Biomass to Liquid – BtL Implementation Report

Summary

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The document presented here is a summary of the conclusions arrived at in the implementation report. The summary was prepared by the Deutsche Energie-Agentur GmbH (dena) - the German Energy Agency. The partial case studies submitted by the various institutes will not be published.

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Executive Summary

Biomass to Liquid (BTL) is one of the most promising processes available in the fuel sector. The greatest advantages of the resulting synthetic biofuel lie in the high biomass yield (up to 4000 litres per hectare), its high potential to reduce CO_2 emissions by over 90% and its high quality, which is not subject to any limitations of use in either today's engine or foreseeable next-generation engines. In its fuel strategy, the German government has therefore stated that BTL fuels have great potential for securing supply, mitigating climate change and providing added value in rural areas, and has decided to promote the development of this innovative fuel in a number of ways. German industry has earned itself a leading position in the global development of this technology.

It is the aim of the implementation report to develop a basis for the implementation of large-scale BTL production in Germany, providing potential investors with an opportunity to assess the prospects and risks associated with investment in large-scale BTL production and at the same time identifying further potential for technical optimization needs, and giving the state an important starting point in respect of the further need for promotion and the creation of suitable political, legal and fiscal parameters.

The focus of the study in Part One is on biomass and logisticsin the five model locations of Gelsenkirchen, Heilbronn, Leuna, Ludwigshafen and Wismar, while Part Two highlights the technological aspects and examines five different technologies. In Part Three a calculation model which evaluates feasibility is presented and sample feasibility calculations are carried out for the five technology options. The fourth part of the study examines financing options.

The technical biomass potential in Germany is sufficient to enable a good 20% of today's fuel consumption to be satisfied using BTL. Today's findings would suggest that 35% of forecast consumption could potentially be substituted by the year 2030, depending on the energy content and competition where usage is concerned, particularly from the electricity, heating and chemical sectors. Unlike the situation in the electricity and heating sectors, biomass is the only renewable alternative to fossil energy sources in the transport sector in the short to medium term, and as such the BTL process, with its efficient use of biomass, is of central importance here. For the biomass potential to be released, a corresponding paradigm shift is necessary in agriculture, but the higher added value also offers great opportunities.

Several different technologies suitable for future industrial applications are currently either under development or being implemented. They differ as to the way the biomass is treated and gasified and in the synthesis process. After mechanical preparation, the biomass is either treated thermally or subjected to direct gasification. The synthetic gas extracted in entrained-flow gasification or fluidized bed gasification is purified, conditioned and finally synthesized to fuel. The best methods for this are the Fischer-Tropsch process, which is already under use throughout the world in coal-to-liquid and gas-to-liquid plants, and processes which produce methanol at an intermediate stage.

There is no clear preference for any one technology, and in fact all of the processes examined are suitable in principle. They are also all technically feasible. Most of the subprocesses are already being used in industrial production. As a whole, however, the process chain is very complex and sophisticated. The implementation report identifies any residual risks related to the individual technologies and discusses the realistic optimization potential. From a technological point of view, for example, it is now necessary to achieve a further increase in synthesis efficiency and in plant availability. A considerable number of synergies can be gained through the integration of BTL production into locations in which refineries or chemical plants already exist.

Overall, today's technological developments make the first large-scale plants for BTL production possible. These will be of prime importance in upholding and extending Germany's technological leadership in this sector. At the same time, continued research, development and demonstration will ensure that the optimization potential identified can be implemented and any residual risks reduced.

The BTL process will soon be marketable, but it has not yet reached market maturity. The report notes further that feasibility will also be determined by the cost of biomass and of financing the project and comes to the conclusion that the cost of BTL production could be considerably less than one euro per litre. For the investor, however, the related risks are still high, but this is only to be expected where such a young technology is concerned. When considered in this light, implementation should realistically be carried out by way of project financing, with the risk spread between private investors and the state.

If **large-scale production** is to be made economically feasible and the technological potential to be exploited, further steps by both industry and the state are necessary. The promotion of research and development on the one hand and reliable political and fiscal parameters on the other are just two of the mechanisms recommended. The tax relief on BTL fuel planned until 2015 is of vital importance, but cannot be considered sufficient today. The continued, but only temporary subsidization of BTL is therefore necessary beyond 2015. Both industry and the political arena should also work to get BTL accepted at EU level.

As a **next step**, the feasibility of the various technology options must be proven. Suitable demonstration projects are an ideal vehicle for this. At the same time, more comprehensive research and development must be carried out as regards releasing further potential to optimize both the complete process chain and individual components thereof. At least one industrial reference plant of the magnitude discussed here should be built as quickly as possible using the technologies available today so as to maintain and develop Germany's technological advantage. The aim is for technology and plant engineering companies to erect a plant at a calculable price in a calculable timeframe and with the maximum possible commitment. An acceptable operator should be found to operate such a plant, with product sales going through the petroleum industry or a direct marketing company and all in a dependable political environment. It is also important that everyone involved is willing to carry part of the project risk. This includes the provision of both capital and guarantees.

Introduction

The biomass to liquid (BTL) technology is one of the most promising technologies in the fuel sector. A technology is required to bridge the gap between today's biodiesel and ethanol fuel, and the fuel of the future, hydrogen. This technology must use biomass and not be subject to any limitations of use in either today's engine or foreseeable next-generation engines. These demands can be fulfilled using biomass gasification and a subsequent synthesization to fuel. As BTL technology makes it possible to harness the energy from all sorts of biomass, the spectrum of usable biomass will be extended considerably. The yield per hectare could be increased significantly compared to first-generation biofuels (up to 4000 litres of fuel per cultivated hectare according to information from the Fachagentur Nachwachsende Rohstoffe).

BTL offers Germany a great opportunity to become more independent from fossil energy sources and could thus be a vital ingredient in the medium to long-term safeguarding of supply in the fuel sector. As it also has the potential to reduce carbon dioxide emissions by over 90 percent compared to fossil fuels, BTL can also make an important contribution to the mitigation of climate change.

In addition to its technical, climatic and supply advantages, the BTL technology could also safeguard existing employment and indeed generate new jobs in plant construction and agriculture. If biomass energy is generated from domestic resources, this improves the economic value of rural areas and provides the agricultural sector with a new market. Both this innovative synthetic fuel and its production in Germany are also of great significance from an industrial point of view. Germany plays a leading role today in the field of BTL technology, and the extension of this would also serve to open up new export opportunities.

