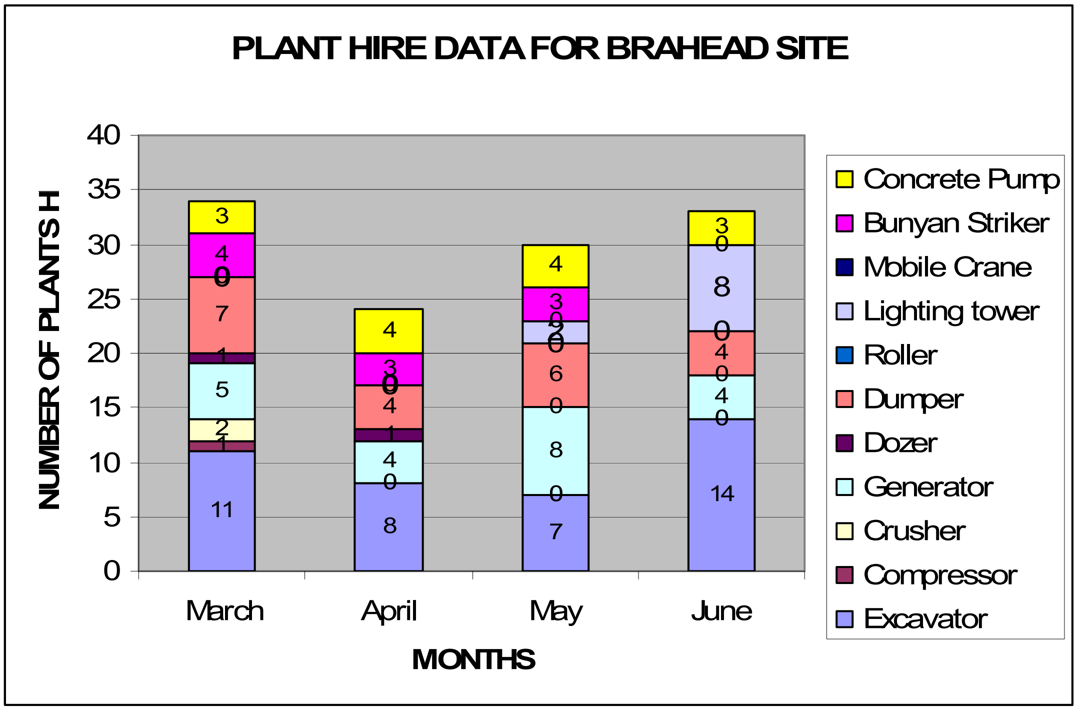

Figure 5.6 Distribution Graphs for the months between March to June '05

As shown in the fig 5.6 from March 05 to June 05 the concrete pump is introduced into work which indicates the start of building the structure. In this stage the main structure is constructed the beams, columns and the suspended floors.

In this stage it can be noted from the above graph, the use of the excavators remain the same as this graph will not give the exact picture of the prominent use of the plants in the construction process as they only give you the information of how many number of plants are hire din the respective months. From the above graph and table it can be noted that the use of excavators is almost the same in the first three stages of the construction with the compressor and crusher being used mostly in the initial stages. The use of the generator is almost steady during the first three stages with some exceptions when specific work related to generators is required such as the tools powered with generators.

ANALYSIS OF PLANT HIRE ACCORDING TO NUMBER OF DAYS

The below graph shows us the data for the number of days the plants are being hired for the respective months.

