Executive Report

The Feasibility of Second Generation Biodiesel Production in the UK

Prepared For:

National Non Food Crops Centre

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October 2007

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Section 1

Project Overview

1.1 PROJECT OVERVIEW

A combination of several factors including high crude oil price, legislation, climate change, etc, is driving biofuel development globally. Different drivers reflect different region-specific issues.

In the UK there is already a developing biofuel industry with a number of biodiesel plants in operation. Capacity is likely to be augmented over the short to medium term and in due course ethanol capacity will also be established.

EU targets for biofuel use in the transportation sector set for 2020 timeframe will have a major impact on the UK as a large consumer of both gasoline and diesel. There are concerns that with current first generation technology and agricultural feedstocks, e.g. wheat and rapeseed, that the UK will not be able to meet long term biofuel demand without considerable impact on the human and animal food chains. One recourse is to commercialise second generation processes that can exploit a much broader biomass pool, reducing impact on the food chain.

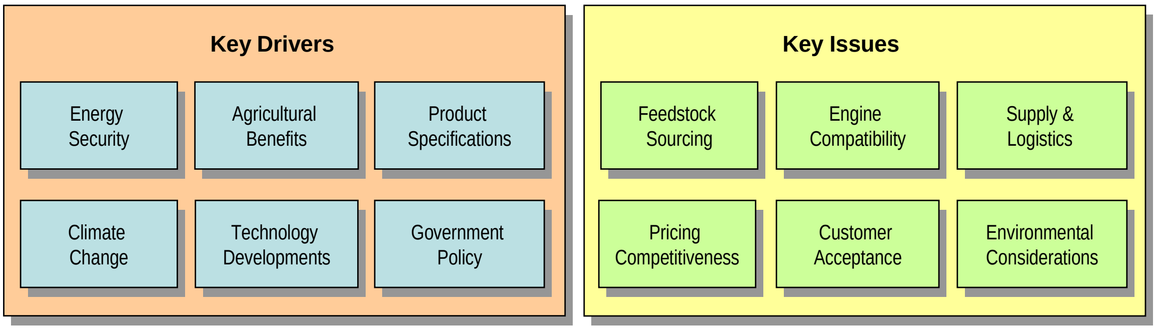
Nexant was therefore engaged by the National Non Food Crops Centre (“NNFCC”) to explore the second generation biofuel opportunity and to opine on its feasibility here in the UK. This document is therefore a brief synopsis of a major 500 page report and outlines the key issues and findings of Nexant’s analysis.

1.2 BIOFUEL DRIVERS

There are number of factors driving the rapid development of the global biofuels industry. The importance of the different drivers and issues varies from region to region. As an example the development of the United States (“US”) ethanol industry was driven initially by legislation (lead phase-out and the oxygen mandate) and latterly the phase-out of MTBE from the gasoline pool. In the US today the emphasis is much more on energy security rather than climate change. This has led to a further surge in biofuel investment, particularly ethanol and a move to second generation technologies.

In Europe climate change is still the major driver, but energy security is becoming much more important. The energy security issue not only impacts crude oil and refined product markets, but also feedstocks for current biodiesel projects due to limited domestic natural oil supply.

Figure 1.1 Biofuel Key Drivers and Issues



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1.3 ENGAGEMENT SCOPE

1.3.1 Overview

The National Non Food Crops Centre has engaged Nexant to provide an independent assessment of the opportunity for second generation biodiesel development in the UK based on a multiple biomass feedstock platform.

This engagement is focused mainly on the commercial and technical feasibility of a UK Biomass to Liquids (BTL) complex. Nexant has carried out the following analysis as part of this project:

- A review of the market opportunity for biodiesel, naphtha and lubricants that can be derived from a BTL platform.
- A review of the fiscal and legislative environment.
- A review feedstock supply options and upstream impact.
- An assessment of refined product price and profitability.
- A review of FAME biodiesel technology, process enhancements and BTL.
- A review of biodiesel cost competitiveness covering FAME, enhancements and BTL
- Development of estimates of greenhouse gas savings.
- Assessment of BTL financial performance, including sensitivity analysis.
- A high level review of alternative and complementary biomass-derived synthesis gas uses.

1.3.2 Abbreviations and Units

A glossary is provided in Appendix A1. Nexant standard notation assumes that 1.0 tons equals 1.0 tonnes equals one metric ton.

Section 2

Market Opportunity

2.1 OVERVIEW

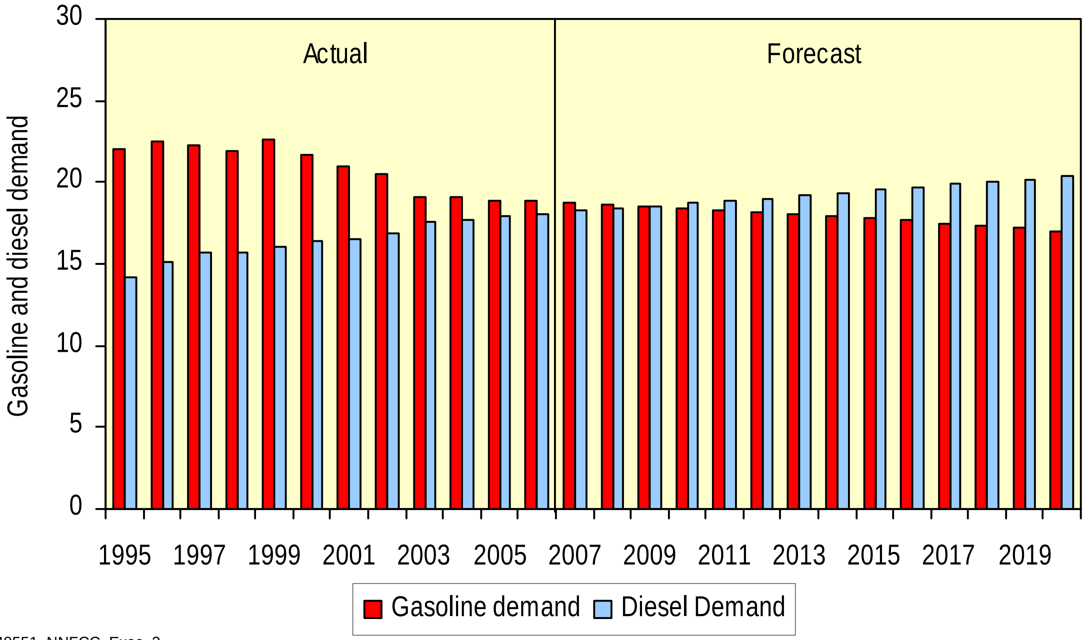
In terms of market review, Nexant has focused on petroleum diesel, naphtha and synthetic lubricants. The reason for this is that all these products can be derived from a BTL technology platform. Although jet kerosene can also be made from this technology platform it was excluded from the analysis.

2.2 BTL DIESEL

The consumption of petroleum diesel in Western Europe reached 160 million tons. Forecast average annual demand growth is of the order of 0.6 to 0.8 percent. In the UK the diesel market is currently circa 18 million tons with growth projected at slightly higher year on year than the European average. In contrast gasoline demand is either static or in slow decline. Drivers for diesel demand include improved fuel quality, e.g. low sulphur, better engine design and fuel economy. The UK diesel market is currently in balance as regards diesel supply but will need imports to meet future demand.

Figure 2.1 UK Diesel and Gasoline Demand Projections

Nexant database, million tons, 1.0 tons = 1.0 tonnes = 1.0 metric tons



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Assuming the planned provisions of the RTFO are equally applied to ethanol and biodiesel, the effective biodiesel demand will be circa 950 000 tons in 2010 and then 2.0 million tons in 2020 based on recently announced EU mandates. Current installed FAME biodiesel capacity cannot meet the RTFO requirements, but several expansions are planned together with new projects. Assuming all planned projects precede as planned then the UK can meet its EU 2020 obligations ahead of schedule.

Many of the new FAME biodiesel projects planned will rely on imported feedstocks like soybean oil or palm oil to supplement limited domestic rapeseed oil supplies. Future feedstock supply security is a concern especially given that imported natural oils are mainly sourced from the Far East.

Biodiesel can be blended into petroleum diesel without the same challenges faced by ethanol supplying the gasoline pool. However, engine manufacturers will only guarantee engine performance up to certain limits. Whilst FAME biodiesel generally meets automotive OEM performance criteria, the use of different natural oil feedstocks varies diesel properties considerably and various blending strategies are needed to maintain steady performance as regards product specifications.

A second generation BTL-derived diesel provides good cetane but has a lower density and is therefore designed to be used mainly as a low sulphur blendstock. However, BTL diesel is the same product as that produced by gas to liquids ("GTL") and coal to liquids ("CTL") plants with limited variation is specification. GTL diesel with a small additives package has been used successfully in automotive diesel engines. Volkswagen has already successfully tested BTL diesel from Choren (Sunfuel®). BTL diesel also limits UK reliance on imported FAME biodiesel feedstocks.