Due to its high quality and the fact that its properties can be optimized systematically during synthesis, BTL is an ideal fuel for the next generation of internal combustion engines (such as VW's Combined Combustion System). It can also be used without problem in jet and turboprop engines. BTL can thus be considered one of the few fuel options available for aviation besides fossil kerosene.

In its fuel strategy, the German government has therefore stated that BTL fuels have great potential to safeguard supply, mitigate climate change and provide added value in rural areas, and in addition to providing financial and active support for this implementation report, it already promotes a variety of BTL fuel projects, one of the aims being to provide answers to unresolved questions regarding the technology and to provide an ecological and economical evaluation of these second-generation biofuels. The Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), which is in charge of the project, is using the promotion to pursue a comprehensive strategy in the production of synfuels using biomass. The promotional measures not only include the narrower technical development of BTL processes, but also cover the complete production chain, from cultivation and harvesting to the conditioning of adapted biofuels. The BMELV's promotional measures thus cover the complete BTL production chain, from research and development projects on provision and cultivation processes in the joint energy crop project EVA, through the conditioning and logistics of biomass being examined in the joint BioLog project, and the project of the Technische Universität Bergakademie Freiberg in Saxony and the Forschungszentrum Karlsruhe aimed at setting up demonstration plants, to fuel synthesis in the methanol-to-synfuel (MTS) process.

Flanked by academic projects on economical, ecological and other non-technical questions, the promotional measures of the German government, with the participation of reputable businesses, are pushing development forwards throughout the production chain. The German government is also working to provide good conditions for the further development of these fuels through introduction of the Biofuel Act[1] and has helped Choren Industries to fund the construction of a first commercial BTL plant in the Saxon town of Freiberg.

Interest in the BTL technology is now also very strong at a European level. The EU Biofuels Directive issued in 2003 requires biofuels to be given a market share of 2% (based on the energy content) by 2005, increasing to 5.75% by 2010. BTL is expected to play an important role in the follow-on regulations, which are currently being drawn up. In the well-regarded Well-to-Wheels analysis, which was carried out by the Joint Research Centre of the European Commission with the European Council for Automotive R&D (EUCAR) and the European petroleum industry (CONCAWE)[2], the outstanding potential of BTL as a climate-friendly fuel option was clearly shown. The recently established European Biofuels Technology Platform is also dedicating a large part of its activities to second-generation biofuels.

If BTL fuels are to become competitive, industrial BTL production in Germany must be made possible. This BTL Implementation report is an important step in the right direction

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[1] *Law on the introduction of a minimum share in the market for biofuels resulting from an amendment to the Federal Immission Control Act (BImSchG) on the alteration of energy and electricity regulations (Biokraftstoffquotengesetz - BioKraftQuG) dated 26 October 2006.*

[2] *CONCAWE / EUCAR / JRC (2005): Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context.*

The aim of the implementation report is to develop a basis for the implementation of large-scale BTL production in Germany, providing potential investors with an opportunity to assess the prospects and risks of investment in large-scale BTL production, while at the same time identifying further potential for technical optimization needs and giving politicians an important starting point in respect of the further need for promotion. The findings in this implementation report should help government and parliament to create suitable political, legal and fiscal parameters.

In this implementation report **four areas** are examined, the results of which are summarized in the following chapter.

Part 1 deals with biomass and logistics. Scenarios showing competition for the use of biomass and its price movement in the period to 2030 based on the technical availability of biomass in Germany and its neighbouring countries are presented. Centralized and decentralized logistics concepts are drawn up for five sample locations in Germany and are compared with one another. Part 1 closes with an assessment of the five locations from a logistical point of view.

Part 2 deals with the technological aspects of BTL production. Five different technologies are chosen from the options currently available, and the development needed to bring them to market maturity is evaluated. Well-substantiated cost estimations are drawn up for the five selected methods as input parameters for the calculations in Part 3. Investment and operating costs are calculated for the construction of a plant with a biomass throughput of one million tons per annum (normalized to the energy from dry wood residue with a water content of 30 percent).

Part 2 builds on this and takes the reader from an evaluation of technical and environmental risks to a description and evaluation of the technologies which have the best potential for large-scale BTL fuel production in Germany. In addition, the general conditions pertaining to a greenfield site are compared with those of integration into a location with an existing refinery or chemical plant, and essential aspects and simplification options are discussed for the approvals process.

The focus of **Part 3** is on the preparation of a calculation model which evaluates the feasibility of large-scale BTL production. This calculation model is used to draw up sample calculations for the five technology options. The calculations are made for a standardized greenfield site and a location requiring integration into a typical refinery. The subsidies currently available for BTL fuels are also examined.

Part 4 considers the general aspects of financing large-scale BTL production. The opportunities and threats related to the conclusions arrived at in Parts 1 to 3 are discussed and translated into concrete recommendations for the parameters needed for a sustainable financing concept.

Results of the Implementation report

Biomass and Logistics[3]

Biomass suitable for the production of BTL fuels is mainly provided by wood (wood crops, industrial wood, waste wood), waste straw, certain types of animal biomass and energy crops. Particularly suitable energy crops include fast-growing trees (short rotation plantations), complete grain plants (and particularly triticale) and miscanthus grass. For these types of biomass the potential yield per area was drawn from the set-aside area. The result showed that the technical potential in Germany today lies between 40 and 70 million tons dry matter per annum (equivalent to 719 to 1219 PJ). With this, up to 15 million tones of BTL could be produced every year (if BTL production was 42% efficient), which when based on the energy content is equivalent to a contribution of approx. 22% of the current fuel consumption in Germany.

Table 1: Technical Potential of Biomass for BTL Production in German

	[mt DM/a]	[PJ/a]
Wood (wood crops, industrial wood, waste wood)	23,4 – 24,7	432 - 458
Waste straw	11,5 – 19,2	199 - 331
Animal biomass	1,0	14
Energy crops (short rotation, triticale plants, miscanthus)	3,9 – 23,6	71 - 416
Total	**39,8 – 68,5**	**719 - 1219**

DM = Dry matter

The current cost of providing biomass varies greatly depending on the biomass in question, and ranges from € 21 to € 180 per ton of dry matter (1.2 to 9.7 €/GJ based on the lower calorific value), although it mostly lies below € 60 per ton. This cost calculation takes into account storage close to the field or forest (max 10 km from source). It is assumed below that energy crops, wood crops and waste straw will be the main components of the biomass.