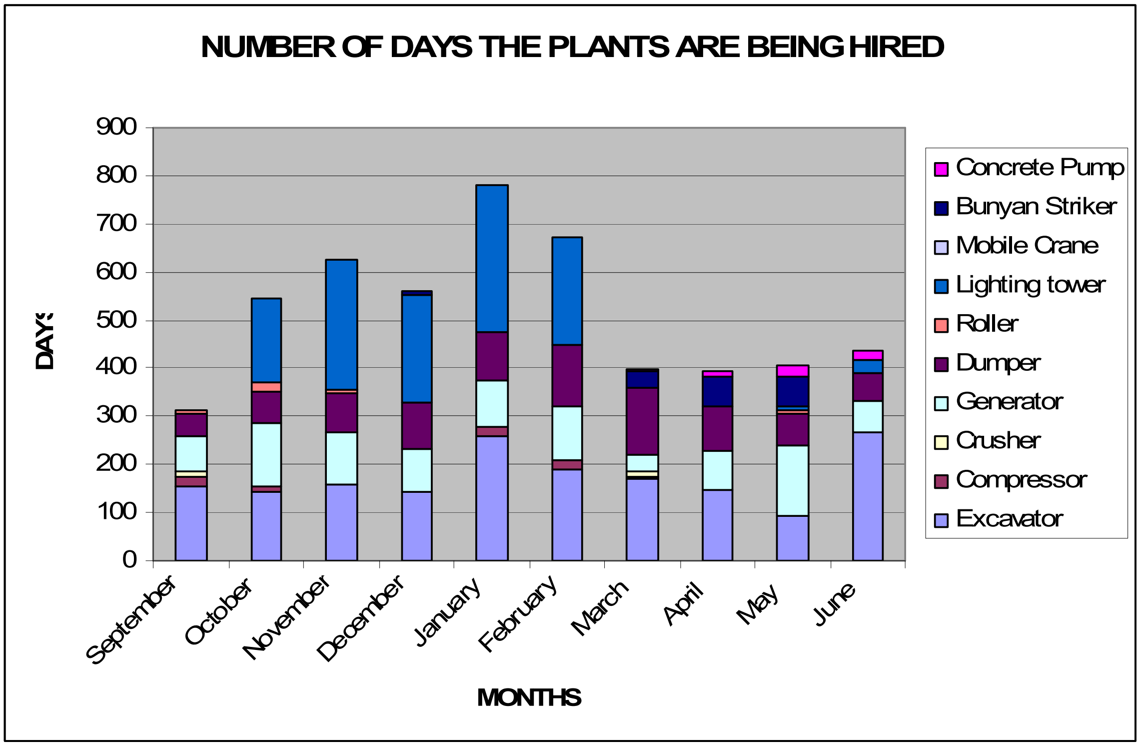

Figure 5.7 Graph showing the Number of Days the Plants Hired

The above graph is tabulated as below

Table 5.2 Plant Hire Data in terms of Number of Days

Description	September	October	November	December	January	February	March
Excavator	153	142	157	141	260	190	170
Compressor	22	12	0	0	18	20	5
Crusher	12	0	0	2	2	0	11
Generator	73	133	110	90	96	110	34
Dumper	44	63	82	94	98	128	139
Roller	7	21	7	0	0	0	0
Lighting tower	0	172	269	227	307	224	0
Mobile Crane	0	0	1	0	0	0	0
Bunyan Striker	0	0	0	7	0	0	34
Concrete Pump	0	0	0	0	0	0	6
TOTAL	**311**	**543**	**626**	**561**	**781**	**672**	**399**

Description					
Excavator	**April**	**May**	**June**		**TOTAL**
Compressor	145	91	267		**1716**
Crusher	0	0	0		**77**
Generator	0	0	0		**27**
Dumper	84	150	66		**946**
Roller	91	65	58		**862**
Lighting tower	0	6	0		**41**
Mobile Crane	0	10	28		**1237**
Bunyan Striker	0	0	0		**1**
Concrete Pump	63	61	0		**165**
	10	23	19		**58**
TOTAL					
	393	**406**	**438**		

If we analyze the number of days they were on site we can notice that the excavators are on average hired for only 1 week i.e. 5 days. The percentage of equipments used was not appropriate as the number of days worked is an important information for the fuel consumption for the particular type of machine. If we combine the excavator, dumper, generator, crusher and the roller they used a total number of 311 days.

The following indicates the use of the machines hire din the month of September 04

Excavator - 153 days
Compressor - 22 days
Crusher - 12 days
Generator - 73 days
Dumper - 44 days
Roller - 7 days

If this analysis is to be made for all the equipments hired in respective months the result will be in the table which shows the number of days the machines have been used.

DIESEL FUEL PURCHASE ANALYSIS

The diesel consumption data are obtained from the respective site for the project period from the start on August 04 to July 05. The analysis of diesel consumption is made for the months i.e. the use of diesel in the months of September 04 to June 05.