2.3 BTL NAPHTHA

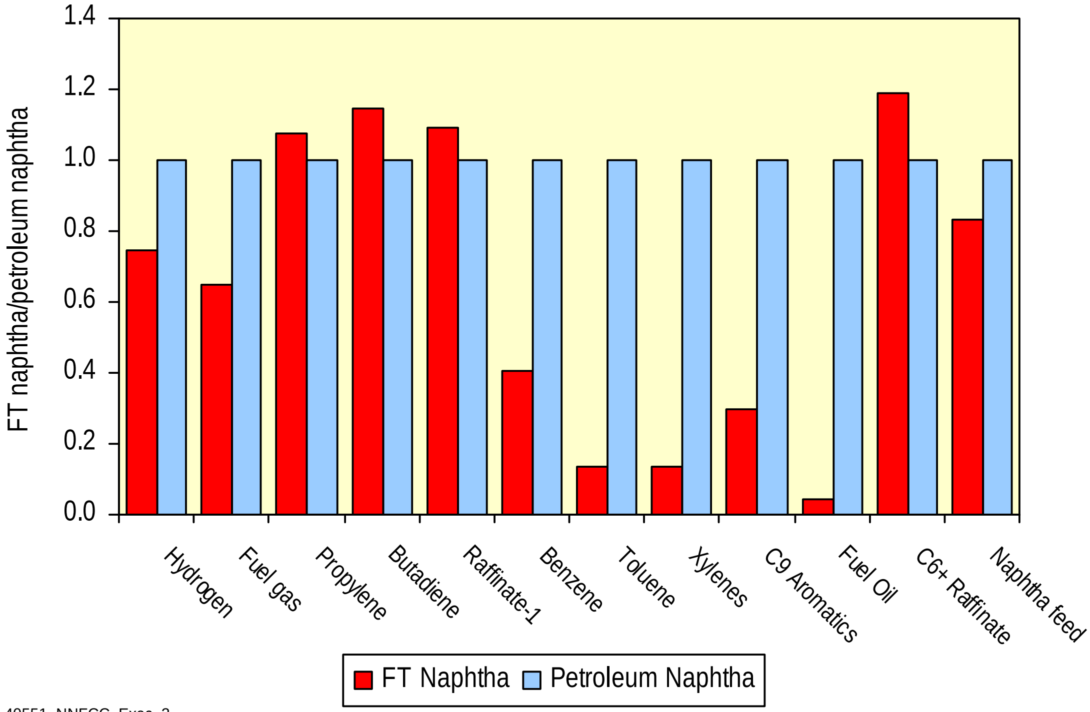
Europe is a major naphtha consumer for the production of ethylene and aromatics. Ethylene production in Europe and the UK shows only modest growth given the European region increasingly imports ethylene derivatives from lower production cost regions like the Middle East. The UK has four steam cracker sites and overall naphtha is the major feedstock utilised for ethylene production.

Ethylene production, as opposed to aromatics production via reforming, is favoured by highly paraffinic naphthas. The composition of naphtha in general is dictated by crude oil source. The advantage of BTL-derived naphtha as that it is highly paraffinic favouring much higher light olefin production at the expense of aromatics in the steam cracking process. Such a feed could help provide both improvements in ethylene production cost and reduce benzene oversupply in future.

In addition, the paraffins in the C_{10} to C_{13} carbon number range found in BTL naphtha can also be separated and consumed for the production of linear alkylbenzene and detergent alcohols to serve the surfactant industry. This range of naphtha components derived from analogous processes has already been approved for surfactant use in Asia.

Figure 2.2 BTL Naphtha Impact on Ethylene Co-Product Slate

Source: Nexant



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2.4 GROUP III LUBRICANTS

The lubricants business is very complex given the specifications set by original equipment manufacturers ("OEM") for particular applications segments be it passenger car motor oils ("PCMO") or for heavy duty ("HDDO"), etc.

Lubricants have been classified according to the American Petroleum Institute ("API") into five categories linked to their performance and not to their composition. The categories are as follows:

- Group I
  - Manufactured as refinery co-products
  - Not sophisticated leading to regular change-out intervals
- Group II
  - Generally part synthetic
  - Improved performance over Group I
- Group III
  - Generally part or completed synthetic including FT derived material.
  - These lubricants show a much improved performance over Group II

- Group IV
  - Wholly synthetic derived from petrochemical feedstocks
  - Very high performance at high cost

- Group V
  - Wholly synthetic derived from sophisticated feedstocks
  - Ultrahigh performance for extreme environments.

There are number of properties key to lubricant performance.

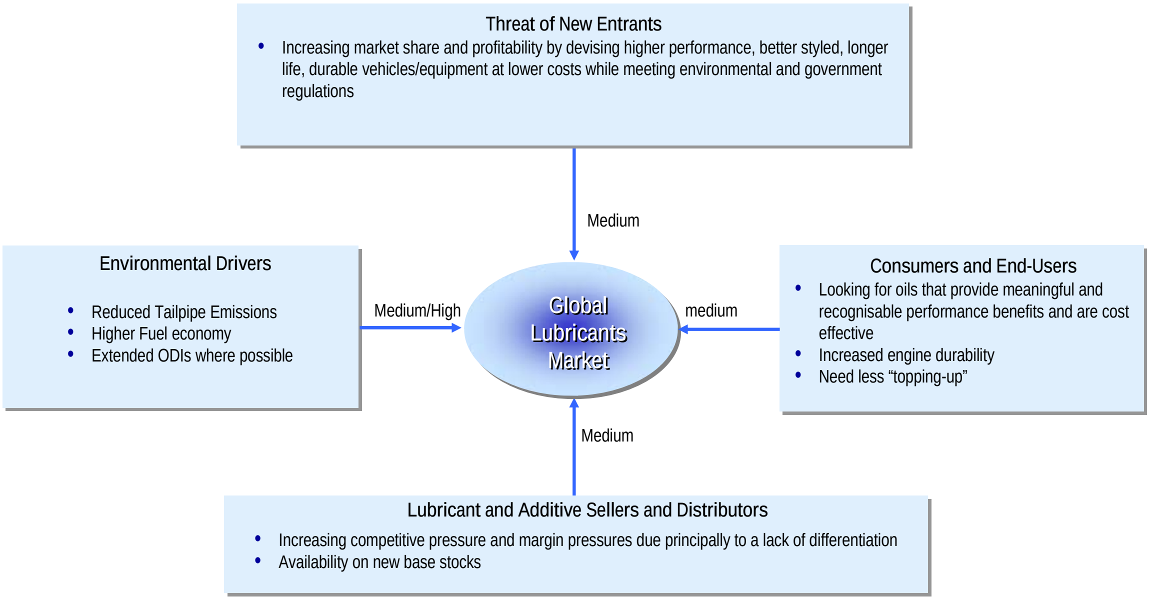
- Viscosity Index ("VI") – a measure of viscosity response to temperature
- Pour Point – a measure of low temperature flow properties
- Volatility Index/Distillation Curve – a measure of thermal stability
- Sulphur, Ash and Phosphorus ("SAP") Content

Table 2.1 API Lubricant Characteristics

Group	Viscosity Index	Kinematic Viscosity, cSt 40 °C	Kinematic Viscosity, cSt 100 °C	Pour Point °C	Saturates, %	Sulphur, %	Volatility Index
I	80-120	5-7	>24	<-18	<90	>0.03	32
II	80-120	4-6	18-24	-9 to -22	>90	<0.03	26
III	>120	3-6	11-32	-12 to -30	>90	<0.03	15
IV	120-145	2-7	6-39	-60 to -80	100	0	14
V	>130	3-6	9-35	-40 to -70	N/A	N/A	<10

There are a number of forces acting on the global lubricants industry, for example environmental legislation to reduce SAP emissions that will have an impact throughout the lubricant value chain. The consequence is a shift to higher performance and the need for more Group II and Group III lubricants. Europe and UK markets are long in Group I supply and manufacture limited Group III material. Thus meeting new lubricant requirements will be challenging. GTL, CTL and BTL-derived lubricants are classified as Group III, so there is clearly an opportunity for BTL-derived lubricants if supply is financially viable.

Figure 2.3 Forces Acting on the Global Lubricants Industry



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Section 3

Legislation

Globally legislation in support of biofuel development and related climate change issues remains a moving target. Even in Europe itself there have been major developments at a regional level and country level. Further changes and amendments are likely so the information provided in the Nexant report could move out of date sooner than originally anticipated.