Table 2: Price (Wood Residue) and Production Cost (Remaining Biomass)

	Wood crops	Waste straw	Energy crops			Wet matter[4] (pressed matter)
			Short rotation	Triticale (whole plant)	Miscanthus	
[€/t_{FM}]	15-75 (30% H_2O)	46-54 (15% H_2O)	29-74 (30% H_2O)	99-109 (15% H_2O)	62 (15% H_2O)	135-162 (10% H_2O)
[€/t_{DM}]	21-107	54-63	41-105	117-128	73	150-180
[€/GJ]	1,2-5,8	3.1-3,7	2,2-5,7	6,9-7,5	4,1	8,3-9,7

FM: Fresh matter; DM: Dry matter, without cost of transportation to conversion plant Published 2006

3 *Part 1 of the Implementation report, prepared by Ludwig-Bölkow-Systemtechnik GmbH*

4 *Wet matter is undried biomass with a high water content. After mechanical drainage and subsequent drying it is turned into pressed matter.*

A variety of scenarios for the areas available and for the biomass mix required for the hectare yield are set out below. The area scenarios are based on varying assumptions regarding the land required for the cultivation of food, the land required for habitation and the land required for nature conservation. In the long term, depending on the scenario, areas of between 2.8 million hectares (environmental scenario) and 4.2 million ha (biomass scenario) are available for the dedicated cultivation of energy crops. For comparison purposes the current set-aside area was also taken into account. For the yield per hectare the low yield scenario assumes that pure short rotation will take place, while the high yield scenario assumes a mix of energy crops. When this is combined with the area scenarios the total biomass potential amounts to between 1,020 PJ or 56 million tons dry matter per annum and 1,850 PJ or 104 mt dry matter per annum. Assuming BTL production was 42% efficient, this would be equivalent to a substitution potential of between 21% and 38% of the fuel consumption forecast for the year 2030 (based on energy content).

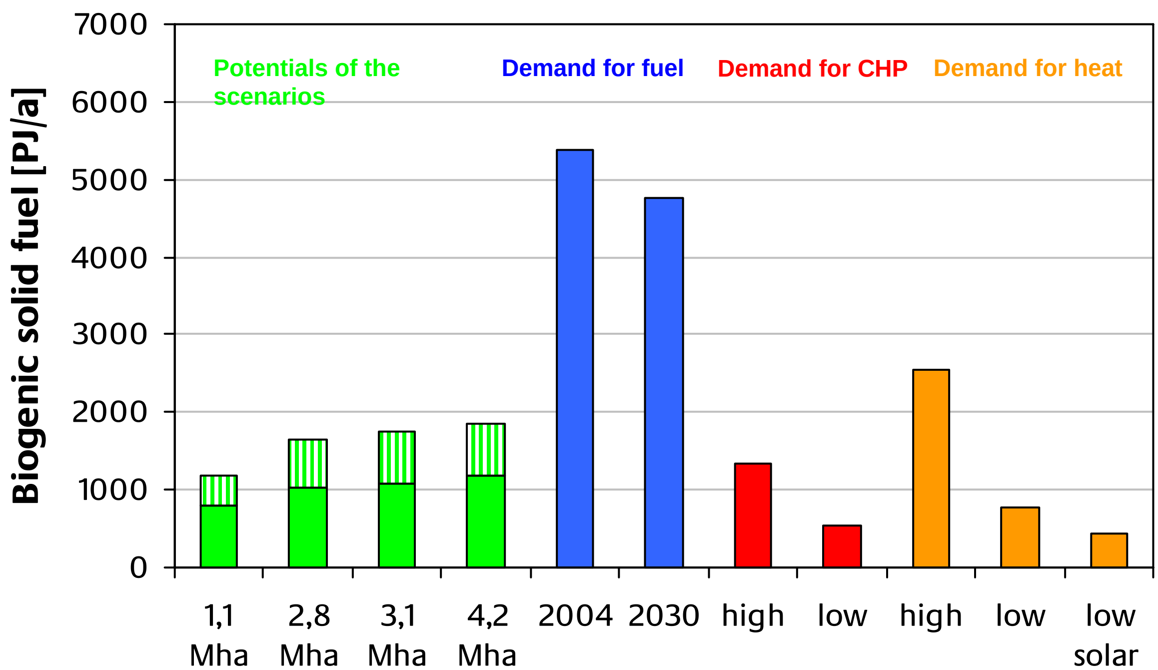
Table 3: Potential of the Biomass Usable for Energy

	Set-aside area In 2003 **1.1 Mio. ha**	Reference scenario **3.1 Mio. ha**	Environmental scenario **2.8 Mio. ha**	Biomass scenario **4.2 Mio. ha**
Low yield scenario	800 PJ/a 44 mt DM/a	1.090 PJ/a 60 mt DM/a	1.020 PJ/a 56 mt DM/a	1.180 PJ/a 64 mt DM/a
High yield scenario	1.190 PJ/a 67 mt DM/a	1.750 PJ/a 98 mt DM/a	1.640 PJ/a 92 mt DM/a	1.850 PJ/a 104 mt DM/a

Conversion of biomass [t] into energy [PJ] via the lower calorific value: 18.2 PJ per ton of dry substance (average of a variety of types of biomass) in the low yield scenario, 17.8 PJ per ton of dry substance (average of a variety of types of biomass) in the high yield scenario. 1 petajoule (PJ) is equivalent to 23.9 kt oil equivalents (oe).

In the feasibility study it is assumed that biomass prices will be set in line with crude oil prices in the medium to long term. In a scenario where crude oil costs 50 to 150 US$ per barrel, it is assumed that, based on the energy content, biomass will cost around half what heating oil costs. In contrast, the influence of rising oil and gas prices on the cost of producing biomass can be disregarded. Where the demand for biomass is concerned, however, BTL can expect considerable competition in future, particularly from the field of heating and from co-generation (CHP) plants. While in the electricity and heat sectors other renewable energy sources are available in the form of hydropower, energy from the wind and sun and geothermal energy, there will be no renewable and CO_2-reducing alternatives to the use of biomass in the power sector in the short to medium term. But the energy-efficient refurbishment of existing buildings (motivated by rising oil and gas prices) could, for example, also result in a reduction of the competition for biomass. The chart below shows the biomass scenarios described above in comparison with possible demand from the different sectors.

