renewable fuels
for advanced powertrains

executive summary

renew

Contents

Abbreviations

BLEF-DME	Entrained Flow Gasification of Black Liquor for DME-production (Chemrec)
cEF-D	Centralized Entrained Flow Gasification for diesel synthesis (UET/CHOREN)
CFB-D	Centralized autothermal circulating fluidized bed gasification for diesel synthesis (CUTEC)
CFB-E	Centralized autothermal circulating fluidized bed gasification for ethanol synthesis (Abengoa/AICIA)
dEF-D	Decentralized Entrained Flow Gasification for diesel synthesis (FZK)
DME	Dimethylether
EF-E	Entrained flow gasification for ethanol synthesis (Abengoa/AICIA)
EN	European norm
FT	Fischer-Tropsch
GJ_{DE}	Giga Joule diesel equivalent
ha	Hectare
ICFB-D	Allothermal Circulating Fluidized Bed Gasification for FT-Diesel production (TUV/RPT/BKG)
ISO	International Organization for Standardization
Mt_{OE}	Million tons oil equivalent
PJ	10^{15} Joule; energy equivalent of ~ 24000 tons oil
SRC	Short rotation coppice

Introduction

In 2003 a consortium of 31 European entities joined forces to increase the knowledge of liquid biofuels produced from ligno-cellulosic biomass (BtL). This consortium was led by Volkswagen and a group of industrial companies from all parts of the production chain, including sectors like automotives (Daimler, Renault, Volvo), the mineral oil industry (BP, Total), representatives of electricity producers (EDF), pulp and paper production (Södra) and process engineering companies (Chemrec, CHOREN/UET). Universities and institutes from nine European countries supported the activities.

The consortium defined three main objectives for a four-year project and provided resources of € 20 million to achieve them. The objectives are:

- to extend the knowledge on BtL production pathways and investigate the suitability and use of BtL fuels in today`s and future powertrains
- to assess the regional biomass potential available in Europe and analyse environmental, economic and technical properties of BtL production and
- to prepare commonly agreed recommendations to stakeholders on the future of BtL.

Of the six subprojects (SP), four were dedicated to the production, optimisation and testing of Fischer-Tropsch fuels, DME and ethanol via the thermochemical pathway. Subproject five was devoted to biofuel assessment and Subproject six to the dissemination of results.

Renewable fuels for advanced powertrains RENEW

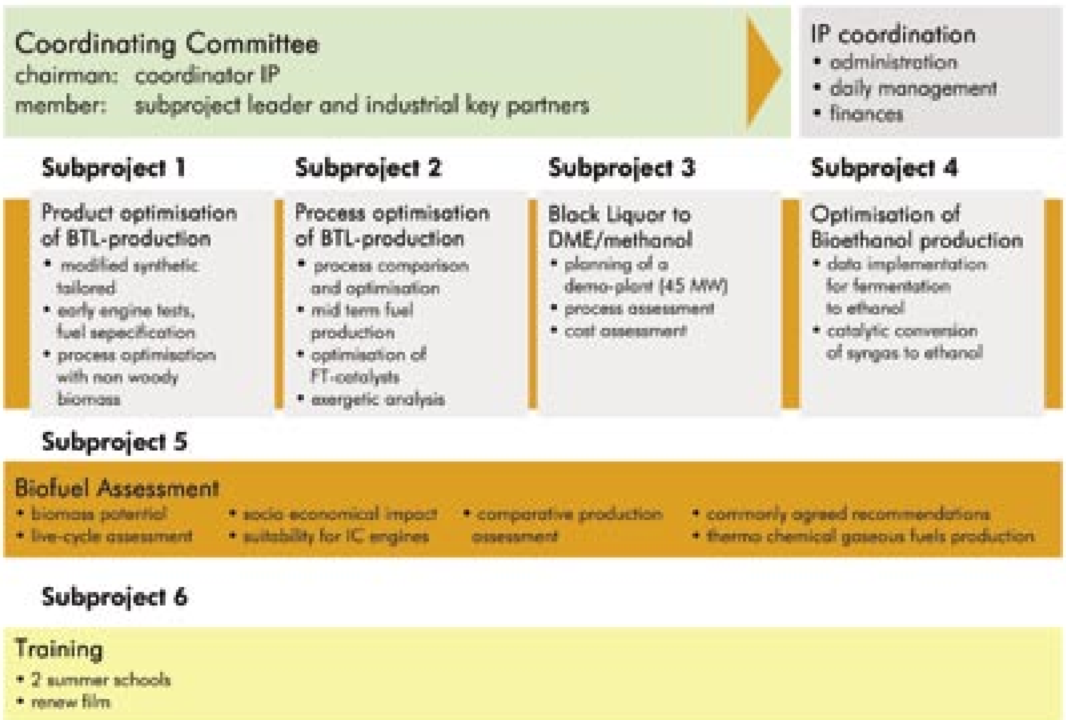


Figure 1: *Structure of the project*

Whereas experimental tests were carried out at 6 different gasifiers, BtL in larger amounts of several thousand litres was produced at the Choren plant in Freiberg. The research concerned the investigation of catalytic reactions, modelling and simulation of the processes in 500 MW size, and processing and upgrading of FT raw products and fuel testing in engines.

To enable a common assessment of different production pathways, three scenarios were developed. These encompass:

- a starting point (SP) – representing today's technology on a self sufficient[1] basis
- Scenario 1 – looking to 2020 and focused on maximising BtL fuel production and
- Scenario 2 – a self-sufficient scenario minimising environmental effects also in 2020.

All BtL production pathways were modelled for 500 MW thermal input which formed the basis for further assessments.

The investigation of biomass potential focused on the regional availability of ligno-cellulosic biomass including residues and energy wood on a regional level (NUTS 2) in EU27 under the prerequisite of leaving the production of food, animal fodder and fibre unaffected.

A life cycle assessment from well to tank (WtT) was performed for all production routes. The LCA was performed according to ISO 14040/44, reviewed by external experts and published in 2007.

The economic assessment determined cost distribution and production costs of biomass and BtL production pursuant to the guidelines of the German standards VDI 2067 and VDI 6025.