Table 5.3 Monthly Diesel Consumption figures in Liters

Months	Liters
September	23410
October	16253
November	46662
December	29000
January	46323
February	60371
March	46588
April	54900
May	82463
June	45800

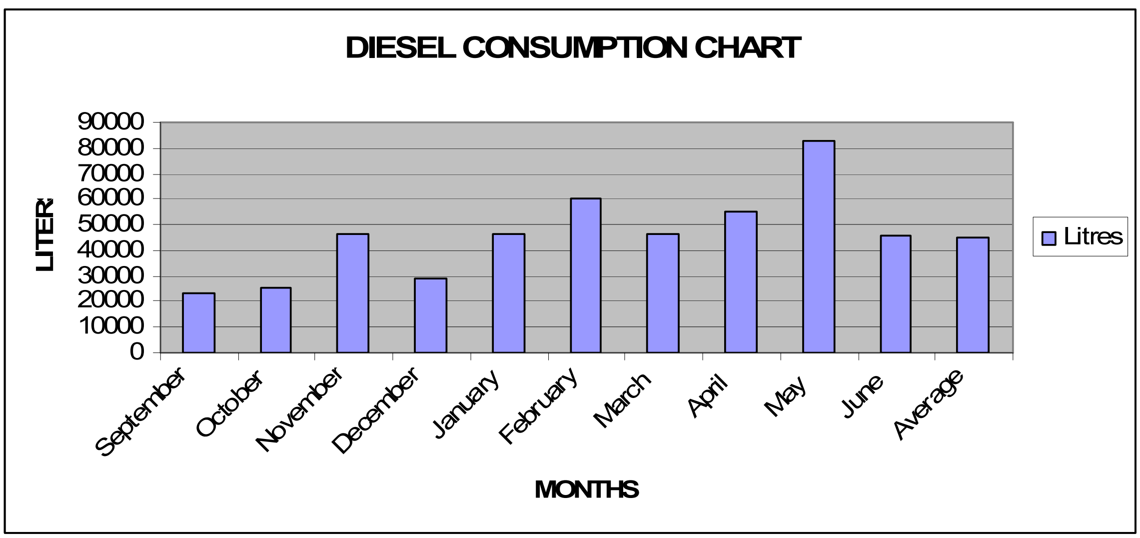

Figure 5.8 Monthly Diesel Consumption Chart

The above graph shows us the diesel consumption pattern on the construction activity for the months from September 04 to June 05. The last column indicates the average across the months which are about 45,177 liters. The minimum use being in the starting months when the process of excavation is going on as the different processes starts the use of fuel also increases with its maximum being recorded in the month of May 05 i.e. 82,463 liters. If we see the data for the plant hire and the number of days the plants worked on the site the main difference in the month of May 05 is heavy due to the use of the concrete pump for the suspended floor construction and the generator which recorded an increase of 75 days of use from the previous month. There is also an indication of increase of fuel use on an average, if the use of the generator changes from the previous month. The total fuel use on the site from the September of 04 to June 05 is **451,770 liters.**

Comparative Performance Studies

This section of Biofuels for Transport provides details of work that has been done on the comparison of regular fossil diesel to biodiesel. Mostly this work has focused on tailpipe emissions as opposed to engine mechanical performance and this is reflected in this section.

Fossil/Biodiesel Comparison

There are a number of ways in which a comparison between conventional road fuels and bio-road fuels can be made. A direct comparison can be made on the basis of the fuels' calorific value. However, it is commonly felt that in some situations it is more convenient and appropriate to make comparisons on the basis of the distance traveled by road vehicles using each fuel type. However, the disadvantage of this method is that it depends on the relative performance of road vehicles using biodiesel and fossil diesel.

Most of the research that has been carried out on engine performance with alternative fuels has been concerned with the resultant tailpipe emissions. The varying factors that come into effect in these instances are type of road vehicle and driving conditions (urban, motorway, rural, etc.). These factors are subsequently specified as standardized tests so that the results produced are meaningful, the test conditions can be easily reproduced, and the test results are comparable. As performance varies with engine design and vehicle technology, it is widely accepted that comparative results are likely to vary over time.

A number of studies have been conducted investigating the comparison of tailpipe emissions from conventional diesel and biodiesel. The test results shown below are from a study conducted by G.S Hitchcock et al. in 1998 in the UK. The comparison generally shows how using biodiesel marginally reduces carbon monoxide (CO), hydrocarbon (HC) and particulate matter (PM) emissions. Net carbon dioxide (CO2) is effectively reduced to zero, as are sulphur dioxide (SO2) emissions. However, by using biodiesel, nitrogen oxide (NOx) emissions are slightly higher. In this study, it was not very explicit about the type of diesel but by the figures it was judged to have been Low Sulphur Diesel (LSD) that was used. If this was the case it could be assumed that such a marked reduction in sulphur dioxide emissions shown here would be less due to the widespread use of Ultra Low Sulphur Diesel (ULSD) in the UK today.