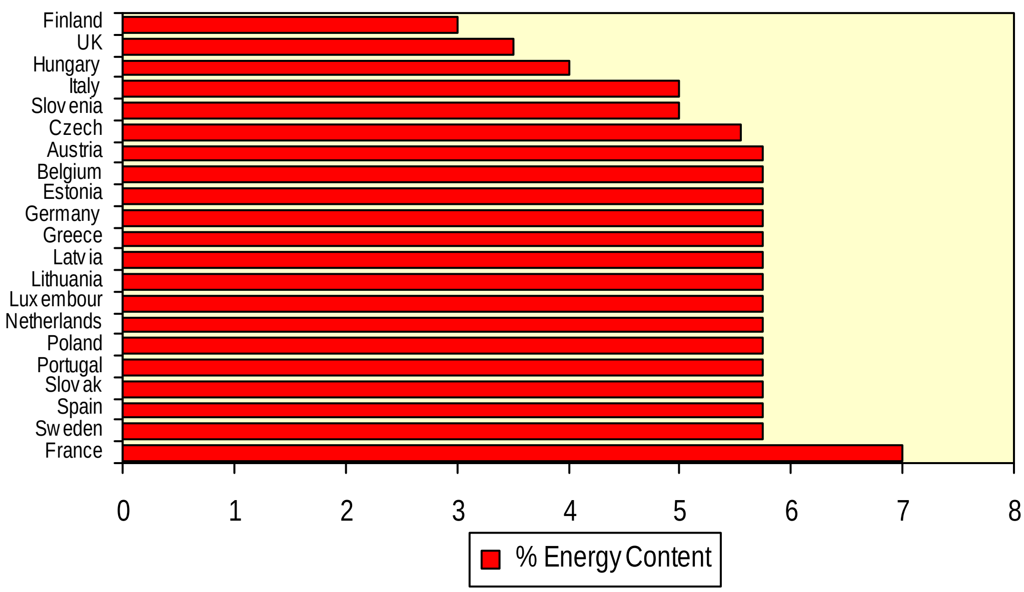
According to the guidelines of the EU Biofuels Directive, each Member State has been required to set indicative targets to fulfil the EU's biofuels target (currently at 5.75 percent by energy content by 2010).

Currently four countries have mandated targets (France, Austria, Germany and the Netherlands), and a number of countries have set lower targets, mainly due to reasons of:

- scarcity of feedstocks for biofuels production,
- or they consider second generation biofuels - a more favourable approach in achieving the EU biofuel blending targets (albeit with currently unproven technology and economics).

The figure below illustrates the current targets submitted to the European Commission on a country by country basis.

Figure 3.1 National Indicative Targets for Biofuel Market Share
(Reference Year 2010, based on energy content)



*The UK has set 5% volume target, the energy content target has been calculated on 50:50 ethanol:diesel split
Germany has set 1.2% mandate for bioethanol to be increased by 0.8% per year to 2010

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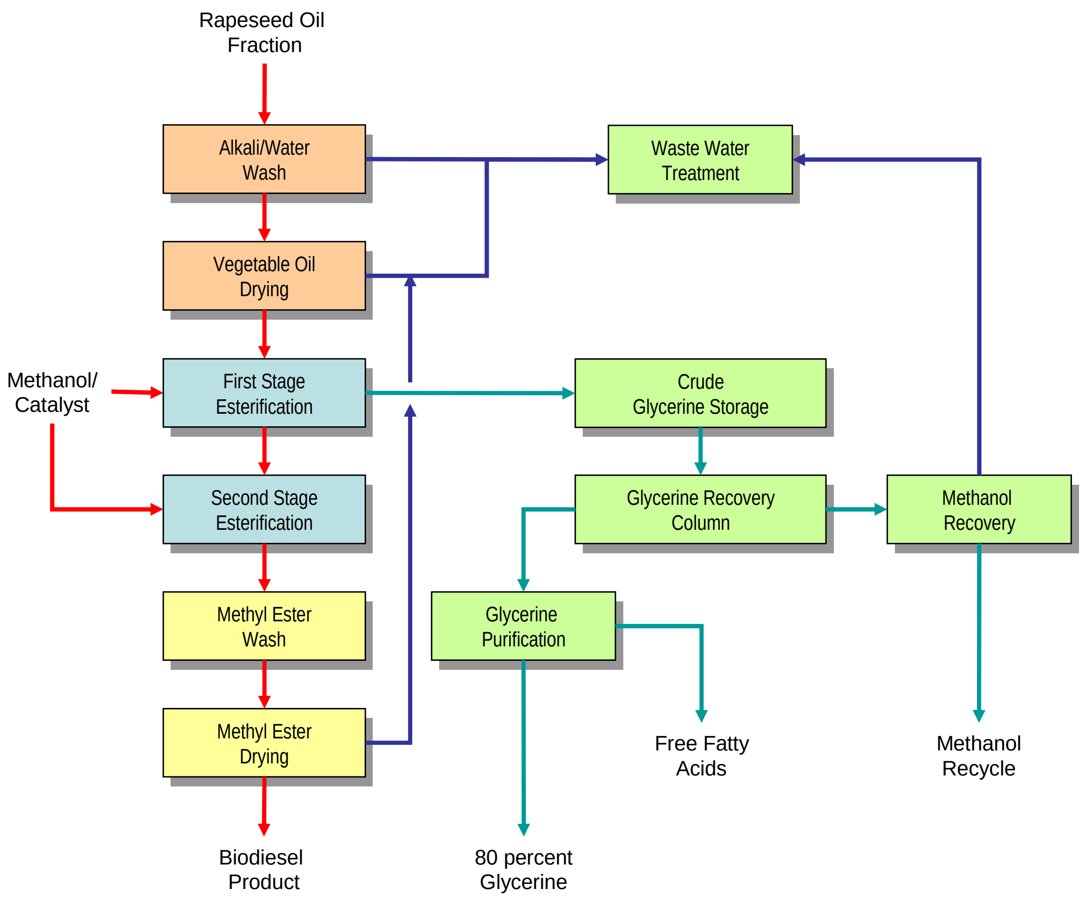
Section 4

Technology Overview

4.1 CONVENTIONAL FATTY ACID METHYL ESTER ("FAME")

First generation FAME biodiesel plants can be licensed from a number of companies such as Lurgi, DeSmet/Ballestra, Westfalia, etc. Each has advantages and disadvantages. The technology is well understood although there can be still operational problems arising from the free fatty acid ("FFA") content of the oil feedstock. A dilute glycerine stream (typically 80 percent) is provided as a by-product. Glycerine prices have been depressed due to oversupply. However, this could in part be alleviated through its use as an accelerant for anaerobic digestion ("AD") or its conversion to propylene glycol. The basic process is utility intensive and relies on homogeneous catalysis. Conventional feedstocks include soybean oil, rapeseed oil, palm oil, sunflower oil and even tallow. Some plants can run on waste vegetable oils and plants in Asia are making use of new biofuel crops like jatropha. Many plants are fixed feed, but there is an increasing move to flexi-feed facilities for commercial reasons, e.g. meeting consumer specifications and insufficient local or domestic feedstock availability

Figure 4.1 Conventional FAME Biodiesel Process
Nexant View



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4.2 TECHNOLOGY ENHANCEMENTS

There have been a number of technology enhancements to improve the economics of first generation biodiesel production. The most notable are:

- Axens with ESTERFIP®
  - This is a heterogeneous esterification process that co-produces a very pure glycerine by-product stream without recourse to further purification as in the conventional process
  - The process has one drawback in that it is very sensitive to the content of FFA

- Neste/Fortum with NexBTL®
  - This is a flexi-feed process using catalytic hydrogenation to produce biodiesel. In this case the technology can handle a broad range of feedstocks from natural oils to tallow
  - The by-product in this case is propane making the process ideally suited to refinery integration.

These enhancements whilst providing technoeconomic advantages do not alleviate the feedstock security challenge overall. Note: Nexant regards NexBTL® as a first generation plus technology, although other commentators may classify this process as second generation.

Section 5

Biomass to Liquids

5.1 OVERVIEW

In the UK situation business cases can be developed for both centralised and distributed BTL facilities. The challenge becomes one of biomass management and the relationship between biomass provider and BTL operator. In Germany for example Choren GmbH who is leading BTL development with a demonstration plant, currently being commissioned at the time of writing, has developed its own biomass trading business and is actively involved upstream in biomass procurement and management. Where sufficient local biomass is available the distributed BTL approach may be more appropriate. Where a broad biomass pool must be exploited then the centralised approach may be more suitable. In the case of the latter a cost effective means is needed to densify biomass at or near source in order to cost-optimise logistics for medium to long distance shipment to a centralised BTL facility

5.2 THE BIO-OIL OPTION

In North America the Dynamotive company has commercialised the bio-oil process employing the fast pyrolysis (also occasionally referred to as fast thermolysis) to convert wood water into liquid form. Other companies have also commercialised similar processes. Overall the process is analogous to charcoal production but instead of operating at the very slow rate associated with the latter the process is fast. The result is a low pH oily liquid of variable composition with a by-product solid residue. In the solids can be ground and dispersed in the oil for gasification purposes. Bio-oil can be shipped in bulk like a fuel oil without stabilisation. However, for long term storage the process needs to be stabilised via etherification or hydrogenation as the composition of bio-oil will change with time rendering it difficult to process.

In the case of centralised BTL approach Nexant envisages a number of bio–oil facilities strategically positioned in the UK near respective biomass sources – farmed wood, wood waste collection, wheat straw collection, etc.