Figure 1: Biomass Scenarios and Types of Use



In order to enable a direct comparison with the biomass potential (primary energy), the demand for fuel was converted into the demand for primary energy (efficiency of BTL production: 42%). Scenario 2030 is based on the Energy Reference Forecast (EWI / Prognos 2005). Also shown are competing ways of using biomass (primary energy) for combined heat and power (CHP) and heating based on in-house calculations, basis for data: The Research Institute for Energy Economy (2006) and Commission of Enquiry into "Sustainable Sources of Energy under Globalization and Liberalization" (2005).

Logistics concepts and costs were examined for the five model locations[5] Gelsenkirchen, Heilbronn, Leuna, Ludwigshafen and Wismar. Whilst biomass was provided to Gelsenkirchen and Leuna from the area surrounding the BTL plant only by lorry, 50% of the biomass delivered to Heilbronn and Ludwigshafen was by barge. In Wismar, 80% of the biomass was imported by sea. Transporting biomass by rail is not worthwhile for distances under a radius of 200km. The cost of logistics in the various concepts lies between € 10 and € 15 per ton of dry matter or 0.6 to 0.9 €/ GJ. Leuna and Wismar come out best overall, as the large amounts of biomass available locally results in smaller transportation distances. As a Baltic port, Wismar also has the advantage of being able to import biomass at low cost.

Decentralized concepts, in which the biomass is converted into intermediate products - either methanol or pyrolysis oil/ coke slurry - in decentralized plants, and then synthesized into fuel in a central BTL plant, are inferior to the centralized concepts where the logistical cost is concerned. Decentralized concepts are only advantageous when the biomass is delivered from more distant regions.

5 The locations were selected by type, taking into account regional distribution, and choosing refineries, chemical plants and greenfield sites, and locations with and without access to a port.

Technology[6]

At present, no large-scale BTL plant is under operation, and as such there is no technology available as a complete process on the market However, general possibilities of upscaling the plant technology currently used can be examined by evaluating existing test, pilot and demonstration plants and existing plant units already in operation.

Biomass gasification can be carried out using either the autothermic fluidized bed method or the entrained-flow method. There is more operational experience using the fluidized bed method to gasify biomass, but entrained-flow gasification is more suitable for upscaling and achieves a better quality of gas. When purifying the gas it must be adaptated for use with biomass.

Fuel is produced from synthesis gas using either Fischer-Tropsch (FT) synthesis, after which the resulting hydrocarbon is refined, or methanol synthesis followed by the synthesis of fuel from methanol. FT synthesis has already been used in large-scale coal-to-liquid (CTL) and gas-to-liquid (GTL) plants throughout the world; the synthesis process is identical to that for BTL. The production of methanol from syngas has also proved successful in large-scale applications, but not the synthesis of fuel from methanol. However, this is partly achieved using standard techniques.

An annual throughput of a million tons of biomass was set as the reference parameter for an analysis of the technological aspects. Five types of technology and the corresponding processes were examined as follows:

Figure 2: The Five Technology Options[7]

	Mechanical treatment	Thermal pretreatment	Gasification	Gas purification	Synthesis	Product conditioning
decentralized	centralized					
1	Milling		Entrained-flow gasification	Gas purification	FT synthesis	Product conditioning
		decentralized	centralized			
2	Shredding	Fast pyrolysis	Entrained-flow gasification	Gas purification	FT synthesis	Product conditioning
					decentralized	centralized
3	Shredding		Fluidized bed gasification	Gas purification	Methanol synthesis	Product conditioning
	decentralized	centralized				
4	Shredding	Pyrolysis	Entrained-flow gasification	Gas purification	FT synthesis	Product conditioning
	decentralized	centralized				
5	Shredding	Pyrolysis	Entrained-flow gasification	Gas purification	Methanol synthesis	Product conditioning

The main procedural design parameters for these technology options were drawn up and corresponding cost estimations carried out.

Because BTL production is still at a development stage and this implementation report aims to provide a comparison of the technologies which is neutral as to location, this is an "order of magnitude" cost estimation, in which deviations of up to 30% are still possible. This means that the investment costs lie at an estimated € 525 million to € 650 million.

6 *Part 2 of the Implementation report, prepared by Fichtner GmbH & Co. KG*

7 *In technology Option 2, the thermal pre-treatment can be carried out decentrally in the form of fast pyrolysis. The pyrolysis product, pyrolysis slurry, is then transported to a central gasification plant. In technology Option 3 gasification and methanol synthesis are also carried out at decentralized locations, and it is not until product conditioning that a central plant comes into play. In Options 4 and 5 only the mechanical pre-treatment is carried out decentrally. All of the remaining process steps are carried out in a central plant.*