Table 5.4 Tail Pipe emissions between Conventional Diesel and Biodiesel Under various vehicle applications [5.1]

Vehicle	Fuel	$C0_2$ (g/km)	CO (g/km)	HC (g/km)	NO_x (g/km)	SO_2 (g/km)	PM (g/km)
Car	Conventional Diesel	139	0.42	0.08	0.64	0.05	0.15
Car	Biodiesel	0	0.37	0.07	0.77	0	0.13
Light Goods Vehicle	Conventional Biodiesel	267	1.33	0.33	1.39	0.09	0.24
Light Goods Vehicle	Biodiesel	0	1.16	0.24	1.67	0	0.24
Heavy Goods Vehicle	Conventional Biodiesel	853	3.92	0.45	13.06	0.28	1.07
Heavy Goods Vehicle	Biodiesel	0	2.63	0.36	15.02	0	0.72
Bus (Old)	Conventional Biodiesel	1119	16.04	5.03	15.86	0.38	1.55
Bus (Old)	Biodiesel	0	10.75	4.03	18.24	0	1.04
Bus (New)	Conventional Biodiesel	885	4.26	0.44	14.09	0.29	1.06
Bus (New)	Biodiesel	0	2.86	0.35	16.21	0	0.71

Sample Of Tailpipe Emissions From Road Vehicles Using Biodiesel And Conventional Diesel For The UK (G.S Hitchcock et al. 1998)

Another study was conducted by M. Kaltschmitt et al. in Germany in 1997 for a car using biodiesel and conventional diesel, the results of which are shown below. For this study it was Low Sulphur diesel that was used and the results show similar levels of CO, HC, and NOx and N_20 emissions for both conventional diesel and biodiesel. For particulate matter, biodiesel emits marginally less and for SO_2 there is a larger decrease. As before, net CO_2 is reduced to zero by using biodiesel.

Table 5.5 Tail Pipe Emissions between Low Sulphur Diesel and Biodiesel

Vehicle	Fuel	$C0_2$ (g/km)	CO (g/km)	HC (g/km)	NO_x (g/km)	SO_2 (g/km)	PM (g/km)	N_2O (g/km)
Car	Conventional Diesel	146	0.5	0.08	0.52	0.041	0.06	0.032
Car	Biodiesel	0	0.5	0.08	0.52	0.005	0.04	0.032

Sample of tailpipe emissions from road vehicles using biodiesel and conventional diesel for Germany (M. Kaltschmitt et al. 1997)

In both the UK and German studies it is Low Sulphur Diesel that is used and so this makes them fairly out-of-date, as ULSD is now the main DERV fuel in use in the UK. However, a study was conducted in Australia by Beer et al, which aimed to compare biodiesel and ULSD by adjusting results from a variety of tests and other studies of alterative road transport fuels. These results are shown in Table 5.6 and judging from the results it is evident that for buses using biodiesel; CO, HC, NOx and PM are actually higher compared with ULSD. SO2 emissions are not provided and net CO2 is again nil.

Table 5.6 Tail Pipe Emissions between Ultra Low Sulphur Diesels with Biodiesel

Vehicle	Fuel	$C0_2$ (g/km)	CO (g/km)	HC (g/km)	NO_x (g/km)	PM (g/km)
Bus	Ultra Low Sulphur Diesel	1406	1.41	0.53	14.32	0.16
Bus	Biodiesel	0	7.68	0.86	17.2	0.6

Sample Of Tailpipe Emissions From Road Vehicles Using Biodiesel And ULSD For Australia (T. Beer et al. 2002) [5.2]

In the same study by Beer et al., substantial variations were experienced in the tailpipe emissions of the same type of vehicle under the same test conditions (see table below). An offered explanation of this variation is that apart from CO2, it is only trace amounts of pollutants being measured.

