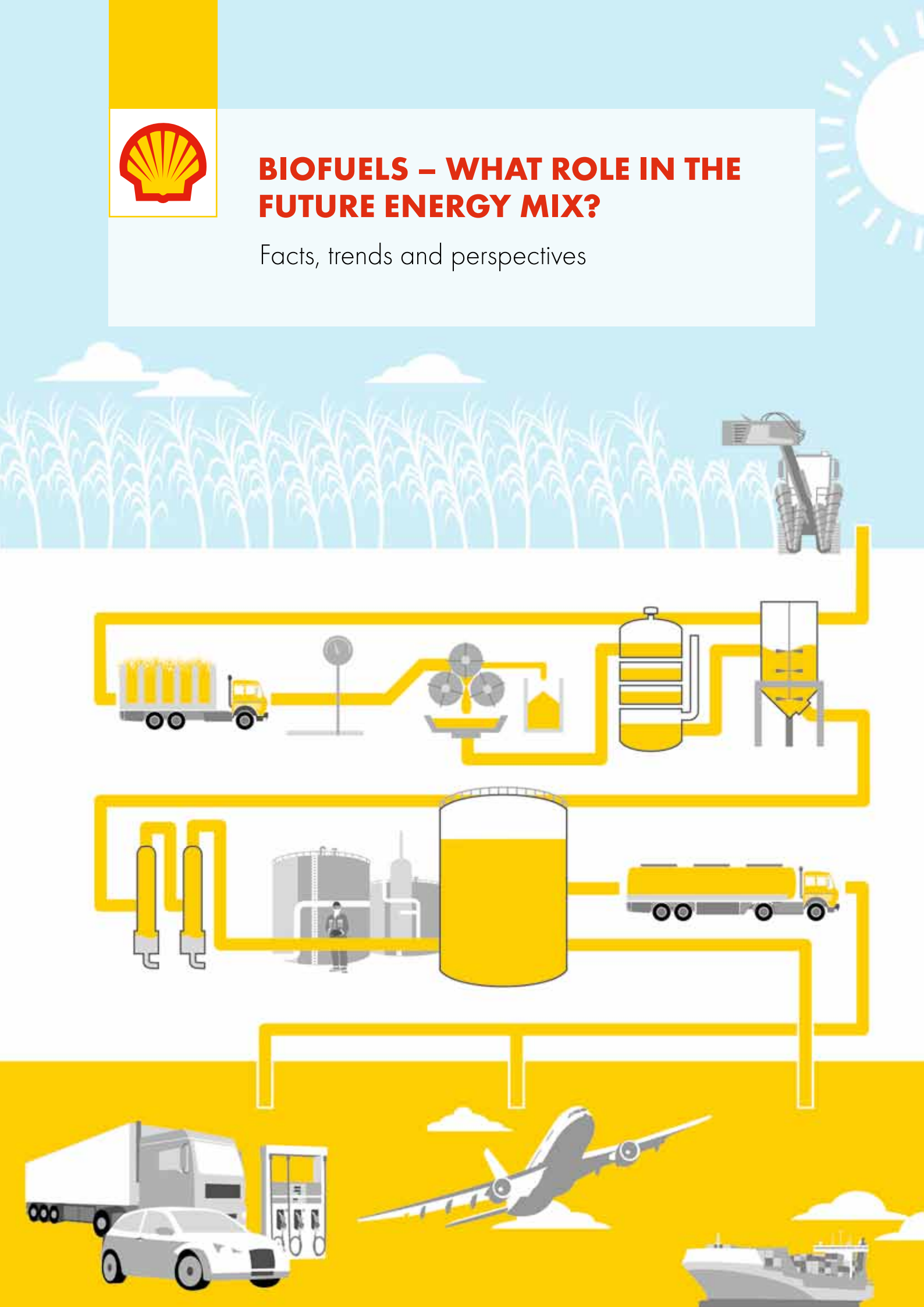




# BIOFUELS – WHAT ROLE IN THE FUTURE ENERGY MIX?

Facts, trends and perspectives



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Facts, trends and perspectives

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### DISCLAIMER

This study is an independent expert report by two scientific institutes, that is the International Institute for Sustainability Analysis and Strategy (IINAS) and the Institute for Energy and Environmental Research (IFEU). Its purpose is to contribute to the current discussion on the role of biofuels in the fuel mix of the future. Contents and statements reflect exclusively the viewpoints and opinions of the IINAS and IFEU authors involved in the project. They may be, but need not necessarily be, in agreement with the positions of the client (Shell). The exception to this is Section 5 (Technical compatibility of biofuels), which was written by Shell authors.