A multi-criteria technical assessment was used to evaluate key technological properties, the maturity of production techniques, as well as the suitability of fuels.

Progress achieved has been published at www.renew-fuel.com, presented to the research and industrial community in several publications, various conferences, and at two summer schools held in 2005 and 2007. A 20-minute TV film was produced to achieve the widest possible dissemination to the public.

[1]Self-sufficient means that all commodities (e.g. electricity, hydrogen,…) required for the fuel production were produced out of biomass

How much biomass is available for fuel in Europe?

In 2005 the biomass potential available for the production of biofuels without affecting that of food, fodder and fibre production was approximately 4 EJ, or 95 million tons oil equivalent (Mt_{OE}) per year. In 2020 the potential will be between 4.7 EJ/a (112 Mt_{OE}) and 7.2 EJ/a (172 Mt_{OE}), depending on the development of agriculture towards an extensive or an intensive production, respectively. The main differences between the scenarios are the degree of fertilization and machinery use, and thus the energy consumption needed for the agricultural production.

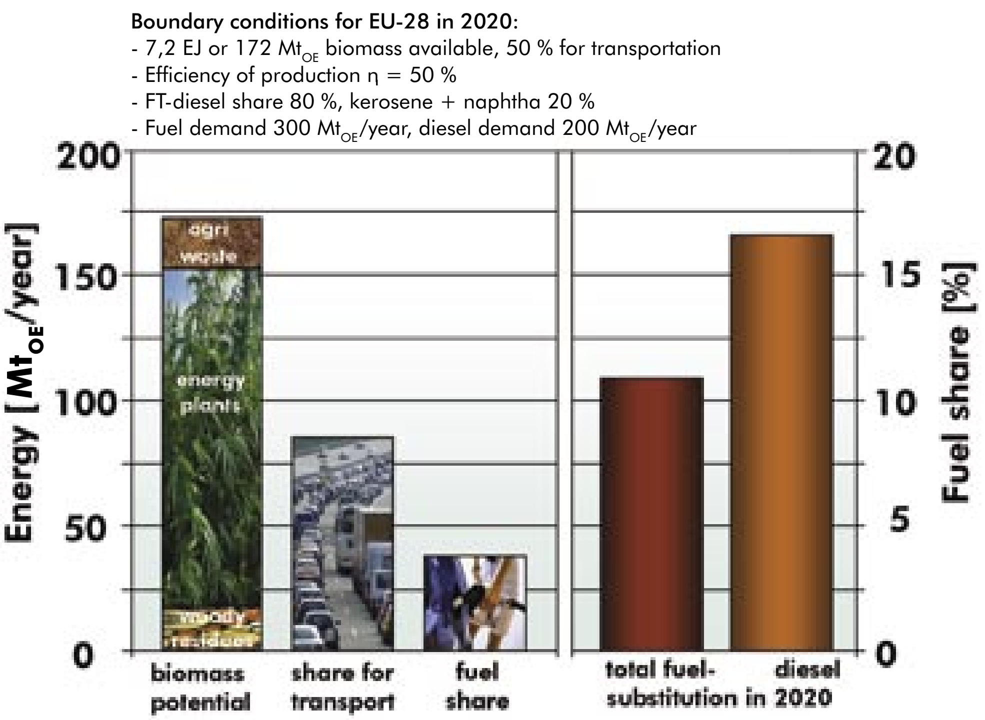
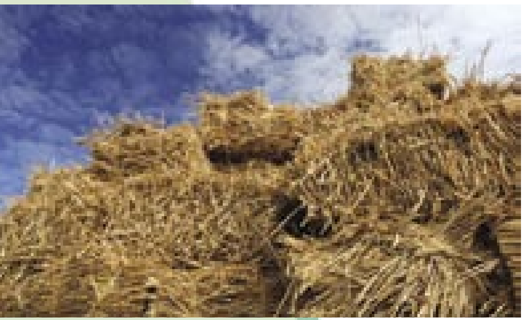


Figure 2: *Substitution potential for EU-28 in 2020*

The main reason for an increase of the potential by 2020 is the expected production efficiency gain in the East European member states, freeing land for energy crop cultivation and the assumed yield increase of short-rotation coppice (SRC) plantations, which are expected to be well-established by that time.



The production potential of energy crops reveals a strong dependence on the category of available land. Although fallow land is easily available for energy crops, this land category usually includes marginal land and poor soils. The ongoing increase of agricultural productivity in Europe would release considerable land areas for future energy crop plantations without affecting the food supply. Central and Eastern Europe harbour great opportunity for further crop productivity increase. In the EU15 countries, crop yields have already reached the technological frontier and not much land would be released. Nevertheless, in France, Germany and Ireland considerable tracts of land would become available as result of a reduction in food exports.

Perennial ligno-cellulosic energy crops, such as short rotation coppice or perennial grasses, have a high potential for an increase in yield, presuming further research in crop breeding as well as learning and scale effects at plantation management level. The current cultivation area of ligno-cellulosic crops for energy use is less than 100,000 ha (<1 %) in Europe. Specific farmer-targeted programs are required to overcome the risks connected with perennial crop implementation in the current farming system.

In general, the competitiveness of energy crops with other agricultural crops will determine their development. However as it is the case of any crop, yields are strictly determined by soil quality and water availability. Thus energy crops may compete with food crops (especially cereals) for the same land. The relation between the prices for grain and energy crops will determine what is cultivated and where it is cultivated – higher grain prices will push energy crop production onto poorer soils.

A powerful way of creating niche areas for growing energy crops is to capitalize on environmental benefits. The potential for using energy plantations in drinking water protection areas, for erosion protection, purification of polluted water or sewage treatment (i.e. as multifunctional energy plantations) may play an important role. However, the use of multifunctional energy plantations as a prime mover for energy crops presupposes that the value of environmental services can be monetized and transferred to the energy crop producer.

Where are the best regions to build the first BtL plants ?