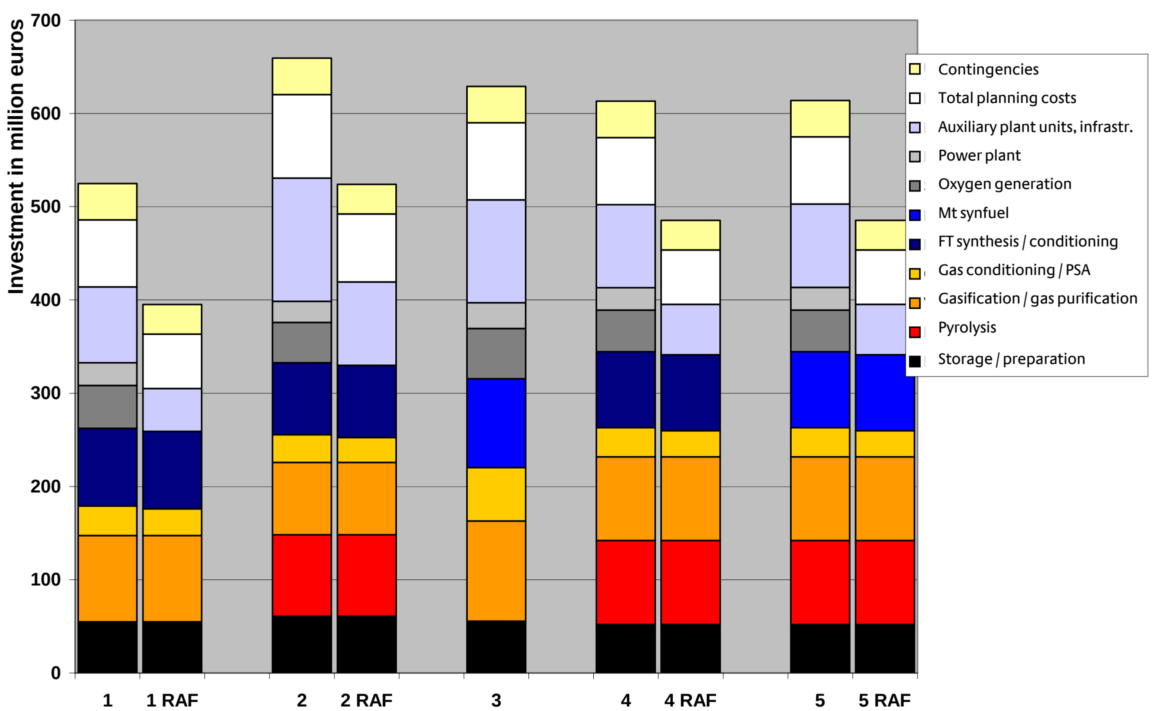
A location using an existing refinery or chemical plant has numerous general advantages over a greenfield site. In addition to lower capital expenditure and operation costs, there are operational and organizational synergies. Integration into a refinery location also significantly lowers the plant availability risk. Generally speaking, the refinery location is also ideal where permissions are concerned, as the suitability of the area from a regional planning aspect has already been confirmed and both refinery operator and the competent authorities have experience with the complex approvals processes. As a result, integration into a location with an existing refinery or chemical plant can lower investment costs by around 25% (for technology option 1, for example, to under € 400 million).
Optimization potential which would also affect production costs has been identified particularly in respect of the following:

→ "Technological learning", i.e. detailled optimization when building follow-on plants, which can result in investment savings in the region of 15%.
→ Optimization, particularly of the Fischer-Tropsch process, which can increase the production yield by about 10%.
→ An increase in plant availability to 90% thanks to existing operational experience, which can also increase the production yield by around 10%.

All methods are technically feasible and in principle worth while. A clear favourite has not yet been identified, however. Biomass gasification can be considered a bottleneck where technical feasibility is concerned. Options 3, 4 and 5 are closest to large-scale implementation, and fluidized bed or entrained-flow gasification with preceding pyrolysis are therefore particularly suitable at present. Both techniques can be followed by either FT synthesis or methanol synthesis.

Seen long term, however, both fluidized bed gasification and prior pyrolysis have disadvantages. If prior pyrolysis is used, upscaling can only be achieved if the number of production lines is increased, leading to high specific costs. The fluidized bed method limits upscaling far more than entrained-flow gasification.

Figure 3: Cost of Investment in the Technology Options



RAF = Refinery or chemical plant location, integration of Option 3 into refinery location not worth while

Options 1 (direct entrained-flow gasification) and 2 (fast pyrolysis with slurry gasification) also promise success in the long term. In Option 1 it is assumed that the problem of adequate shredding and of the direct use of biomass which has not been pre-treated is solved. In Option 2 fast pyrolysis is also limited as to throughput. However, this is a decentralized process step. The suitability of the fast pyrolysis of biomass, which has not yet been implemented on a large-scale, still needs to be proven and tested successfully at a pilot stage.

Before implementation in the magnitude discussed here of a million tons of biomass, experiences made in existing projects (e.g. the Värnamo plant after conversion, the Choren beta plant and the IEC Freiberg Engineering Study) must be evaluated.
At 7000 operating hours and a biomass throughput of one million tons per year, total production (diesel and naphtha) lies between 106,400 t and 118,300 t per annum, depending on the technology used. The proportion of diesel ranges from 60% to 90%.

The production of BTL poses no appreciable environmental threat. The electricity generated from fuel is mainly used for the product and not emitted into the air (unlike the usual biomass gasification plant) As a result of the thorough gas purification which is carried out as a matter of course in the system, the airborne pollutants inherent in fuel are isolated almost completely, leaving only minor emissions from the pollutants NOx and CO caused by combustion. Any CO2 emitted is biogenic and as such without effect on the climate. If the substituted fossil fuel and the substituted electricity generation in partially fossil-fuelled power stations are roughly taken into account, there is a significant reduction in CO2.

Acceptance problems from the general public are also unlikely to arise, while the acceptance of the technology itself can be expected to be high. Acceptance of an actual large-scale plant, particularly on a greenfield site, would be subject to the same opposition as any other large-scale industrial plant, and BTL-specific problems are not to be expected.

Feasibility[8]

The feasibility of the various processes was assessed using a calculation tool, i.e. the cost of production and market price was calculated for the end products BTL and Naphtha. With this tool it is possible to adjust price increases, the cost of operation and investment and other parameters. Investors and other interested parties can also assess the cost of and risks associated with the individual cases and calculate expected revenues. Taking the results of other parts of the implementation report as a basis, feasibility and sensitivity analyses were carried out for the technology options defined in Part 2 for the greenfield site and refinery locations (technology option 3 was only carried out for the greenfield site, as integration of this option into a location with a refinery is not technically worth while).

The lowest market prices can be achieved using technology option 1 in a location with an existing refinery or chemical plant. The synergies from and lower investment costs in a refinery location result in a clear cost advantage for all of the technology options considered. The revenues from the by-products such as residual gas, steam and electricity are included in the calculation of production costs, i.e. the flow of payments between BTL plant and refinery are taken into account. If further optimization potential is not exploited, the production costs for Option 1 would amount to € 0.88 per litre. If an internal rate of return (IRR) of 10% and a debt service coverage ratio (DSCR) of 130% are to be achieved by the project owners for such a plant, the market price ex BTL plant must amount to € 1.09 per litre. The cost of reducing carbon dioxide amounts to 280.28 €/t CO2 equivalent. This option is used as the base case scenario without further optimization.

The sensitivity analysis showed that the main influencing factors are plant efficiency, and the cost of biomass and of financing the project. Their influence on the cost of production is considerably higher than that of the cost of investment and the equity ratio.