5.3 THE BTL PROCESS

Nexant has developed its own conceptual design for a bio-oil gasification complex based on its experience with gasification, Fischer Tropsch and FT wax upgrading technologies. Nexant has assumed that bio-oil will be provided using proven technology such as that commercialised by DynaMotive. As described above bio-oil acts as a densification mechanism to provide a common feed from different biomass sources, e.g. wheat straw, miscanthus and farmed/waste wood. Bio-oil can be blended to provide a gasification feed with limited variation in composition and specifications.

Figure 5.1 Dynamotive Bi-Oil Process

Illustrative, Source: DynaMotive

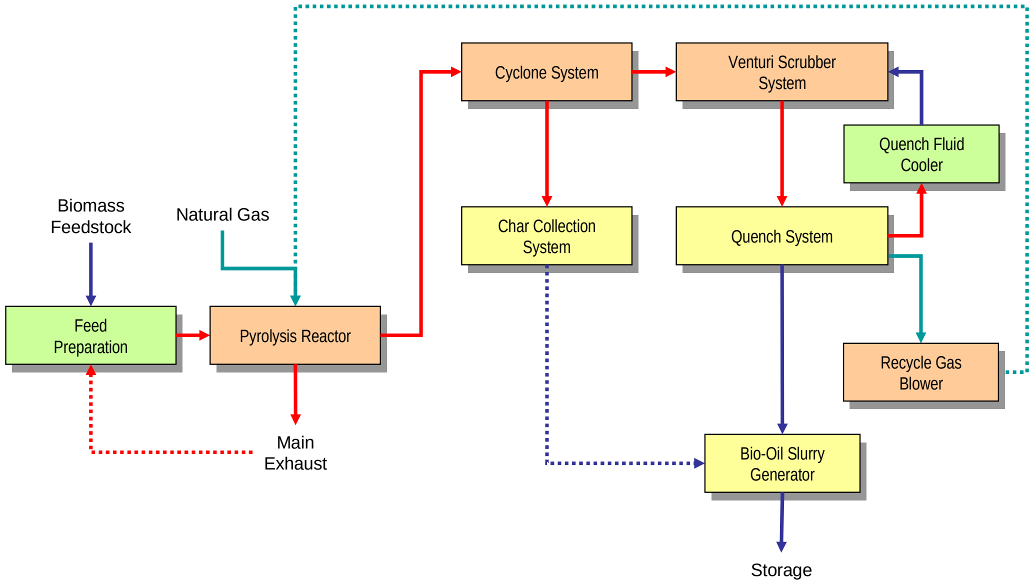

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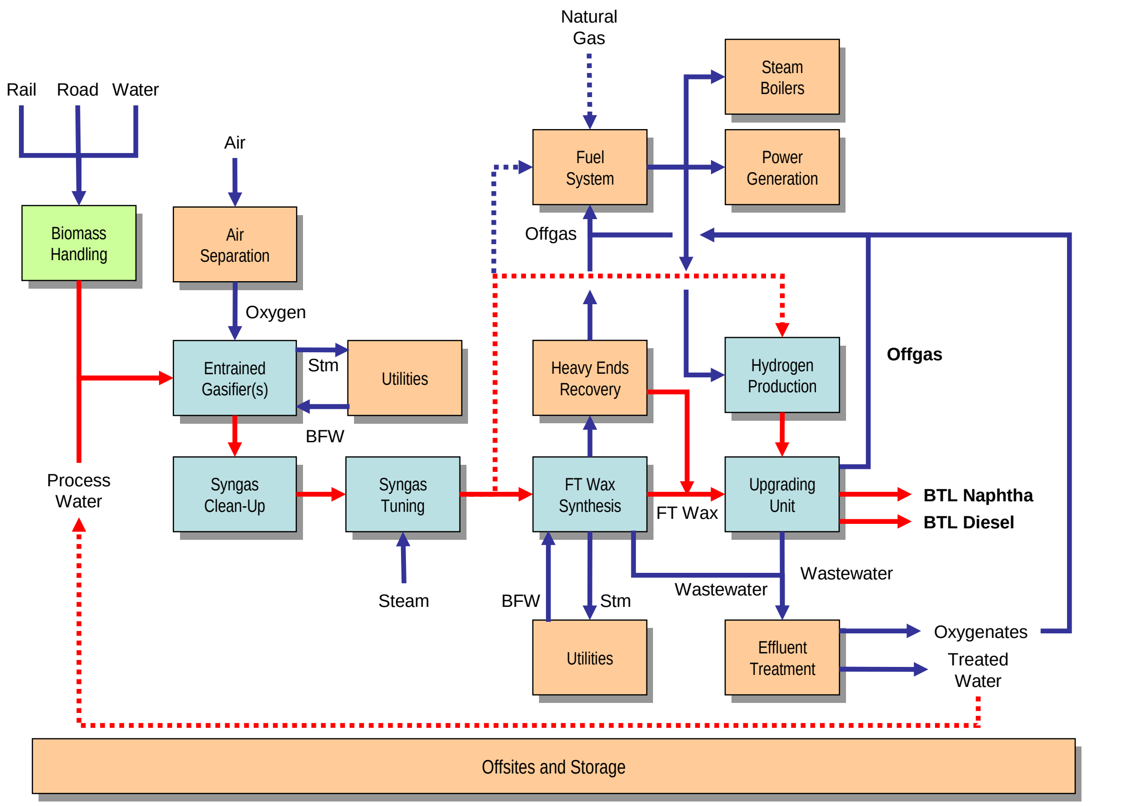
Figure 5.2 Bio-Oil Based BTL Complex –Nexant Detailed View

dotted lines indicate various process options, blue indicates main process units, brown indicates utilities



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The entrained gasification process produces synthesis gas. This needs to be purified and its composition adjusted to obtain a carbon monoxide/hydrogen ratio suitable the FT process. FT wax is produced in fixed bed reactors (assuming a Shell approach) and this wax subsequently upgraded to diesel with a naphtha co-product. The FT and upgrading process can be designed to produce a variety of products from naphtha through to lubricant basestocks. The overall complex is integrated for maximum energy recovery and efficiency. The complex can be self sufficient or alternatively import a small amount of natural gas. Some make-up water will need to be imported. For a 200 000 tons per year (5 KBPSD) bio-oil to BTL complex Nexant estimates a capital investment in the range of €520 million (£340 million) to €650 million (£425 million) at today’s EPC rates and steel prices.

An important fact to note is that most of the technology is in commercial operation today. FT processes are in commercial operation in Bintulu, Malaysia (Shell), Secunda, South Africa (Sasol) and Mossel Bay, South Africa (Mossgas). At the time of writing the ORYX® project in Qatar is in start-up and Shell is also planning another major investment in Qatar.

Wax upgrading technologies via hydrocracking are commercial in a number of refineries worldwide. Biomass gasification is also practised where biomass is co-fed with coal.

Section 6

Technoeconomics

Nexant has compared the cost competitiveness of various conventional and enhanced first generation biodiesel processes with a bio-oil based BTL diesel complex.

On a fully financed basis current conventional biodiesel costs are considerable given feedstock pricing. Whilst economies of scale are modest, feedstock selection is vital to ensuring economically viable FAME production. The glycerine disposition is not so important compared to feedstock, although it is essential to have some off-take either for upgrading, fuels use or more likely its use as a feed for anaerobic digestion. Chemical uses for glycerine are also under serious commercial development, e.g. propylene glycol from Cargill in the United States.

First generation biodiesel enhancements from Axens and Neste make a considerable impact on net raw material cost leading to an overall production cost improvement within the limits of the analysis undertaken.

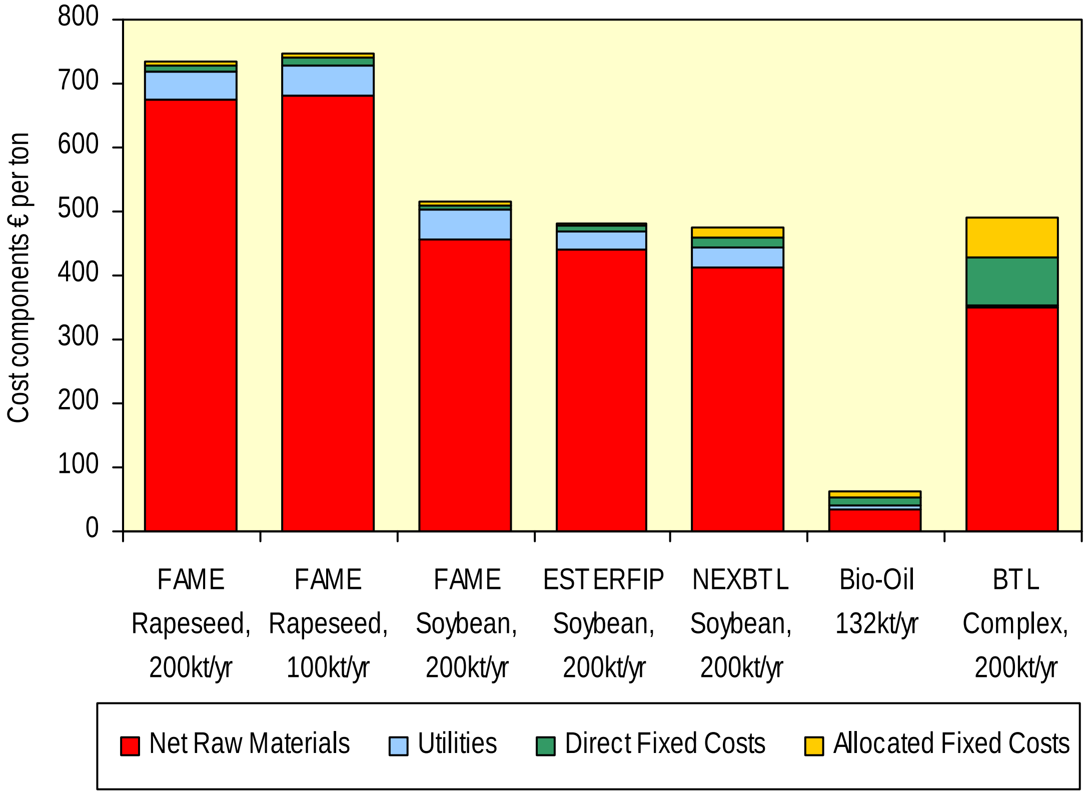
Based on Nexant's analysis the fully integrated BTL case is compelling on a cash cost basis within the limits of the analysis. However, once investment is also considered production costs become extremely high. However, given high natural oil feedstock costs the BTL option is currently comparable with conventional biodiesel even when depreciation is considered. Including some element of capital recovery in ex-works penalizes BTL versus FAME.