The RENEW approach was to show the energy density (bioenergy potential divided by land surface) on a resolution of NUTS 2 provinces. Willow plantations of average yield on 10 % of the land thus result in an average energy density of 19.4 GJ/ha*year. This allows estimation of the catchment area of a bioenergy plant and the identification of promising plant locations taking into account the large influence of logistics on the economic and environmental success of a BtL plant. For example, a 500 MW BtL plant has a requirement of approx. 16 PJ, or one million tons dry biomass per year. A NUTS 2 straw energy density of 16 to 32 GJ/ha*year translates into a catchment area encompassing a radius of 40 to 55 km around the plant site. The total straw energy of NUTS 2 provinces in this highest category amounts to 380 PJ when using the background data. So, principally there is enough agricultural biomass available for the first 23 BtL 500 MW plants, forest residues not included. However, local site studies are needed for justification.

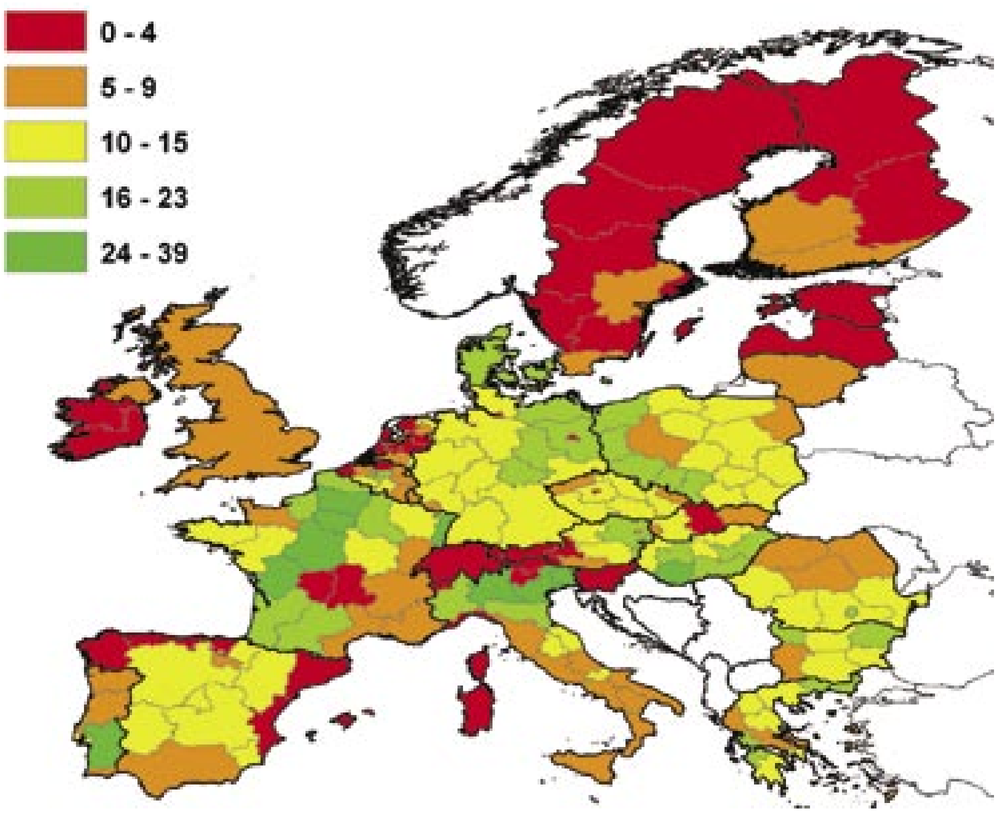


Figure 3: *Today's agricultural residues (straw) and energy crop potential in GJ/year*ha of total land surface of the NUTS 2 provinces.*

From a biomass potential point of view, the first BtL plants should be built in areas of high potential bioenergy density to keep the transport distances and thereby the cost and environmental burden low. Today, the share of the already available residues dominates in most regions the *hypothetic* potential of energy crops. Among other, France and East Germany / West Poland are expected to have a high potential in future thus qualifying for the first BtL-plants. However, Sweden with its well developed biomass supply system (and thus low *surplus* potential) is an appropriate location for a concept which is well integrated in the existing pulp&paper industry due to the relatively low requirement of additional biomass.

Energy crops have the highest potential in future scenarios. Combined with residues energy densities up to 60 GJ/ha*a are reached (catchment area radius of 30 km), allowing to further reduce the feedstock costs of established plants and to improve the security of biomass supply.

However, in order to identify the exact site for a BtL plant in a promising province, further investigation such as detailed analysis of land-use structure and infrastructure as well as current utilization of the biomass for energy purposes is required.

Which technologies are efficient and sufficiently mature?

A multicriteria assessment of six different BtL-concepts and strategies for the production of synthetic Diesel, DME and Ethanol was used to identify advantages and drawbacks like the efficiency of the fuel production and the maturity of the concept.
Today, the most advanced concepts for fuel production are the black liquor gasification concept with a DME synthesis (BLEF-DME) and the centralised entrained flow gasification with a Fischer-Tropsch (FT) diesel synthesis (cEF-D), having an net conversion efficiency of 69 % and 54 % respectively.

The BLEF-DME is designed as an integral part of a pulp mill substituting a recovery boiler. The efficiency is high due to a shift to more advanced technology in the chemical recovery unit of the pulp mill.
The cEF-D is a stand-alone plant, producing synthetic diesel directly applicable in unmodified engines. Both concepts also scored highly regarding maturity when detailed engineering was done. In the case of cEF-D, a demo-plant of 15,000 t_{OE}/year (~50 MW) is currently in the commissioning phase.
Other concepts have certain specific advantages, like the long-term gasification experience with the ICFB-D concept or the decentralised pyrolysis for very large BtL plants, but fall back in the sum of all criteria considered.

The integration of fuel production to other processes increases overall efficiency. In case of integration in a pulp mill, the recycling of spent cooking liquor is coupled to fuel production. In case of connecting a BtL plant to a district heating system, larger amounts of the process heat can be used.

From a technical point of view, all concepts are flexible in terms of biomass feedstock or the type of fuel produced. However, for practical reasons of different storage, conditioning and transport systems for the various types of biomass, commercial BtL plants will probably be adapted to five or six biomass types at maximum. And of course only one synthesis unit will be chosen, depending on the market conditions either FT fuel, DME, methanol, ethanol, or SNG.