# SUMMARY

**Biofuels have been until now the only alternative energy source that has significantly contributed to supplying the transport sector with energy. Biofuels shall contribute up to 10% to the EU road transport fuel supply by 2020. But biofuels that once had such a green image, and enjoyed broad support, have come under criticism; the development of the market for biofuels has lost considerable momentum. We have therefore asked the following question once more: What role can biofuels play in the fuel mix in the future?**

► The use of biofuels grew strongly in Germany between 2004 and 2007, but its share has been stagnating since then, at between 5.5-6%. Biodiesel made from rape led the way, ahead of ethanol made from grain – both 1<sup>st</sup> generation biofuels. Biofuels have significant long-term potential in Germany – by 2030, domestic biofuels could cover 20% of fuel needs, and a good 70% by 2050. In the EU too, biomass compliant with sustainability criteria could in the long-term cover around a third of energy needs. Globally, Brazil and the USA dominate the biofuel markets, with bioethanol as the leading product. Worldwide, residues and degraded areas alone represent a bioenergy potential of 100 to 200 exajoules, which in the long-term could cover all liquid fuel needs. The trade of bioenergy is increasing throughout the world, because the availability of and the demand for biomass, bioenergy and biofuels vary from one region to another.

► The increasing use of bioenergy can give rise to competing uses. Globally, the use of agricultural biomass for feed (74%) is in the lead, followed by food (18%), and then for energy and as a material at around 4% each. The competition between fuel and food is given most attention. Biofuels can contribute to price increases and fluctuations for agricultural products; they can, however, also create employment and income. Of even greater importance for food security is the increasing demand for foodstuff. Worldwide, at the moment, 1% of agricultural land is used for modern bioenergy; in Germany the figure is 6.8% for biofuels, and 5.7% for biogas. Other competing uses arise with regard to the use of the material – for solid biomass (wood), and in the future, for bio-refineries, synthetic biosubstances, and similar. Competing uses are also emerging between different sectors that use them (power, heat, transport), as well as within the transport sector. They may – at least partially – be resolved

through regulation of the rights of use and exploitation.

► The discussion about the sustainability of biofuels has led in recent years to a large number of sustainability standards. Sustainability standards require improvements to the greenhouse gas balance for biofuels; the biofuels used in Germany reduce greenhouse gases by around 50% on average. The issue of indirect land-use change (iLUC) has not yet been resolved; bioenergy carriers with a low iLUC-risk are therefore to be preferred. Other, mostly less specifically governed protected natural resources include biodiversity, the soil, water and social issues. The implementation of binding sustainability standards is to be seen as progress. In order to avoid undesirable side-effects, binding sustainability standards are necessary beyond European level; these are to be extended to all bioenergy and biomass uses.

► Over 99% of all biofuels produced today are of the 1<sup>st</sup> generation, obtained from field crops. Biofuels of the 2<sup>nd</sup> generation are, on the other hand, obtained mainly from residues, wood and grasses. They may be hydrogenated vegetable oils, cellulosic ethanol and Fischer-Tropsch diesel; however, it has not yet been possible to develop them sufficiently ready for the market. Bio-refineries, and bio-fuels from algae (3<sup>rd</sup> generation) go even further.

► Biofuels indeed possess similar, but also different product characteristics, compared with fossil fuels. According to their chemical characteristics, biofuels can only be added to a limited extent to fossil fuels or be total substitutes for them. The 1<sup>st</sup> generation biofuels used the most today are usually partial substitutes that can only be added to a limited degree, or require technical adjustments to engines and vehicles. Road transport is the forerunner when it comes to biofuels;

blends with up to 5% biofuel are standard throughout the world; with B7 and E10, in Germany / Europe, technical blend walls seem to be reached for the time being. Of all transport carriers, heavy-duty trucks, aircraft and ships (as long as LNG does not become successful) are those with the fewest possibilities for substituting liquid fuels; the strategic value of biofuels is the highest here – for aviation, only drop-in fuels that can be deployed seamlessly are to be considered.

► Ambitious climate action scenarios examined how much of the biofuels potential could be implemented and by when. According to those analyses, the sustainable bioenergy potential is sufficient to cover a significantly reduced need for liquid fuels for transport by 2050 with (2<sup>nd</sup> generation) biofuel; and this applies both to Germany and the rest of the EU. Worldwide, it has been calculated that global biofuel needs will reach 30 exajoules.

► In order for there to be a (bio) energy transition in the transport sector, existing, sustainable biomass potential must be used as effectively as possible. Comprehensive greenhouse-gas balances and applying the same standards for all bioenergy carriers shall improve the competitiveness of the 2<sup>nd</sup> generation.

In addition, a European market introduction programme for them should be set up to run for 10 years, neutral and open to new technologies. Strategic investments must be made both in the production of 2<sup>nd</sup> generation biofuels, and in cultivating the raw materials needed. To increase the acceptance of biofuels, we need biofuels and automotive technology coordinated optimally, or drop-in fuels, as well as increased transparency with regard to the provenance of biomass and biofuels. The (bio) energy transition in the transport sector requires regular “adjustments”; course corrections are part of this.