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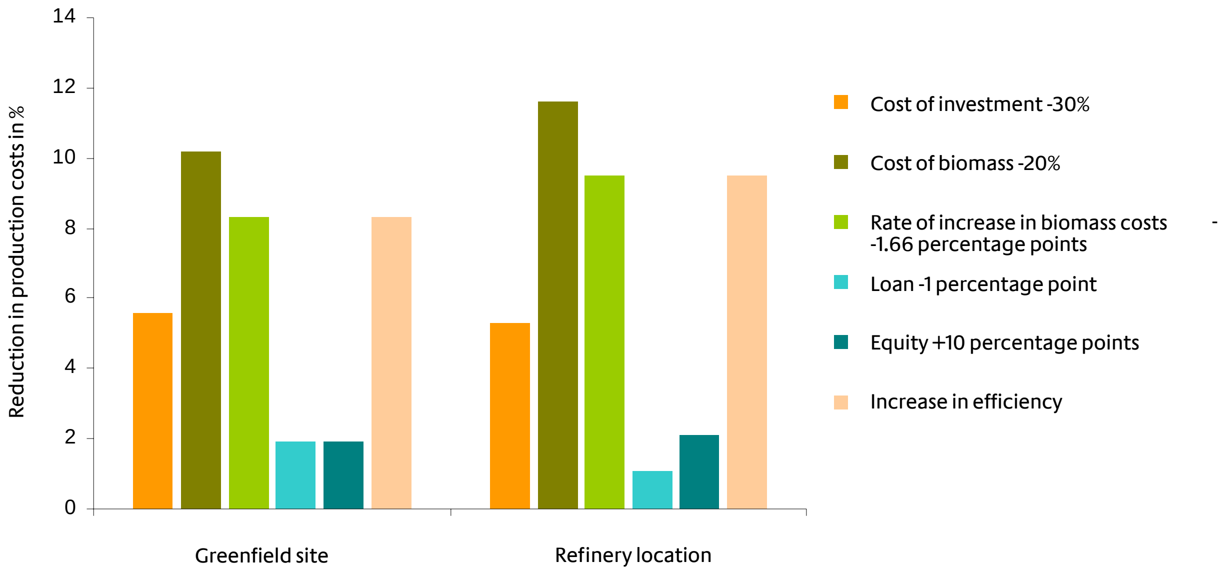
8 *Part 3 of the Implementation report, prepared by Rödl & Partner GbR*

Figure 4: Results of the Sensitivity Analysis



The underlying data chosen for the feasibility study is conservative, in line with the current status of technological development. Depending on the technology and location, the cost of production may be considerably higher than 1 €/l. In the next step, the concrete and realistic improvements which could be made to the base case conditions were examined. The result showed that the cost of production could be lowered to around 0.80 €/l. It is important to understand that this is realistic optimization potential, the exploitation of which is seen to be a definite task for the next two to five years. The following steps were identified:

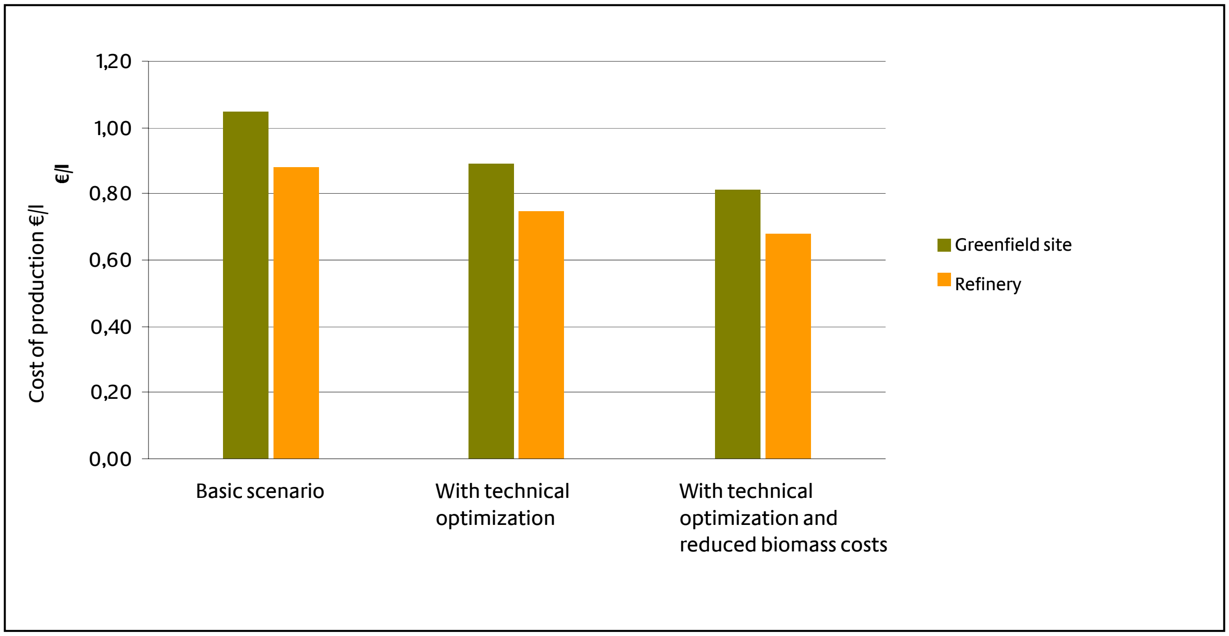
→ To increase the implementation rate in FT synthesis to 90%. For this, syngas purification must be without error, but this is a realistic expectation.

→ A 25% reduction in the cost of investment. In view of the 15% savings potential as a result of successive optimization and technological learning, and the conservative cost estimation, this can also realistically be achieved.

→ An increase in plant availability to 7,500 hours per annum, to be achieved after the second year of operation. The experiences gained in the first years of operation and the optimization carried out in the meantime make this a realistic increase, but the availability of FT synthesis, fuel treatment, gasification and purification will have to increase.