There is a trade-off between fuel yield and overall energy efficiency (including heat and power). If a big amount of diesel is to be produced, the cEF-D concept is a good choice (fuel efficiency 52 %). If a high overall efficiency including heat and power has priority without consideration of economic aspects, it may be concluded that the present ICFB-D concept is the best choice (efficiency fuel 26 %, power 14 %, heat 40 %).

Demonstration on a pre-commercial scale of the most advanced BtL concepts (Black-liquor based DME production, centralized FT-diesel production via entrained flow gasification) is of utmost importance. These two most advanced concepts are ready for a demonstration on the scale of 15,000 t/year. Complementary research activities are needed to gain detailed process knowledge of these plants and would subsequently facilitate the upscaling process to large-scale plants with a capacity of e.g. 200,000 tons per year. Demonstration of these full-scale BtL facilities is a must for paving the way to broad market implementation.

How suitable are the fuels produced?

From detailed experiments with the available FT-diesel and FT-naphtha fuel samples, a draft FT BtL-specification was derived for application in conventional engines. First experiments are encouraging, revealing that kerosene (future BtL 100) or naphtha (BtL naphtha 100) type fuel might be appropriate choices for future powertrains. However, kerosene type fuels have disadvantages in their production, as both the remaining higher and lower fuel cut have limited properties not fitting to the market.

Table 1: *BtL fuel properties (Fischer-Tropsch-fuels)*

BTL fuel properties		Conventional engines (Diesel)		Future Powertrains (Homogenous combustion)[5]	
		BTL 100	BTL as 20% Blending component	Future BTL 100	BTL naphtha 100
Parameters					
5% recovered at	°C	170	170	160	50
95% recovered at	°C	320	350[3]	250	160
%-n paraffin/iso-paraffin		Cannot be derived from RENEW results			
Olefine	mass %	< 1	< 1	< 1	< 1
Aromatics	mass %	< 1	< 1	< 1	< 1
Sulfur	ppm	< 5	< 5	< 5	< 5
Oxygen content	mass %	Cannot be derived from RENEW results			
Characteristics					
Cetan no.		> 60	> 60	< 50 / > 65[1]	< 45
CFPP	°C	< -22	< -17[4]	< -22	< -23
Flash point	°C	> 55	> 50	> 55	-
Density	g/ml	0.76	> 0.76	0.74	0.70
H/C	mol/mol	> 2	> 2	> 2	> 2
Lower heating value	MJ/kg	44.8	44.8	44.6	44.3
Lubricity	um	< 460[2]	< 460[2]	< 460[2]	< 460[2]
Others		EN 590	EN 590	EN 590	-

1. for engine demands < 50 is required, modern Co-based low temperature FT units do offer > 65 as a standard product
2. can only be achieved with additives
3. influence on engine emission have not been proven and might change the recommendation
4. probably lower
5. very prelimenary because of early stage of engine development

Besides the specific investigations of FT derived fuels, a thorough fuel evaluation in terms of suitability was conducted. All RENEW fuels show considerably improved emission behaviour. This is particularly pronounced and important for FT-diesel and DME. They exhibit less or equal fuel consumption as conventional fuels when compared on an energy base. Together with future engine concepts the improved combustion process can also lead to better efficiency and thus reduced fuel consumption.

Assessment Criteria	Compared to	UET BTL	UET BTL naphtha	Ethanol	DME	SNG
Emission reduction potential	conv. Fuel	☺☺	☺☺	☺	☺☺	☺
Fuel consumption reduction potential	conv. Fuel	😐	☺	😐	☺	😐
Suitability with modern aftertreatment technologies	conv. Fuel	☺☺	N.A.	😐	☺	☹
Suitability for advanced combustion process	conv. Fuel	😐	☺☺	Not tested	☺	Not tested
Drivability						
Cold start, cold weather behaviour	conv. Fuel	☺☺	☺	☹	☺	☺
Hot weather behavior	conv. Fuel	☺	Not tested	☹	☺	😐
Deposit formation, sludge information	conv. Fuel	☺	Not tested	☹	☺	☺
Compatibility with materials						
Compatibility with polymer materials	conv. Fuel	😐	😐	😐	☺	😐
Corrosion behavior	conv. Fuel	😐	😐	☹	☹	😐
Lubricity and abrasion	conv. Fuel	😐	Not tested	😐	☹	😐
Storage properties						
Energy density	conv. Fuel	😐	😐	☹	☹	☹☹
Payload	conv. Fuel	😐	😐	☹	☹	☹☹
Cruising range	conv. Fuel	😐	😐	☹	☹	☹☹
Infrastructure aspects						
Suitable for blends with conventional fuels	Other alternative fuels	☺☺	☹	☺	☹☹	☹☹
Additional infrastructure necessary	Other alternative fuels	No	Yes	No	Yes	Yes
Dedicated vehicles necessary or reasonable	Other alternative fuels	No	Yes	No	Yes	Possible
Environmental and safety aspects						
Biodegradability	conv. Fuel	😐	😐	☺	Gaseous	Gaseous
Flammability , risk of explosion	conv. Fuel	😐	😐	😐	☹☹	☹☹
Toxicity	conv. Fuel	😐	😐	☺	☺	☺

Table 2: *Comparison of fuel suitability, weighted by automotive partners.*

From a suitability point of view, all RENEW fuels have advantages in environmental and safety aspects compared to conventional diesel or gasoline – with the exception of the gaseous fuels, which exhibit a higher flammability and explosion risk. With regard to synthetic fuels derived from biomass, BtL-FT fuels are generally a favourable solution for passenger cars and long haul heavy duty vehicles, whereby BtL-DME might be a good solution for fleet applications, i.e. delivery, heavy duty trucks and buses.

What is the environmental performance of BtL fuel?

The production pathways for FT-BtL and DME have been investigated from an environmental point of view by means of a WtT-Life-Cycle Assessment (LCA) pursuant to ISO 14040/44 including an independent external review.

The WtT LCA includes the production of biomass, transport to the production plant, self-sufficient conversion processes and fuel distribution to the filling station.

The environmental profile of self-sufficient BtL production concepts is dominated by the biomass production and subsequent processes, such as fertilizer production etc. Only for the category Photochemical Oxidation Potential is the conversion process more important than the biomass production. In this case the conversion process has higher emissions in hydrocarbons/nitrogen oxides than the biomass production.