Table 5.7 Tail Pipe emissions between Conventional Diesel and Biodiesel

Vehicle	Fuel	Variation	$C0_2$ (g/km)	CO (g/km)	VOC (g/km)	NO_x (g/km)	PM (g/km)
Bus	Conventional Diesel	Maximum	-17%	-68%	-38%	-46%	-92%
		Minimum	+33%	+275%	+35%	+73%	+124%
Bus	Biodiesel	Minimum		-43%	-22%	-62%	-50%
		Maximum		+55%	+19%	+39%	+114%

Sample Of Variability Of Tailpipe Emissions In Road Vehicle Tests (T. Beer et al. 2002)

Even though it is only trace amounts of pollutants being produced (with the exception of CO2), it is known that PM emissions have a link with respiratory diseases in humans. This is where the suggestion arises that biodiesel could be put to good use in sensitive areas such city centres or just to maintain a pristine environment such as in national parks. This is possibly one of the reasons why some countries have adopted biodiesel use for buses and taxis. Another advantage over conventional diesel, which these tests results don't show, is the fact that biodiesel is non-toxic and biodegradable.

In extensive tests comparing biodiesel with conventional diesel, bus trials were conducted in Austria by Graz University (T. Sams et al). In the test, Low Sulphur Diesel was used as the conventional fuel and the test took place over three years on two city buses. In the table below it can be seen that emissions of CO are 20% lower than conventional diesel. Tailpipe emissions of SOx are reduced by almost 100% while particulate matter is reduced by almost 40% by using biodiesel. VOC's are reduced by approximately a third. Emissions of NOx from biodiesel can be reduced substantially by altering the timing of injection. T. Sams et al. stated that, with reference to the buses used in their study, NOx emissions could be reduced 23% compared with fossil DERV by advancing injection timing.

Table 5.8 Percentage Reductions in the Emission levels using Biodiesel

Emission	SO_x	CO	NO_x	NO_x *	PM	VOC
Reduction with biodiesel	-99%	-20%	+1%	-23%	-39%	-32%

Sample Of Emissions From Austrian Bus Trials Relative To Low Sulphur Fossil Diesel (T. Sams et al. 1996)

In the US, tests were carried out by the Southwest Research Institute (Sharp) in 1997 using a 5.9L Cummins pick-up truck as its chosen vehicle. In this study a blend of fossil diesel (20%) and biodiesel (80%) was used. It was found that by just using the blended biodiesel, substantial decreases in the trace substances can be attained. VOC emissions fell by nearly 30%, benzene decreased by 78%, PAH's dropped 35% and butadiene decreased 85%.

Biodiesel / Fossil Diesel LCA Comparison

CO_2 Emissions

For each MJ of biodiesel produced 0.025Kg of CO2 is released.

For each MJ of fossil diesel produced 0.087Kg of CO2 is released.

From this it is possible to work out the emissions savings from the introduction of biodiesel produced in the UK. In the section on the quantitative biofuels production in the UK we worked out how much fossil diesel could be displaced by growing rapeseed on half the set-aside land in the UK. This land produced enough biodiesel to displace 2% of current UK diesel consumption by volume.

To work out the emission savings the following steps are used:

2% of current diesel consumption = 0.38 billion litres

Energy in 0.38 billion litres of diesel = 0.38 * 45.1
= 17.1 billion MJ

Emissions from 0.38 billion litres of diesel = 17.1 * 0.087
= 1.49billion Kg of CO2

Biodiesel has lower energy content than fossil diesel so rather than find the emissions for biodiesel from the volume being replaced it is more correct to find the emission from the energy being replaced, therefore:

Emissions from 17.1 billion MJ worth of biodiesel = 17.1 * 0.025
= 0.43 billion Kg of CO2

Total CO2 emissions savings = 1.49 – 0.43
= 1.06 billion Kg of CO2 every year over full fuel life cycle.

In 2000 the UK produced 148 million tonnes of CO_2 [5.4], or 148 billion kg.
So a 2% biodiesel blend would create a 0.72% reduction in the UK's total CO2 emissions.

GHG Emissions

Exactly the same process can be used to work out the GHG emissions and savings.

For each MJ of biodiesel produced 0.041Kg of GHG CO2 equivalent is released.
For each MJ of fossil diesel produced 0.095Kg of GHG CO2 equivalent is released.

Total GHG saving each year = 0.92 billion Kg of GHG CO2 equivalent over the full fuel life cycle

Energy Requirements

For each MJ of biodiesel produced 0.45 MJ is required.
For each MJ of fossil diesel produced 1.26 MJ is required.

Fossil diesel is an energy negative fuel, requiring more energy to produce than it has available within it. Biodiesel is an energy positive fuel containing more energy than was required to produce it.

Biodiesel Modification

Based on detailed study done above regarding biodiesel on various applications, it seems that almost all modern diesel engines will run biodiesel quite happily provided that the biodiesel is of high enough quality. Generally speaking biodiesel requires much less engine modification than bioethanol.