Table 6.1 Biodiesel Production Cost Summary

Euros per ton

Product Feedstock	FAME Biodiesel Rapeseed Oil	FAME Biodiesel Rapeseed Oil	FAME Biodiesel Soybean Oil	ESTERFIP Biodiesel Soybean Oil	NEXBTL Biodiesel Soybean Oil	Dynamotive BioOil Wood	BioOil Gasification/FT BioOil
Scale, 000 tons per year	200	100	200	200	200	132	200
ISBL, €millions	15.2	9.7	15.2	16.7	57.0	9.4	310.2
OSBL, €millions	6.1	3.9	6.1	6.7	22.9	7.5	104.6
Raw Materials	702	709	484	464	482	45	532
By-products	(27)	(27)	(27)	(23)	(68)	(11)	(164)
Utilities	45	45	45	27	29	7	4
Variable Cost	720	727	502	468	443	41	372
Direct Fixed Costs	9	13	9	9	18	12	74
Allocated Fixed Costs	6	8	6	6	14	8	62
Cash Cost	735	748	516	483	475	61	508
Depreciation	11	14	11	12	41	12	216
Full Cost	746	761	527	495	516	73	724
Price for an Instantaneous ROI 15 percent	762	783	544	513	579	93	1 048

Figure 6.1 Biodiesel Production Cost Summary
Euros per ton



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Section 7

Biomass Supply

7.1 OVERVIEW

There is today in the UK over 600 000 hectares of set-aside or fallow land according to DEFRA statistics (Change in the Area and Distribution of Set-Aside in England in 2005 and its Environmental Impact, DEFRA Agricultural Change and Environment Observatory, Published February 2006).

7.2 MISCANTHUS BIO-OIL FEED

Miscanthus has been trialled under a DTI sponsored project (Project Summary No PS254 – A trial of suitability of switchgrass, reed canary grass and other speciality grasses as biofuels crops under UK conditions, A.B. Riche Jan 2006, published August 2006). Coincidently miscanthus showed best overall growth performance on sites in the South East Midlands, specifically Woburn and Rothamsted sites. In this region there is considerable set-aside land available for expanding miscanthus production. The Brooms Barn site in East Anglia also showed reasonable miscanthus yields.

However, circa 10 000 hectares per year are committed to miscanthus in the UK with some already consumed for power generation. For this analysis Nexant has assumed two South Midlands based bio-oil plants of 66 000 tons per year, each requiring circa 6000 hectares per year of miscanthus supply. The largest 132 000 tons per year bio-oil facility is assumed to be located in East Anglia. This requires circa 12 000 hectares per year of miscanthus supply. In total, miscanthus could supply in this approach around 25 percent of the bio-oil for a gasification facility which in this case is centralised on Humberside. The bio-oil would most likely be shipped by both road and rail to a BTL facility.

7.3 STRAW AS A BIO-OIL FEED

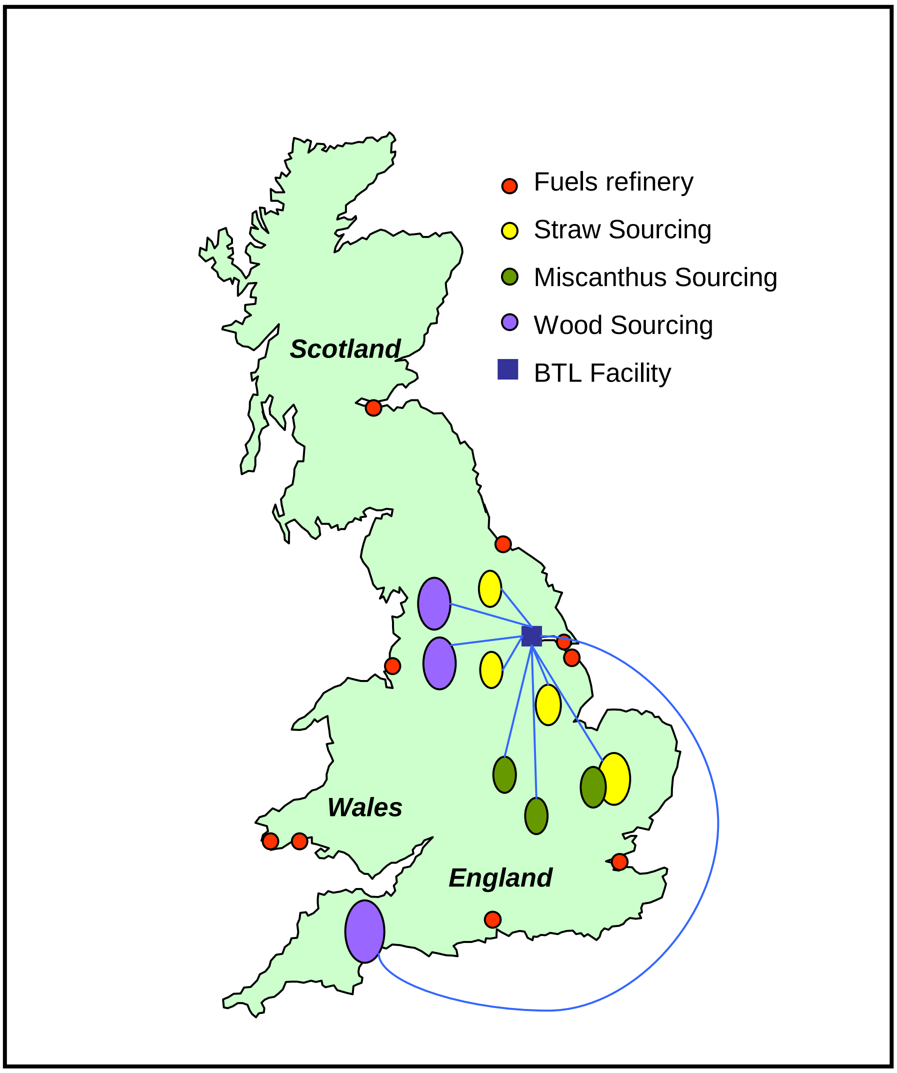
The Vale of York and East Anglia are the major wheat growing areas in the UK, although other regions like the South West provide considerable local supply. Average wheat straw yields per hectare amount to circa 3.5 tons (according to Nix, Farm Management Pocket Book, 37th Edition, published in September 2006). With the assumption that yields could be increased in the future, the assumption is made that this could increase to around 5 tons per hectare. Barley straw could also be used. Barely straw yields are circa 2.5 tons per hectare (Nix).

Nexant has assumed two straw-supplied bio-oil facilities in the Vale of York, one North of the Wash and the other in East Anglia. The assumption of 3x 66 000 tons per year of straw-derived bio-oil and one facility of 132 000 tons per year has been made as a starting point. Circa 60 000 hectares are needed. At an average wheat yield of 8 tons per hectare, then a rough figure for the wheat area required is around 1.90 million hectares. This assumes the UK produced 15.1 million tons of wheat in 2006 according to NFU findings (Farmers Weekly, 9th October 2006). This is roughly 3.0 percent of the available straw make in the UK.

7.4 WOOD AND WOOD WASTE

Wood supply for bio-oil is very likely to need a multi-source feedstock supply solution based on wood waste (forestry, domestic and industrial), current woodland harvesting and dedicated on-purpose wood for fuel production.

Figure 7.1 Bio-Oil Feedstock Supply Locations
Nexant View



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Nexant has chosen various locations for wood to bio-oil projects. Two plants could be located on the Western side of the Pennines, with another in the South West. These sites are chosen for the availability of local woodland and natural wood waste. These also provide a variety of bio-oil transportation approaches by road, rail and ship. Northern Scotland too is also a potential location for a large scale bio-oil production.