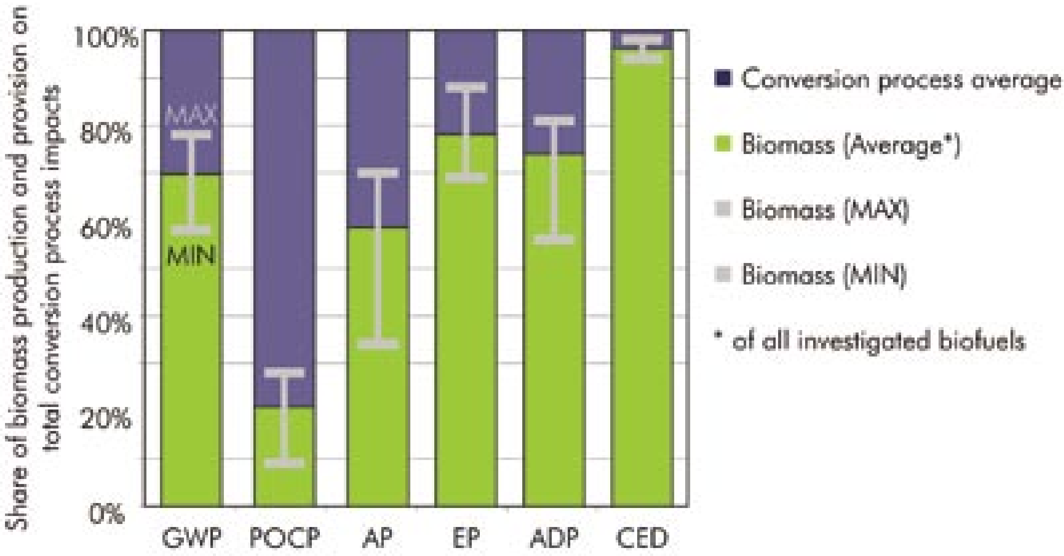


Figure 4: *Share of biomass (production and provision) in total conversion processes (incl. fuel distribution) impacts. GWP: Global Warming Potential; POCP: Photochemical Ozone Creation Potential; AP: Acidification Potential; EP: Eutrophication Potential; ADP: Abiotic Ressource Depletion Potential; CED: Cumulative Energy Demand*

Correspondingly, the environmental profile of BtL will be improved by biomass production of enhanced sustainability and by an amelioration of the efficiency of the biomass-to-biofuel conversion of the respective production process. This is also reflected in the good environmental profiles of the processes with high energy efficiency cEF-D of UET (53%) and BLEF-DME of Chemrec (69%).

One of the main drivers for BtL is climate protection and the subsequent potential for achieving a reduction in greenhouse gases emmission. The emissions which dominate the global warming potential of BtL production are shown in Figure 5.

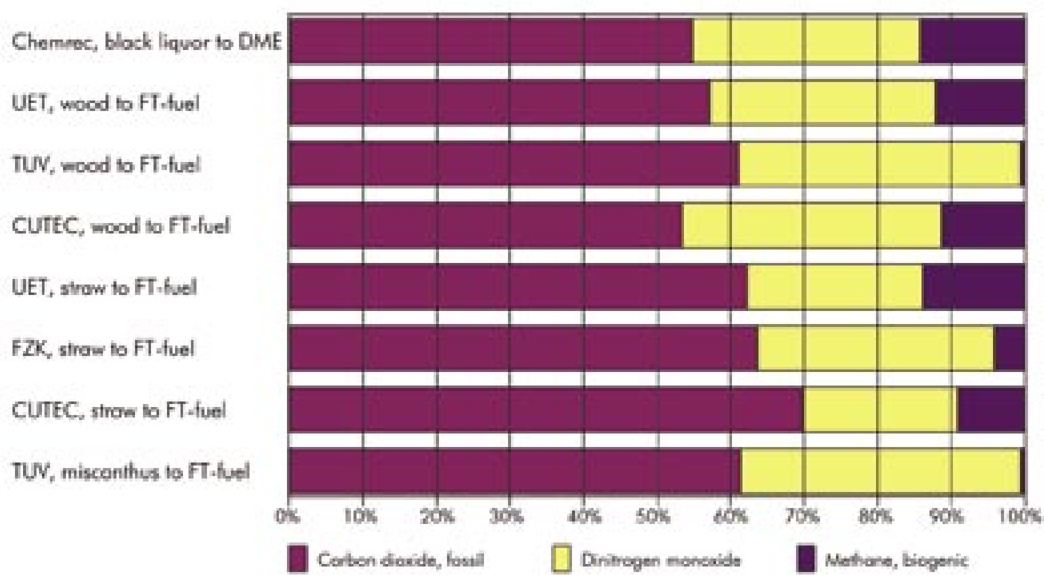


Figure 5: *Emissions contributing to the Global Warming Potential of BtL production.*

Three substances are most significant for the global warming potential of BtL production: Carbon dioxide (CO_2), Dinitrogen monoxide (N_2O) and Methane (CH_4). The emission of N_2O contributing to the overall global warming potential is in the range of 12-35%. N_2O emissions are directly linked to fertilizer production and usage. The respective agricultural processes, including the estimated emission of N_2O per kg N-fertilizer, were modelled with literature data representing the conventional agricultural practice of today. A sensitivity analysis showed that the N_2O emission can vary by a factor of 2, depending on the model. However, it shows that fertilizer use needs to be closely monitored and that the models need to be adapted to perennial crops.

Environmental improvement potentials for self-sufficient BtL production concepts include (i) a more sustainable biomass production with reduced fertilizer application and increased biomass yields, together with (ii) increased energy efficiencies for the conversion processes.

What are the costs for BtL?

The cost assessment took into account the costs of biomass production, costs for biomass transport to the plant, and costs for conversion into fuel.

The data were calculated for Sweden, Poland, Germany, Greece, Switzerland and Ireland, representing the European regions North, East, West, South, Alps the UK and Ireland using todays' average yield levels of average soils (e.g. ~10 t_{DM}/ha*a for willow) except for energy crops grown on fallow land were yield levels of poor soils were used.