Rubber Seals

With some older vehicles rubber seals used in the fuel lines may require replacing with non-rubber products such as VITONTM. This is due to the way biodiesel reacts with rubber. If a low blend is used (5% biodiesel for example) then the concentration of biodiesel isn't high enough to cause this problem.

Cold Starting

Cold starting can sometimes be a problem when using higher blends. This is due to biodiesel thickening more during cold weather than fossil diesel. Arrangements would have to be made for this, either by having a fuel heating system or using biodegradable additives which reduce the viscosity. This effect is only a problem with higher blends.

Oil Changing

It was noticed that during many field trials that engines running on biodiesel tended to require more frequent oil changes. This was generally the case with blends above 20%. During an ALTENER project where two Mercedes Benz buses were run on diesel and biodiesel it was found that the bus running on biodiesel required an oil change after 12,000 km compared to 21,000 km for the bus running fossil diesel. It is worth noting however that the engine had not been significantly affected in any adverse manner.

Engine Timing

For higher blends engine performance will be improved with a slight change to engine timing, 2 or 3 degrees for a 100% blend. The use of advanced injection timing and increased injection pressure has been known to reduce NOx emissions. It is worth noting that catalytic converters are just as effective on biodiesel emissions as on fossil diesel.

Long-Term Effects of Biodiesel

It is difficult to make assumptions about the effects of long-term use of biodiesel, as there is only limited experience of its use. Beer et al. and Hitchcock et al. both reported problems of the softening or failure of rubber engine components but this trouble can be avoided by the replacing of selective components with more compatible materials.

Summary

From these previous studies of the topic of biodiesel performance versus conventional diesel performance, it is still difficult to come to any definite conclusion. However, generally speaking almost all the previous studies describe how biodiesel does reduce the majority of its tailpipe emissions when compared with conventional diesel. The problem found with the previous studies was the variation in their results. This was unsurprising as each tests used a different form of transport. In fact, it would be difficult to come up with a more diverse set of vehicle types, engine design, technical modifications and driving conditions for the comparing of biodiesel with fossil diesel. We see that this is directly responsible for the lack of clarity on the subject of biodiesel versus fossil diesel and it will be hard to make the issue any more transparent by offering more test results completed under new conditions and circumstances. However, it is feasible to say that every study returned similar results as far as biodiesel claiming carbon neutrality. This is possible because the fuel crop grown to make the biodiesel absorbs CO_2 and balances the CO_2 produced when the biodiesel is eventually burned.

The term 'carbon neutral' is a misnomer in this situation as fossil fuels are consumed in the production of biodiesel so this does upset the carbon balance. It is possible to measure this discrepancy in the balance with regards to its comparison with conventional diesel but it is necessary to use life cycle assessment.

Cost Benefit Analysis

What is Cost Benefit Analysis ?

Cost Benefit Analysis or CBA is a relatively simple and widely used technique for deciding whether to make a change. As its name suggests, the technique simply add up the value of the benefits of a course of action, and subtract the costs associated with it. Costs are either one-off, or may be ongoing. Benefits are most often received over time. We build this effect of time into our analysis by calculating a payback period. This is the time it takes for the benefits of a change to repay its costs.

Here we could classify various cost and the benefits obtained upon implementing the above projects on real time applications as shown below in the table. The data's used below gives only approximate price of components such as fuel, which may change from time to time with a percentage rise or fall on its prices. They are calculated based on the saving obtained from one construction equipment and hence the final value depends upon the total number of equipments used on the construction site.

Expected cost involved upon implementing the projects are

	Cost
1.	Engine modification 5. Rubber Seals 6. Cold Starting 7. Oil changing 8. Engine Timing
2.	Effects on Engine Warranties
3.	Escalation on biofuel prices
4.	Reduction on tax incentives for biofuels

	Benefits
1.	Direct Cost Savings (by means of reduced fuel cost for biofuel Blends)
2.	Reduction on Carbon Dioxide emissions from vehicles
3.	It helps to comply with Governments policy for meeting its the targets for 2010, 2015 and 2020 for various biofuels blends
4.	Increases the Environmental Awareness among staff
5.	Provide a good Brand Image for the company, which invites more investors.
6.	All the company vehicles can also be converted to run on those blends

Hence we see that based on the above classifications between the cost and the benefits we are able to clearly tell that the benefits over run the actual cost involved in the project. By putting all the parameter in term of the cost we would be able to find the actual cost involved and the actual benefit which we are going to get from the above project. This will give us a clear idea about the effects of implementing the above project. Based on our details case study done earlier we see that the upon implementing the above projects we are able to get more benefits in terms of Carbon Dioxide savings, reduction in fuel costs by using biofuel blends which are tax exempted, which bring about a huge change on annual energy bills, and they provide a very good brand image to the company thereby attracting lots of new investors.