In due course bio-oil production based on waste wood from major conurbations and industry could also be envisaged. However, wood waste quality, especially if wood has been chemically treated. is variable. In the case of set aside farmed willow and poplar could generate per hectare yields of circa 8 “oven dried tons” (The Economics of Forest Plantations and On-farm Planting as a Rural Income-generating Activity in the UK and Sri Lanka, HC Coote, National Resources Institute, University of Greenwich).

On this assumption around 75 000 hectares of set-aside land could be used for on-purpose wood for bio-oil production assuming that 57 percent of the bio-oil requirement for the centralised BTL facility is supplied form this source. This is over ten percent of current set-aside capacity.

In principle any specific bio-oil/BTL development project will require a focused analysis of logistics to optimise the biomass to bio-oil chain and then the bio-oil to BTL chain.

Section 8

Carbon Performance

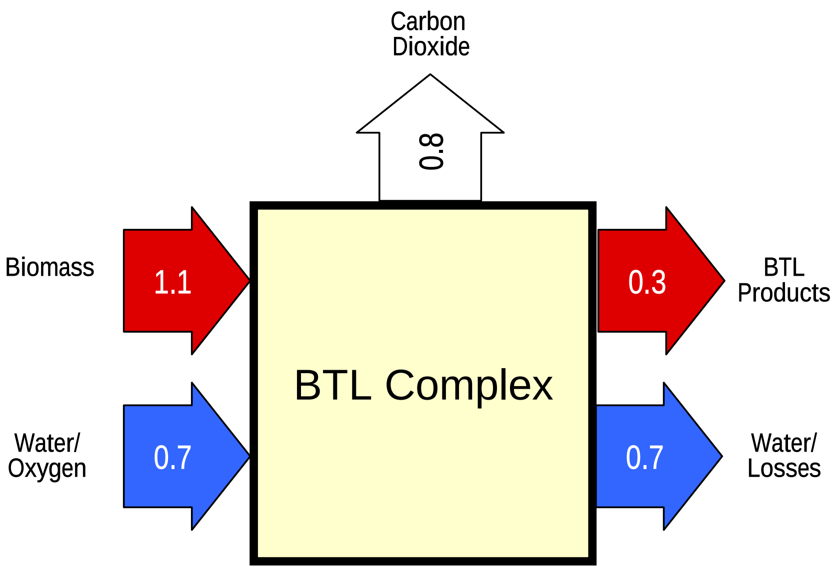
Processes for the production of synthetic fuels via Fischer Tropsch chemistry are generally large producers of greenhouse gases (“GHG”). The mass balances for GTL and BTL complexes indicate that a considerable amount of starting available carbon in the feedstock is actually converted into carbon dioxide. In the case of the GTL complex the reformers are the major GHG generator and in the case of BTL it is the gasifier. FT processes themselves do produce small volumes of GHG as do integrated power and steam generation facilities. However, in the BTL case the GHG produced is renewable. Compared to FAME biodiesel and petroleum diesel BTL diesel shows extremely strong GHG performance even when the bio-oil intermediate is considered.

According to DEFRA the UK is acting now to adapt to climate change and to reduce the risk by reducing its contribution to the causes. The EU Emissions Trading Scheme (“ETS”) is one of the key policies introduced by the European Union to help meet the EU’s greenhouse gas emissions reduction target under the Kyoto Protocol. The EU is required to make an 8 per cent reduction in emissions compared to 1990 levels by the first Kyoto Protocol commitment period (2008 to 2012). Phase I of the scheme is already underway having started in January 2005 with a plan to run to the end of this year. Carbon dioxide is the only greenhouse gas covered by the EU ETS in Phase I. Other greenhouse gases or activities could be covered from Phase II (2008 to 2012) of this scheme if Member States choose to include additional gases or activities, or if the EU ETS Directive can be amended.

Were a BTL complex to eligible for inclusion in ETS, then considerable co-product revenues could be realised based on renewable carbon dioxide emissions.

Figure 8.1 Simplified BTL Mass Balance

Illustration, million tons per year



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Section 9

Financial Analysis

9.1 OVERVIEW

Nexant has developed indicative project financials for the 5KBPSD BTL complex for both a mixed feed reflecting a centralised approach and maximum wood case reflecting a distributive case. The major general assumptions for modelling both cases were as follows:

- Fixed crude oil at $75 per bbl
- Tax break at 20 pence per litre for Project duration
- Buy out at 15 pence per litre for Project duration
- Price set by BTL blend premium, tax break and buy-out.

The financial model developed by Nexant reflects internal Nexant methodologies and practises. The model was designed to provide indicative financials for various scenarios to understand major influences as well as provide a platform to discuss potential Government incentives as part of any future BTL support package.

The figures presented may vary from other Nexant presentations as minor variations in parameters can markedly influence financial metrics. Nexant has not developed here a lenders model typical of the detailed due diligence projects it undertakes in the biofuels sector. Project-specific models tend to be more detailed and suited to lenders specific needs. Whilst reflecting most sensitivities here, the Nexant model provides only indicative financial metrics.

9.2 CENTRALISED CASE WITH BIO-OIL

For this case the IRR for the project is circa 12.0 percent with positive NPV assuming discount rates of 8 percent, 10 percent and 12 percent. Capital investment is the major influence on financial performance and provides a key sensitivity, much more then any other factor save crude oil itself. Reducing capital investment by 30 percent lowers the crude oil price for project viability to circa $60 per bbl.

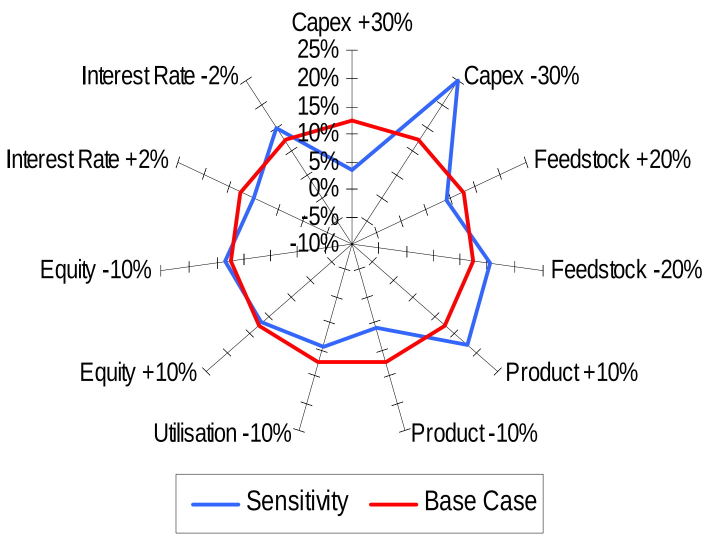
In order to make this BTL configuration viable at a $45 per bbl crude oil price a number of “incentives” are needed, typically a combination of more favourable tax incentives discounted feedstocks and reduced capital investment (via some form of grant mechanism). In such circumstances the discounted payback time amounts to seven years after start-up. Revenues from carbon trading credits could also improve overall financial performance possibly by five percent in terms of IRR.

Table 9.1 Mixed Feed 200 000 tons per year BTL Complex – Project Financials

Current US dollars

	BTL Facility			
Sensitivity Analysis	**IRR** (percent)	**NPV, 8%** (€MM)	**NPV, 10%** (€MM)	**NPV, 12%** (€MM)
Base Case	12.3%	119.1	52.0	5.4
Capex Increase (30%)	3.5%	(144.8)	(172.3)	(187.4)
Capex Decrease (30%)	25.3%	379.2	273.0	195.3
Feedstock Price Increase (20%)	9.0%	27.2	(20.8)	(53.1)
Feedstock Price Decrease (20%)	15.3%	211.1	125.0	64.0
Product Price Increase (10%)	17.9%	293.3	190.8	117.4
Product Price Decrease (10%)	5.8%	(55.9)	(87.4)	(107.0)
Operating Rate Decrease (10%)	9.2%	33.1	(16.8)	(50.5)
Equity Increase (10%)	11.5%	109.6	38.4	(11.4)
Equity Decrease (10%)	13.4%	128.8	66.0	22.7
Interest Rate Increase (2%)	9.6%	46.0	(9.4)	(46.6)
Interest Rate Decrease (2%)	15.0%	187.2	109.3	54.0

Figure 9.1 Mixed Feed 200 000 tons per year BTL Complex – IRR Sensitivity



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9.3 DISTRIBUTIVE APPROACH

In order to simulate the case envisaged by Choren with a mainly wood-based feedstock platform locally sourced, Nexant has adapted the feedstock management of the project to a totally wood based platform at large scale. Bio-oil freight cost is minimised. This reflects a compromise solution based on how the Choren process actually works.