Today, costs for the short rotation coppice (SRC) willow are in the range of 4.3 to 5.8 €/GJ (80 to 107 €/t_{DM}), and for the annual whole Triticale crop in the range of 5.3 to 7.1 €/GJ, depending on the region. For comparison, costs for residues are on average 3.4 €/GJ for straw, 2.4 €/GJ for logging residues, and about 5 €/GJ for thinning wood.

The exemplary breakdown of energy crop costs in Figure 6 reveals that cost reductions of 10 % are expected for the cultivation on large-scale field area and farm size and of 35 % in 2020 on large scale as compared to the average of today. For the future scenario it is assumed that improvement of the seedlings and cultivation techniques will lead to higher yields and reduced fertilizer requirement and pest susceptibility. Moreover, a better usage of machinery is expected due to the closer proximity of fields. Hence, costs for SRC would be in a range of 3.3 to 3.8 €/GJ.

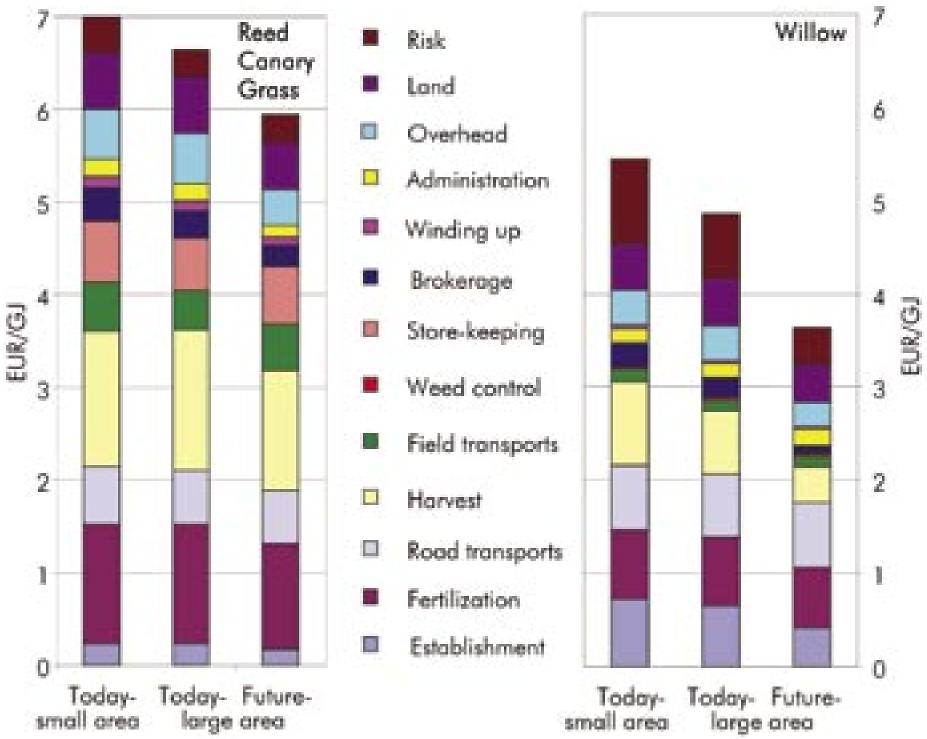


Figure 6: *Example of cost breakdown for two energy crops, reed canary grass (RCG) and willow, calculated under the RENEW frame conditions for NORTH (Sweden)*

Biomass logistics costs depend on the transport distance, road infrastructure and truck payload. Thus, the potential biomass density which encompasses the crop yield per ha of a field and the number of fields in an area has a strong influence. In the most promising regions the high biomass potential density leads to logistics costs in the range of 1-2 €/GJ.

Energy crop production today and also in the future is more expensive than using residues (otherwise wasted), but the yield per ha is higher and less scattered in the area. Once high-yielding ligno-cellulosic energy crops are commonly cultivated some years after the start up of a BtL plant (or generally in 2020), densities of 50 GJ/ha*year will be exceeded in some provinces. This corresponds to approximately 30 km road transport on average and lowers the logistics costs, securing a cheap and stable biomass supply.

The conversion costs are dominated by the costs for biomass, followed by capital costs for the BtL plant. Operational costs and other consumption related costs are of minor importance. Thus, the efficiency of the biomass conversion to the BtL fuel is of utmost importance.

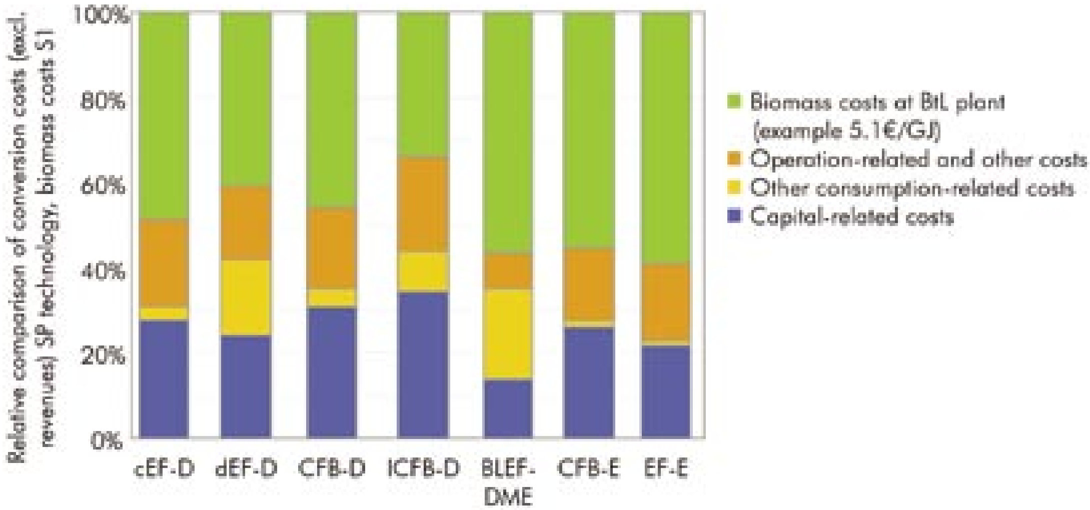


Figure 7: *BtL-specific production costs for region EAST*

It has to be mentioned that the calculated TCI (Total Cost of Investment) for conversion is based on values from early 2004 and does not take into account the steep increase of steel prices, for instance, or capital costs incurred in the meantime.