Further it complies with the government's energy policies and thereby satisfying the need for using higher biofuels blends on longer term.

Reference:

5.1) Submission for Biodiesel and Bioethanol by BABFO
http://www.biodiesel.co.uk/press_release/submission_for_biofuell_1.htm

5.2) Evaluation Of The Comparative Energy, Global Warming And Socio-Economic Costs And Benefits Of Biodiesel
http://www.defra.gov.uk/farm/acu/research/reports/nf0422.pdf

5.3) Bioenergy Feedstock Characteristics
http://bioenergy.ornl.gov/papers/misc/biochar_factsheet.html

5.4) Carbon dioxide emissions: by end user
http://www.statistics.gov.uk/STATBASE/Expodata/Spreadsheets/D6459.

5.5) http://www.sjsu.edu/faculty/watkins/cba.htm

Chapter 6

Conclusion:

As Biofuel Sector as whole is a very vast field involving various aspect in it, hence our conclusion could be done by analyzing three main areas, Such as

i) The Land Use/Production looks at the issues involved on using the UK set aside land to produce biofuels and the issues involved with production.
ii) The Environment part looks at the possible environmental gains that could be had through biofuel production.
iii) And finally the Policy section looks at the various issues involved with the UK policy on biofuels.

Land Use and Production

The UK has a relatively small area of land available for the growth of fuel crops compared with that of other countries that might promote their use more aggressively. This stands true for countries such as France, Canada, USA, Brazil and Australia to name a few. It is found that Austria, which leads Europe with its promotion and use of biofuels, was able to include a 2% mandatory adding of biofuels due to the fact that this only amounted to 70,000 tonnes. For the UK, this equivalent amount would be around 350,000 tonnes and would be considerably harder to achieve.

Another factor is weather; warmer climates can produce greater yields. Brazil is an example of this where sugar cane is grown in vast amounts to produce bioethanol, this make production far more economically viable.

While the UK does have an amount of available land which has been set aside, this is still not enough to satisfy a sufficient substitution with conventional fuels (see quantitative section). This is why the market penetration of introducing biofuels would only equal 3.5% of total.

Using bioethanol does seem more acceptable than biodiesel as an intermediate replacement to petrol due to the fact that it can be derived from more raw materials than biodiesel and thus better yields can be gathered and monoculture can be avoided. Europe has adopted a more pro-biodiesel policy due to the higher number of diesel vehicle to petrol vehicle ratio.

Perhaps a better use of the land would be to produce fast growing wood such as short rotation coppice. This fuel can be combusted directly to create electricity or heat, or liquid and gas fuels could be produced through Anaerobic Digestion, Pyrolysis or destructive distillation.

Environmental Conclusions

One of the main arguments for a heavy investment into biofuels is the possible environmental benefits.

Since biofuels are partially carbon neutral then one of the main benefits is a net reduction in CO_2 emissions. Based on the Life cycle assessment we could tell that , a 2% biodiesel and 5% bioethanol blend will result in a 0.72% and 1.9% reduction in CO_2 emissions respectively (based on 2000 emissions). This total of a 2.62% reduction seems worthwhile until one takes into consideration the economic costs that would be incurred.

The table below is taken from reference x and compares the CO_2 reduction effectiveness of various energy saving and electricity producing measures.