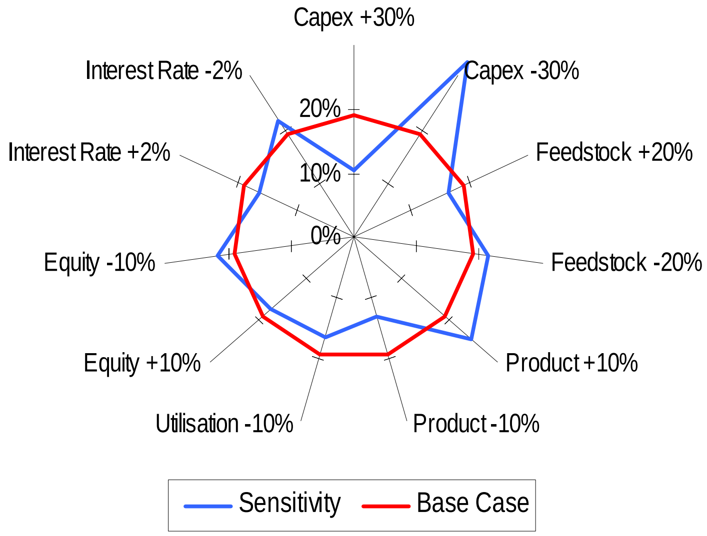
This approach improves BTL financial performance markedly to circa 19 percent with strongly positive NPVs. Financial performance is still acceptable, i.e. >15 percent IRR, with an oil price of circa $65 per bbl. A reduction in capital investment by 30 percent makes the project viable at around $40 per bbl to $45 per bbl. This suggests that under specific conditions in Germany with favourable local and regional government support that the Choren approach is viable in a mandated environment.

Table 9.2 Maximum Wood 200 000 tons per year BTL Complex – Project Financials

Current US dollars

	BTL Facility			
Sensitivity Analysis	**IRR** *(percent)*	**NPV, 8%** *(€MM)*	**NPV, 10%** *(€MM)*	**NPV, 12%** *(€MM)*
Base Case	18.9%	290.5	193.5	123.7
Capex Increase (30%)	10.5%	77.7	11.8	(33.0)
Capex Decrease (30%)	32.5%	502.8	374.8	280.2
Feedstock Price Increase (20%)	16.3%	212.2	131.5	74.0
Feedstock Price Decrease (20%)	21.5%	368.8	255.6	173.6
Product Price Increase (10%)	24.3%	453.0	323.0	228.2
Product Price Decrease (10%)	13.1%	127.7	63.9	19.2
Operating Rate Decrease (10%)	16.3%	214.9	133.0	74.7
Equity Increase (10%)	17.2%	282.8	182.0	109.4
Equity Decrease (10%)	21.6%	298.5	205.4	138.6
Interest Rate Increase (2%)	16.3%	227.3	140.4	78.7
Interest Rate Decrease (2%)	21.6%	349.4	243.1	165.8

Figure 9.2 Maximum Wood 200 000 tons per year BTL Complex – IRR Sensitivity



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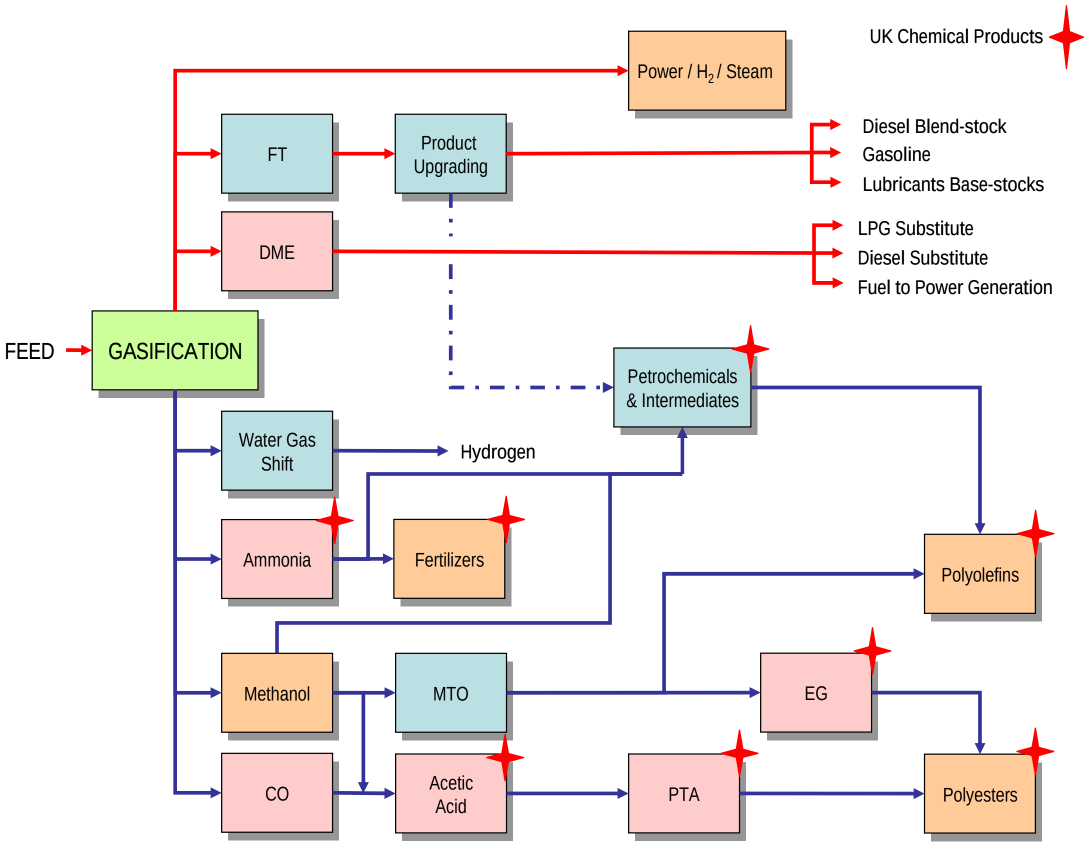
Nexant has also considered the potential impact of revenue from carbon trading and an integrated 500 MW IGCC. Using a bio-oil synthesis step is slightly deleterious to overall emissions performance versus the BTL case reported by CONCAWE/EUCAR in its March 2007 Well to Wheel update report. However, the potential carbon trading revenues generated could improve project IRR performance by the order five percent. In contrast even with a need to double capital investment and manage a four fold increase in biomass, financials are substantially improved with an IRR circa 21 percent for the mixed biomass feed case assuming ROC revenues are included.

Section 10

Integration Opportunities

Nexant has examined in outline a number of opportunities to exploit biomass and gasification for both alternative fuels like dimethyl ether, through to commodity chemicals. In countries like China where there are large very large coal reserves, coal gasification is being widely used to provide synthesis gas for power, fuels and chemicals. Major projects are underway at worldscale to generate power and to manufacture synthetic fuels, methanol, methanol to olefins, fertilisers, etc. China has the advantage of low cost coal especially when chemical plants are located close to the mine mouth. China is focused in this case on reducing reliance on imported crude oil and refined products.

Figure 10.1 Platform Chemicals Integrated with Gasification
Nexant View



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Using biomass and gasification in the UK could also provide selective opportunities for chemicals production. Apart from the large scale biomass gasification platform, virtually all the syngas upgrading technologies considered in this engagement are already in commercial operation at worldscale levels. This reduces the technical risk of such activities where a biomass gasification to chemicals platform is considered.

However, biomass requirements are considerable for worldscale operations and the capital investments required very substantial. Each project opportunity based on a biomass platform will need to be evaluated on its own merits.

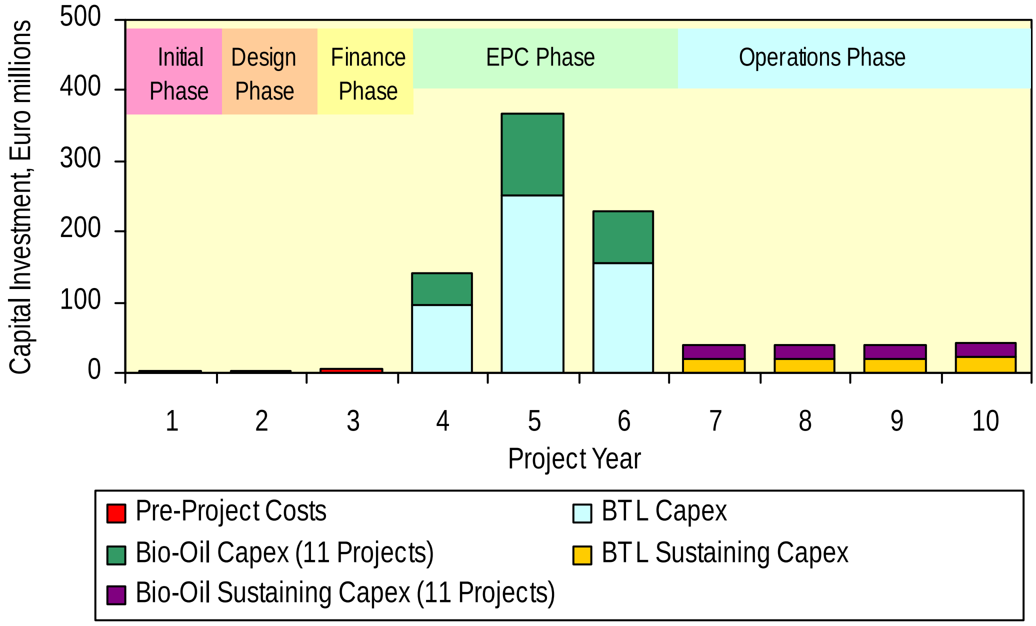
Section 11

Project Development Roadmap

11.1 PRELIMINARY DEVELOPMENT ROADMAP

In developing a UK-based BTL complex with a supporting bio-oil infrastructure, there are many challenges covering not only technology, but also legislation, financing, etc. The level of overall capital investment required for this concept is circa €750 million. There is not only the cost of the BTL complex itself, but also the costs of individual bio-oil facilities located close to biomass sources. A development plan is needed in discrete phases to meet the possible investment timeline shown below.