The technically and ecologically most advanced concepts (cEF-D, BLEF-DME, see above) are also the concepts which result in the lowest BtL production costs of 0.5 € (DME) to 0.86 € (FT diesel) € per litre diesel equivalent in SP scenario. 2020 these costs are expected to drop to 0.8 € per litre FT-diesel. However, biomass costs have a strong influence on the BtL cost as have soaring construction costs or interest rates. On the revenue side, BtL production profits from the increasing price of oil.

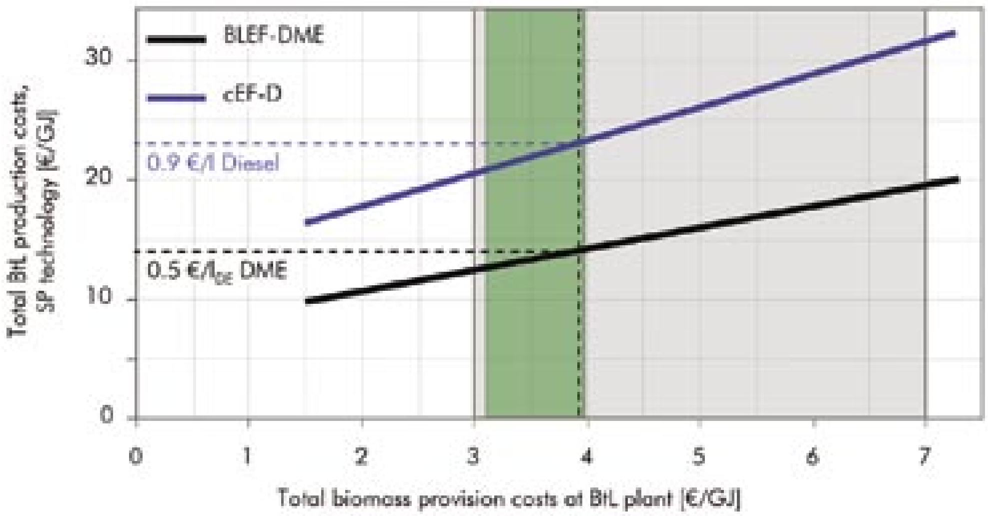


Figure 8: *Influence of the cost of biomass on the BtL production costs of the examined BtL concepts BLEF-DME and cEF-D. The dashed line is the 2007 price for wood chips in Sweden (3.9 €/GJ or 72 €/t_{DM}), the grey shading illustrates the bandwidth of estimated cost for forest residues in SP (2004), the green shading is the bandwidth of estimated energy crop cost in S1 (2020). 1 €/$l_{Diesel\ Equivalent}$ is approximately 28 €/GJ*

How should BtL market implementation proceed?

Advanced biofuels of the second generation like BtL fuels are at a rather early stage of development. Therefore many challenges and risks must first be overcome, e.g. competitiveness with fossil fuels without political support. Figure 9 shows the essential steps of a market implementation strategy, illustrating suitable measures to deal with the four main challenges currently facing BtL, i.e.

- economic competitiveness
- ensuring biomass supply
- risk involved with new technology
- risk of BtL market

Figure 9 also shows the development of BtL production capacity under optimal conditions in EU25 up to 50 plants in 2020, representing a substitution potential of 4 % of the total expected demand for diesel in 2020. Realization requires the following essential steps which would best be integrated into an overall bioenergy strategy, i.e. last step harmonisation:

Year 2008

1) Elaboration of **sustainability criteria** for biomass and BtL production, since all support schemes should be judged in terms of their sustainability
2) **Support scheme assessment,** i.e. calculation of different long-term support measures (quota system, taxation system) based on sustainability criteria for synthetic biofuels by a consortium of stakeholders (mineral oil, biofuel, car industry, politics) to evaluate the overall economic effects and ultimately to address the least expensive procedure
3) **Cultivation incentives** for SRC, which need up to 5 years before the first harvest and initial cash-flow; one million tons or 100,000 ha SRC are needed per BtL plant
4) Definition of **binding targets** for synthetic biofuels in 2020 in the frame of the EU biofuel directive, e.g. 1 million tons BtL per year*
5) **Direct investment subsidies** as well as **loan guarantees** for the first three large-scale (> 500 MW) plants*
6) Establishment of a **reliable long-term support scheme** based on results of step 2, e.g. sustainability related taxation system

*Points 4 and 5 are demanded by the plant operators but not supported by the mineral oil industry.