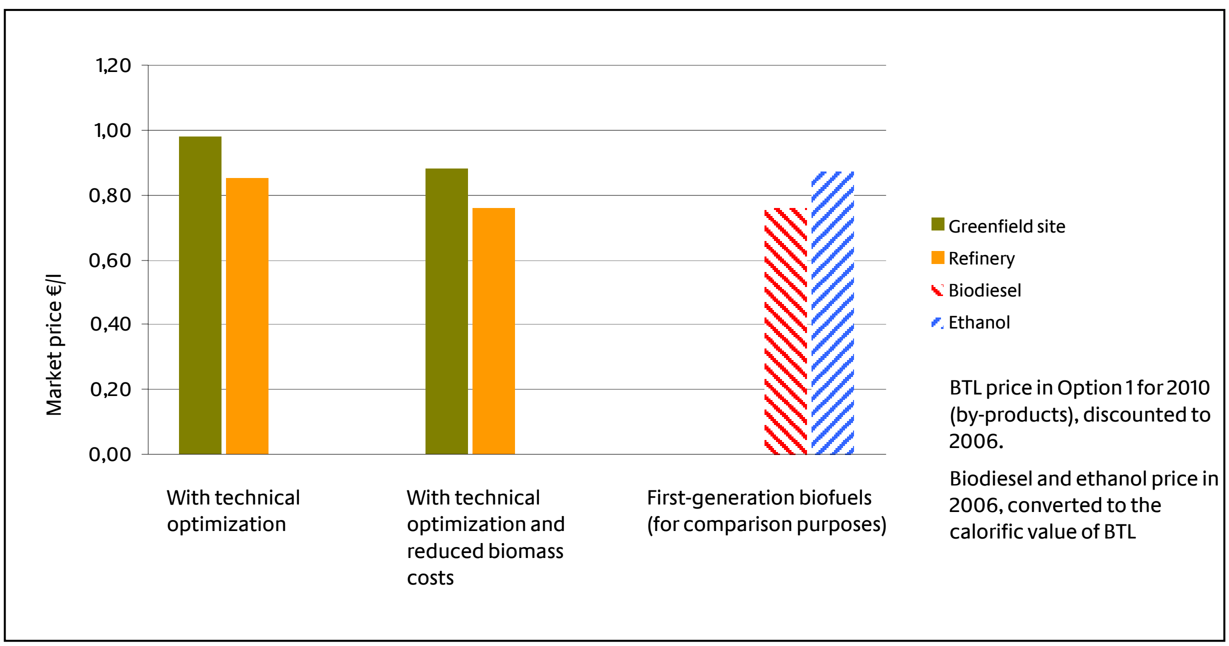
If this optimization potential is completely exploited, the cost of production could be reduced to less than 0.80 €/l. If the biomass price was also reduced by around 20% at the same time, something which should be aimed for through the negotiation of long-term supply contracts, the cost of production could be reduced to under 0.70 €/l. The chart below shows the cost of production for technology option 1, which is the cheapest option. The cost of production for the first year of operation 2010 (discounted from 2006) is shown for the base case scenario (today's technology without further optimization) and for a scenario which incorporates the optimization potential which has been identified as being realistic.

Figure 5: Cost of Production in 2010 for Option 1, discounted to 2006



This results in the following BTL market price for technology option 1:

Figure 6: BTL Market Price, Comparison with Biodiesel and Ethanol[9]



9 *Biodiesel price: Average for the months July 2005 to June 2006 according to data provided by the Union zur Förderung von Öl- und Proteinpflanzen (Association for the Promotion of Oil and Protein-Bearing Plants, http://www.ufop.de). Ethanol price: Average for the months July 2005 to June 2006 according to data from F.O. Licht's European Ethanol Price Report.*

Promotional measures were also examined, taking as a basis a hypothetical BTL project with a throughput of around 1 million tons biomass (wet), 400 employees and an investment volume of 400 - 700 million euros. Investment grants, low-interest loans, guarantees and tax-based subsidies were all examined at a regional, federal, and EU level. Many of the promotional measures available are aimed at SMEs (small and medium-sized enterprises) and are therefore not applicable. In addition, many of the grant programmes have so limited a budget, or are tied to certain applications, that a project of this size could not be subsidized. The only support can be provided under the Investment Allowance Act (*Investitionszulagengesetz*), which allows the promotion of investment in Germany's new Länder. Subsidies in the form of state guarantees and potential investment grants would depend on the political climate and cannot be taken for granted.

Financing[10]

Finally, the report discusses the specific project requirements - regardless of the five technology options considered - which a bank would consider necessary for the long-term debt financing of a first large-scale BTL plant. The emphasis in the evaluation of these criteria is on the presentation and minimization of the main project risks.

Investors and banks will only be interested in the long-term financing of BTL plants if the interest paid on equity and borrowings is in line with the expected return on investment. The early introduction of follow-on regulations for long-term, reliable support from the government beyond 2009 (including the introduction of a compulsory blending of biofuel with fossil fuels, safeguarding the competitiveness of domestic production in international trade agreements, and the extension of R&D activities in the field of BTL) is of the greatest importance for the biofuel industry in general and for BTL in particular. The bank would also not consider that tax relief on BTL until the end of 2015, which is now regulated in the Biofuel Act (BioKraftQuG), provides sufficiently reliable planning security in such long-term financing, particularly as the widespread market introduction of BTL cannot be expected until 2010 at the earliest.

The investors would play the more important role in any project financing. As the sponsors of the project, they would have to guarantee the financial success of the project. In addition to the provision of sufficient equity, they must also assume other obligations important for project survival (e.g. provision of additional capital, project development and implementation), depending on the stage the project has reached. The providers of outside capital consider good financial health and the long-term interest of the investors in the success of the project to be essential requirements for participation in BTL project financing. The financing banks require the main investors to have a credit rating at least comparable to the A rating of a reputable credit rating agency. Companies from the petroleum industry, who would also be ideal product purchasers, would be the first choice for an initial large-scale BTL plant. Leading plant suppliers, operators and biomass suppliers involved in the project would also be ideal investors. For the banks, it is essential that the BTL plant be completed on schedule and duly commissioned, and that the investment budget be kept to, as only then can the underlying cashflow actually be generated.

The risk carried by the general contractor in respect of this first plant can be expected to be so large that it is unlikely that a plant engineer would be prepared to take on such a risk and build a first large-scale BTL plant at a fixed price (the case would be different for any subsequent plants or follow-on projects). Ultimately, the investors must provide a completion guarantee covering the repayment of all loan demands until final inspection and acceptance of the plant. It is important that a sufficient amount of biomass is available at economically acceptable prices, within a reasonable timescale. As rising biomass prices can be expected in the medium term, the conclusion of a long-term biomass supply contract (at least for the loan period) with fixed quantities, prices and quality should be sought with a well-known agricultural or forest management company with a solid credit rating. If several companies supply biomass during the project, a joint delivery commitment should be agreed.

As part of the project financing - particularly where the bank is concerned - the market risk should be minimized through long-term supply contracts (at least for the loan period) with reputable, credit-worthy purchasers (ideally from the group of investors), thereby indirectly ensuring that the debt can be serviced.