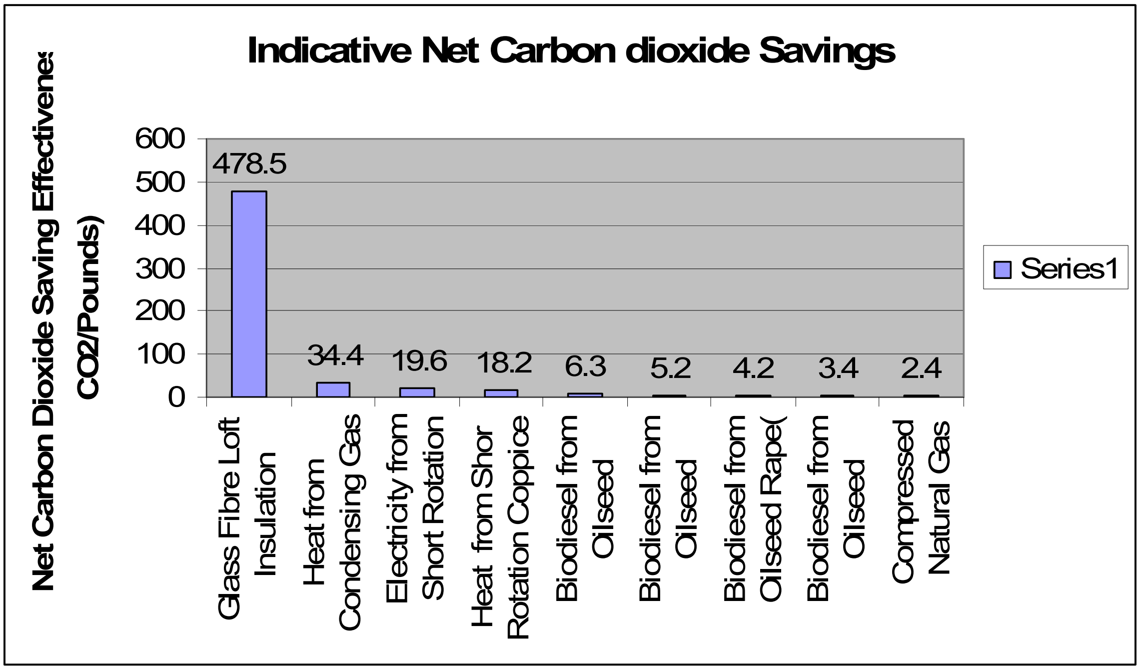

Figure 6.1 Indicative Net Carbon dioxide Savings

What can be seen from this table is that there are many more economically effective ways to reduce CO_2 emissions.

With regards to local air pollution, it is difficult to arrive at any definite conclusions. Many different tests had been conducted on tailpipe emissions using biofuels with varying results. Generally speaking, biofuels did improve on most emissions but in each case different vehicles were run under different conditions. It is fair to say that biofuels are probably cleaner but this is by no means definite. Even assuming that biofuels are cleaner, and then similar to CO_2 emissions the relatively marginal benefits do not outweigh the very high costs.

Policy

We felt that our resultant policy would be easily introduced and widely accepted as the methods and economic instruments we proposed are tried and tested. However, we feel that introducing the policy would not have an impact sufficient to counteract the various costs associated with the switch to biodiesel and bioethanol.

Another factor is the monetary cost of a change in policy, which obviously plays an important role. While we did expect there to be a price differential between conventional fuel and biofuels (conventional fuels being the cheaper), we did not expect that the government would incur such a large cost. The lost duty to the UK government would be £875million over 3 years from lowering the duty on biodiesel and bioethanol. However, an advantage of the policy we are proposing places the cost of plant construction firmly in the private sector and encourages it through tax incentives.

The Future of Biofuels

At present it is very hard to justify an aggressively pro biofuel policy simply due to high costs for comparatively low benefits.

In order to make biofuels more realistic there are a few things that could happen. Perhaps the main thing would be the complete depletion of the world's oil reserves. Should this happen then biodiesel and bioethanol will become the only suitable alternative fuel for use in current I.C.E. The problem with this scenario is the amount of land that would be required to produce anywhere near the quantities of fuel the UK requires would be quite staggering. By the time this happens it is quite likely that fuel cell technology will have reached a level of maturity whereby it is commercially viable. This is estimated to occur around 2010 to 2015. This would effectively make biofuels obsolete.

As oil reserves become scarcer, due to continues rise in Demand for the oil, invariably their prices have driven up to a very high extent. Eventually the price of oil will be high enough that biofuels may be able to compete, however this is very difficult to predict for several reasons. As oil becomes scarcer then the price of energy as well as fuel will rise. This may mean that the energy inputs required for biofuel production will become more costly, driving up the price of biofuels.

At present biodiesel produced from waste vegetable oil is commercially viable due to lower duty (20p per liter lower than conventional diesel). The loss in duty associated with this will never amount to too high a value as there is only a limited amount of waste vegetable oil available. Although we feel that biofuel produced directly from agriculture is not worth while, we feel that biodiesel produced from waste vegetable oil is as it has a lower economic cost and produces a useful product from a waste material.