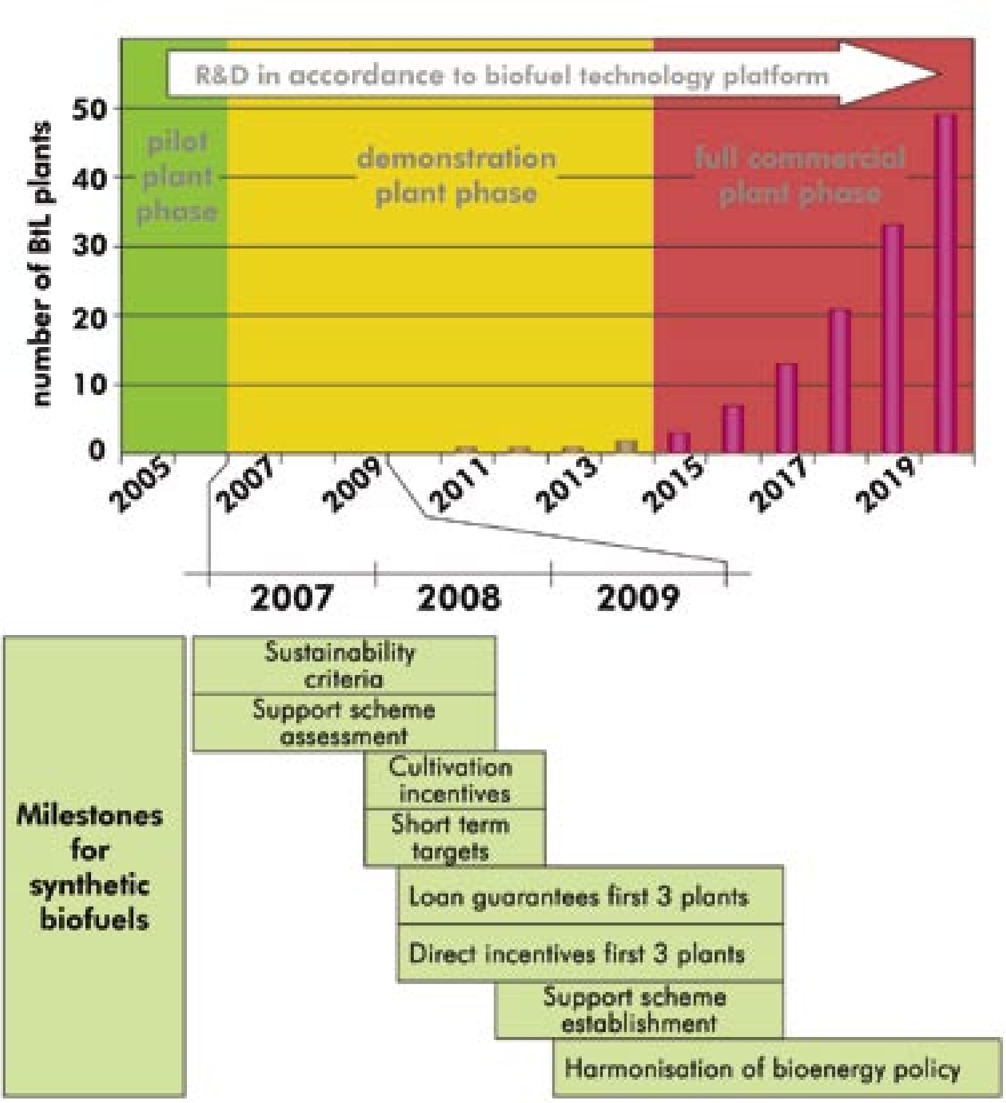


Figure 9: *Roadmap for a market implementation strategy for biofuels*

Overall conclusions

There are multiple opportunities for BtL production in Europe.

Synthetic BtL fuels could exert a substantial effect on reducing emissions of transport. BtL-Diesel and BtL DME are favourable fuels for combustion in present powertrains and could lead to a further reduction of consumption and emissions in future powertrains.

The environmental effects of BtL production result mainly from biomass production on the basis of present agricultural practice. Less environmental effects may be achieved by applying more sustainable biomass production and yield increase due to new species and by an increase of conversion efficiency.

In Europe's most promising provinces, technically sufficient residue biomass is available today to build around 50 industrial size BtL plants and substitute up to 4 % of the European diesel fuel demand in 2020.

Among the regions with highest biomass density for the first industrial scale BtL plants, central France, East Germany and West Poland would be the most favourable choice. Concepts for integration to existing pulp and paper mills (some 65 in Europe) requiring less additional biomass are interesting for the respective countries Sweden, Finland, Spain, Portugal and France.

Today, costs for the short rotation coppice willow are in the range of 4.3 to 5.8 €/GJ, depending on the region. For comparison, costs for straw and forest residues are between 2.4 €/GJ and 5 €/GJ. For the future, it can be expected that biomass costs will equalize throughout Europe and drop to about 3.5 to 4 €/GJ free plant gate. This conforms to the present biomass price in Sweden and Finland, which both have a well developed industrial system of biomass sourcing and utilisation. A further increase in the number of suitable locations for BtL production is thus expected by 2020.

Among the production routes studied, the most efficient, mature and ecological were concepts of Choren (cEF-D) for FT- Diesel and the BLEF-DME concept of Chemrec for the production of DME.

Today FT-Diesel could be produced from available biomass for costs of 0.86 €/l_{DE} and with short rotation crops 0.8 €/l_{DE} could be possible by 2020. DME via black liquor gasification could be produced today and in the future for 0.50 €/l_{DE} as co-product of a pulp mill. However, this depends on the development of cost for plant construction, interest rates and biomass feedstock.

Recommendations

Demonstration:

Demonstration of cEF-D and BLEF-DME concepts on a 50 MW scale is essential.

1st fully commercial BtL plants:

The best regions for first industrial scale BtL plants for cEF-D or the BLEF-DME concept would be West Poland and Sweden.

- West Poland is favourable due to the low costs at which the necessary amounts of biomass are available. The costs amount to 4.1 to 4.4 €/GJ for forestry residues and straw respectively, which are supposed to be the main feedstock for the first BtL plants. In the long-term perspective, Poland offers high densities of SRC plantations from the biomass potential point of view (up to 48 GJ/ha*a) at comparatively low cost (5.1 €/GJ). Presently, the c-EF-D concept would produce BtL-FT-diesel for 24 €/GJ, which equates with 0.86 €/l_{DE}. In 2020, intense SRC cultivation would exceed a regional biomass density of 50 GJ/ha*a – allowing BtL costs to drop to 22 €/GJ, i.e. 0.79 €/l_{DE}.
- Sweden offers a well established forestry industry which currently enables the delivery of forest residues at rather low costs, i.e. 3.9 €/GJ. Applying BtL concepts which require rather low amounts of additional biomass will take into account concerns about biomass availability, which might be not as high as in other regions. The BLEF-DME concept would currently entail production costs of 14 €/GJ, i.e. 0.50 €/l_{DE}.
- Site specific studies of biomass availability and respective prices are required



Research & Development:

Besides these recommendations for demonstration and first large-scale commercial BtL plants, RENEW has elaborated some key areas where more R&D work is necessary:

- Local studies on biomass production, supply and respective costs
- Studies on socio economic effects of new biomass plantation, e.g. SRC
- Technology related R&D work in terms of integration of BtL plants in refineries, pulp & paper mills, heating grids
- For less mature concepts, research in gas conditioning and – as long as FT-catalysts are not commercially available – in synthesis is recommended harmonized with the EC Biofuel Technology Platform.

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