10 *Part 4 of the Implementation report, prepared by Nord/LB Norddeutsche Landesbank Girozentrale*

Summary of Results

The conclusions reached in the BTL implementation report on the availability, logistics, technology, feasibility and financing of biomass are summarized below:

→ Enough biomass could be provided in Germany today to cover a good 20% of current fuel needs using BTL. Today's findings would even suggest that a good 35% of forecast fuel consumption could be covered using BTL by the year 2030, depending on the biomass scenario, the energy content and competition where usage is concerned, particularly from the electricity, heat and chemical sectors.

→ While the biomass for a first plant would initially be provided mainly from by-products, in the medium term most of the resource will come from cultivated biomass (energy crops).

→ For this biomass potential to be released, a corresponding paradigm shift is necessary in agriculture, but the higher added value also offers great opportunities.

→ The current cost of providing biomass varies greatly depending on the biomass in question, and ranges from € 21 to € 180 per ton of dry matter (1.2 to 9.7 €/ GJ based on the lower calorific value), although it mostly lies below € 60 per ton.

→ The cost of biomass has considerable influence on the feasibility of BTL production.

→ In principle, all five locations examined are suitable in terms of biomass availability.

→ The biomass logistics would not pose a great challenge for any of the locations.

→ In principle, from a technological viewpoint, large-scale BTL production is feasible.

→ The technological options examined all appear to be sensible in principle, but a clear favourite has not yet been identified.

→ This is a very complex and sophisticated process chain, in which continued research, development and demonstration can minimize the remaining scale-up risks and unleash optimization potential.

→ Realistic potential to optimize BTL technology has been identified.

→ The integration of the plant into locations with existing refineries or chemical plants would provide wideranging synergies.

→ Germany plays a leading role in the field of BTL technology today. A first large-scale project is of prime importance in upholding and extending this leadership.

→ The cost of production can be further reduced through the technological learning process and through the exploitation of further optimization potential.

→ Additionally, if the cost of biomass is reduced through corresponding long-term supply contracts, then the BTL price ex refinery will drop to under 0.80 €/l.

→ This means that BTL can compete with first-generation biofuels.

→ The potential of BTL to reduce CO_2 compared to fossil-based diesel is about twice as high as the potential of first-generation biodiesel to reduce CO_2 levels.

→ Project financing is the best type of financing mechanism.

→ Long-term biomass supply contracts and long-term purchasing contracts are required if the project is to be considered financially feasible, particularly from the bank's point of view.

→ Clear and reliable political parameters are absolutely necessary if the banks are to provide long-term financing for the first large-scale BTL plant.

Recommendations for Action

The results of the implementation report show the potential of BTL in detail. A considerable amount of fuel can be produced with feasible technologies, thus making an important contribution to the security of supply. BTL also has a high potential to reduce carbon dioxide emissions. To exploit these possibilities, further steps by industry and the state are required. The company is responsible for the economic risk when assessing its decisions on how far to go in the development and production of BTL. Today, the cost of BTL production, which is higher than that of conventional fuels, is of great importance here. If large-scale BTL production is to be made economically competitive with first-generation biofuels, the optimization potential identified needs to be exploited. Industry and investors will have to provide the necessary capital; government investment grants and guarantees are also required for the first plants. Reliable legal and political parameters are also of prime importance. Cooperation and networking between all of the players involved - agriculture and forest management, investors, operators, and the petroleum and automotive industries - will be both beneficial and expedient. Reliance is placed on market mechanisms for the long-term and cheap provision of biomass. The producers must be shown the perspectives related to this and provided with incentives to achieve attractive yields with suitable plant crops. The aim is to achieve a supply of biomass from agriculture and forest management which is predictable in the long term and thus to ensure that biomass is reliably, sustainably and competitively available. The development of a structured biomass supply chain in the agricultural sector and the increased cultivation of energy crops in Germany are further worthwhile measures.

The technology paths discussed in the implementation report and the comparison of locations will help companies to decide which direction to take with their BTL strategy. The actual decisions lie with the companies themselves. The development of such a strategy can definitely be recommended, and from a political point of view would even be considered necessary, with development directed at reducing carbon dioxide emissions and ensuring the reliability of supply. It is therefore in the interest of the state to create the necessary incentives. These should, however, only serve to boost market introduction. BTL should not result in long-term subsidization. With the right political environment, it will be of particular interest for a business to continue investing in BTL. The ministries involved in this implementation report therefore expect a positive commitment to BTL from German companies if this environment can be provided. The promotion of research and development on the one hand and reliable political and fiscal parameters on the other are just two of the mechanisms recommended to push BTL forwards for the good of both industry and state. The tax relief provided until the year 2015 is of vital importance for further progress, but cannot today be considered adequate in helping BTL to win through in the long term. Further, but not long-term promotion of BTL beyond 2015 is therefore necessary. It is recommended that the biofuels be promoted according to sustainability criteria (for example their potential to reduce CO_2 emissions).
At the same time, both businesses and the political arena should work to get BTL accepted at EU level, too. They should use their various areas of responsibility to ensure that the EU environment is advantageous to BTL and that conditions are comparable throughout the EU Member States.

As a next step, the feasibility of the various technology options must be proven. Suitable demonstration projects are an ideal vehicle for this. At the same time, more comprehensive research and development must be carried out into how to release further potential to optimize both the complete process chain and individual components thereof. At least one industrial reference plant of the magnitude discussed here should be built as quickly as possible using the technologies available today so as to maintain and develop Germany's technological advantage. The aim is for technology and plant engineering companies to erect a plant at a calculable price in a calculable timeframe and with the maximum possible commitment. An acceptable operator should be found to operate such a plant, with product sales going through the petroleum industry or a direct marketing company and all in a dependable political environment.
It is recommended that preparation of the structures for the investment phase is started now, in particular by refining and substantiating the technical concept and going into more detail in the estimation of cost. For this, an appreciable amount of investment must be made by businesses, with support from the state. The group of companies involved in this implementation report has already started doing the relevant preliminary work, but further partners are required. It is suggested that the state examines in particular the possibility of providing investment subsidies and guarantees for a project of a magnitude such as that discussed here.
The construction of the first industrial BTL plant could be commenced on this basis, making the large-scale production of BTL fuels realistic in the near future and competitive in the medium term.