Figure 11.1 Potential Project Development Timeline



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The plan should consider the following factors in a phased approach to project development.

- The facilitation role of the NNFCC
  - Development of the BTL Development Action Plan
- Sponsor and Partner selection
  - Consider local groups, agriculture, oil companies, private equity and government
- Financing
  - Consider approach to lenders, government – both regional and central

- Technology selection and integration
  - Consider not only Choren but also a combination approach which may fit technologies already available from partners

- Site Selection
  - Bio-oil production will need to be close to biomass with suitable logistics
  - A BTL site will need optimised logistics, utilities infrastructure typical of a worldscale petrochemicals facility

- Legislation
  - At the European and UK level legislation will be needed to support energy crops production dedicated to second generation biodiesel
  - At the UK level further fiscal incentives for BTL production will be needed together carbon credits for renewable carbon dioxide

- Project Development Process
  - As part of the phased action a “go to market” plan will be needed to take the project through development phase, design phase, financing phase to commercialisation

Section 12
Conclusions and Recommendations

12.1 OVERALL CONCLUSIONS

There is a market opportunity for the development of second generation biodiesel in the UK. The drivers are not only climate change, but also energy security, agricultural benefits, etc. The BTL concept supplied not with wood directly as in the Choren case in Germany, but with bio-oil, allows the exploitation of wide variety of agricultural by-products (wheat and barley straw) and energy crops such as miscanthus and farmed wood (poplar, willow, etc). Wood waste from various sources industrial and domestic, can also provide a BTL/bio-oil supply option in due course subject tot feedstock quality.

A BTL project is very capital intensive compared to existing FAME biodiesel plants. Financial performance is best supported in a high oil price environment with strong fiscal incentives. With a mixed feed bio-oil BTL complex, an incentive package and investment support is needed. A wood-focused plant as per the Choren concept shows improved financial performance over a mixed feed configuration. The latter however, is more suited to the UK and offers far more feedstock flexibility.

The BTL option can be adapted to produce highly paraffinic naphthas, lubricant basestocks, jet/kerosene as well as supporting the potential production of alternative fuels like DME. Such a platform could also as support commodity chemicals manufacture.

An action plan is needed to take this analysis further in order to develop a realistic bio-oil BTL commercialisation strategy.

12.2 NEXANT RECOMMENDATIONS

Nexant makes the following high level recommendations for the NNFCC in respect of the next phase of developing a "Road Map" for a second generation biodiesel Project in the UK:

- In developing a second generation biodiesel project in the UK a mixed feedstock platform should be assumed making use of bio-oil as an approach to densification and cost effective biomass movement from agricultural facilities to biodiesel synthesis.
- Develop a strategy for assessing the quality of and selecting appropriate partners (refining, petrochemical and agricultural) to support a BTL Project and its supporting bio-oil infrastructure.
- Build a case for UK Government support via DEFRA and DTI to seek realistic financial commitments.
- In due course provide a vehicle for credible lenders to support the project through a suitable project finance mechanism.
- Develop a plan for technology selection and integration as the Choren approach is not the only option for the UK environment.
- Instigate a site selection process to assess the best site for a BTL project and the most appropriate sites for bio-oil facilities.
- Build a realistic case to lobby relevant UK Government Ministries to amend Legislation and Incentives to support second generation BTL development building from the agricultural chain upwards through bio-oil to the use of BTL diesel in the UK diesel pool.
- Specifically UK Government policies need to be tailored to second generation biodiesel by increasing the biofuel tax break to at least 35 pence per litre. This is in addition to the RTFO "buy out" already planned. The tax break will need to be in place for a period greater than five years.
- In addition the UK Government should favourably support reform of the Common Agricultural Policy to actively encourage widespread growing of energy crops to support bio-oil production.
- Develop a seven year "Action Plan" with credible sponsors to develop the project from its initial phase to execution and operation.

Nexant is very well placed to support the NNFCC in developing its BTL "Road Map" and supporting sponsors and lenders in the project development process.

Section 13

Project Synopsys

13.1 SYNOPSYS

Nexant has reviewed the ***Second Generation Biodiesel Opportunity*** from an ***independent*** perspective and observes:

- The fundamental ***market drivers*** *for biodiesel* are ***compelling***
  - ***EU*** Directives ***promoting*** (and mandating for 2020) increased use of biofuels, due to their lower emissions (than fossil fuels) and sourcing from "renewable" feedstocks.
  - UK ***proposed RTFO mechanism*** to align with the above.
  - Availability of a ***fiscal incentive*** (and selective regional grants) in the UK to ***encourage investment*** in new plants [albeit with no guarantee that the current incentive (20 pence per litre), or any fiscal incentive, will be kept in place over the medium or long term].
  - Wider opportunities in BTL naphtha and Group III lubricants also look encouraging
  - BTL integrated opportunities also exist in the chemical and alternative fuels sector.
- That said the ***"long term" answers*** to the ***fundamental questions*** in respect to servicing this market opportunity will ***only become clear over time***:
  - ***Who*** should build (biomass driven or demand driven)?
  - ***What*** should they build (1st or 2nd Generation)?
  - ***Where*** should they build it (close to biomass, close to product blending/refiner)?
  - ***When*** to build (short, medium or longer term)?

In respect of the *BTL Diesel Opportunity* Nexant has identified the following*:*

- Choren will commercialise its process at 5KBPSD capacity (200 000 tons per year) based on wood. However, this may not be the best approach for the UK where a mixed biomass platform is more likely.
- For the UK a *bio-oil intermediate* should provide a vehicle for local conversion of different biomass sources, straw, miscanthus, farmed wood and wood waste into a movable and blendable feedstock for an appropriately located centralised BTL complex. Adequate biomass is available in multiple sources around the country to support the BTL facility.
- The *capital investment* for a *BTL complex* is of the order of *€520 million*. *Bio-oil* plants require investments circa *€20 million* subject to scale and feedstock.
- Under the *sensitivities* examined by Nexant *adequate financial performance* at *crude oil prices* of circa *$45 per bbl* can only be supported by *improved fiscal incentives* and *capital investment grants*. Higher oil prices to *$65 per bbl* make a very substantial improvement in IRR and NPV performance. Carbon emissions trading options could also make a positive impact on BTL project financials.

Nexant has identified the following ***Key Features*** in developing a ***BTL "Go to Market Plan"***:

- An *"Action Plan"* for a *BTL project* needs to be developed between interested parties from *UK Government* departments and *private sector* companies facilitated by the *NNFCC*.
- The *"Action Plan"* should cover several areas ranging from *project marketing*, *legislation*, *technology*, *financing*, etc, into developing a realistic BTL commercialisation proposal.

Nexant is well placed to support the parties concerned in developing such an Action Plan

Appendix A

Glossary

A.1 GLOSSARY

Nexant has included a glossary of terms used throughout the report as follows:

- AD — Anaerobic Digestion
- bbl — barrel (usually used for crude oil references)
- BTL — Biomass to Liquids
- CTL — Coal to Liquids
- DWE — DWE Deggendorf GmbH, a company of the MAN Group
- ETBE — Ethyl Tertiary Butyl Ether
- FAME — Fatty Acid Methyl Ester
- FAEE — Fatty Acid Ethyl Ester
- FCC — Fluid Catalytic Cracker
- GTL — Gas to Liquids
- KBPSD — thousand barrels per stream day
- IRR — Internal Rate of Return
- ISBL — Inside Battery Limits
- IGCC — Integrated Gasification Combined Cycle
- MTBE — Methyl Tertiary Butyl Ether
- NNFCC — National Non-Food Crops Centre
- NPV — Net Present Value
- ODI — Oil Drain Interval
- ODT — Oven Dried Tons
- OSBL — Outside Battery Limited
- PCMO — Passenger Car Motor Oil
- ROC — Renewables Obligation Credit
- ROI — Simple Instantaneous Return of Investment
- RTFO — Renewable Transport Fuel Obligation
- TAEE — Tertiary Amyl Ethyl Ether
- TTW — Tank to Wheel
- WTT — Well to Tank
- WTW — Well to Wheel
- ZDDP — Zinc dialkyl dithiophosphate

Note: Nexant standard notation assumes that 1.0 tons equals 1.0 tonnes equals one metric ton.