# INTRODUCTION AND OVERVIEW

Germany has embarked on a programme of energy transition (known as the “Energiewende”) – and while there are already a range of alternative fuels for power generation and heating, and renewable energy sources are growing rapidly in those sectors, transport still relies largely on liquid fuels based on petroleum. So where is the energy transition in transport? There has been much discussion of electric vehicles and hydrogen propulsion, etc., as technologies for the future. But the most important renewable energy source in transport so far is biofuels – are they the answer?

## BIOFUELS BOOM ...

Let us start with a brief retrospect. In the early 2000s there was broad consensus in Germany across all political parties on rapid expansion of the use of biofuels; automotive manufacturers, representatives of agriculture, media, the petroleum industry, politicians and many groups in civil society were advocating biofuels – not only in Germany.

No wonder, because biofuels had a green image. They were propagated as a key element in sustainable mobility and climate change mitigation.

Biofuels were to create a broader base in energy sources for transport, especially road transport. Biofuels were also to give new opportunities for jobs, income and development for farmers in industrial and developing countries – particularly important at a time when world trade was being liberalised and subsidies for agriculture and exports removed.

The result was strong support worldwide for the application and use of biofuels, led by industrial countries with large vehicle fleets and fuel markets – such as the USA, the EU and Germany.

Global production of biofuels was multiplied several times in just a few years, even if starting from a low baseline. The most significant expansion was for biofuels in Germany, which is by far Europe's largest fuel market. Compared with an EU market share for biofuels of only 1% in 2005, the German biofuel share was

already close to 4%. In 2007 it rose to as much as 7.4%, which was the high point in biofuels development so far.

In 2007 Germany set itself a target of 17% biofuels by 2020; in 2008 the target was corrected just slightly to between 12 and 15% – which was still double the 2007 figure.

Since 2009, the Renewable Energy Directive (RED) has been applicable to all EU member states, setting a binding goal of 10% renewable fuels, that is mainly biofuels.

## BIO-ELECTRICITY AND MORE ...

Bioenergy is not only used in transport. Biomass is an important component in the global energy mix – in fact it is the leading renewable energy resource, with a share of more than 10% in global primary energy consumption. Its use is dominated by traditional applications, often with very simple technologies and low efficiencies, particularly in developing countries.

For example a high proportion of bioenergy use in household cooking and heating, with large regional differences. The share of “advanced” bioenergy in the form of electricity and transport fuels is about 2% in global electricity/transport fuel production, which is still quite low (IEA 2011).

Here, too, the use of renewables accelerated in the mid 2000s. Many countries launched subsidy programmes to promote the use of biomass in energy supply.

In 2004 Germany adopted an amendment to the Renewable Energy Act (EEG), setting strong financial incentives for generating power from recycled wood, forestry waste wood, and in particular biogas, and rewarding the use of wood chippings, and also bioliquid for combined heat and power (CHP). The use of wood (mainly thinnings, and increasingly also wood pellets) in home heating systems has also doubled within just a few years.

And finally, biomass is used not only for food and feed, but also materially, for bioproducts such as building materials and cosmetics, paper and textiles. The dominant global use of agricultural biomass is for feed, followed by food, while a smaller quantity goes into energy and material use. That is the context of the increased use of biomass for energy purposes, which has taken place and could continue in the future.

## GROWING TRADE IN BIOENERGY

As consumption of biomass rises, production and consumption have become increasingly separate, and that has boosted global trading in bioenergy – mainly transport biofuels and the relevant feedstocks. In Europe, imports of pellets from Canada, Russia and the USA have also risen.

Many countries, especially developing countries, hope for additional income from exports. International investors and emerging countries such as China have started buying up land for bioenergy pro-

duction, mainly in developing countries, in order to secure access to the necessary raw materials. Infrastructure investments have also increased worldwide in handling centres, storage and pipelines, and loading facilities in ports for bioenergy and biofuels. There has been significant growth most recently in international trading in wood pellets for co-firing in coal-fired power stations, and this demand will continue to grow.

## BIO COMES IN FOR CRITICISM ...

What has become of the great hopes pinned on biomass for sustainable mobility? As demand for biomass grew, negative effects began to emerge, attributed in particular to politically supported expansion of biofuels – with slash-and-burn clearing of forests for crop growing, with expulsion of smallholder farmers, questionable greenhouse gas inventories, and high subsidies and price impact on food. As food has become scarcer and more expensive worldwide, the critical discussion of sustainability of biofuels reached a first climax in 2008.

Though the benefits of biofuels and bioenergy were still recognised for agriculture, energy supply and climate change mitigation, the green image which they originally had was increasingly called into question. This culminated in attempts to re-name biofuels as “agrofuels”.

The use of biomass for power generation and heating was also criticised for “maizing up the landscape”, with warnings of loss of grassland and other negative effects.

Sugarcane plantation in Brazil

But today the arguments for and against biofuels are determined not only by sustainability aspects. Increasing biofuel percentages in gasoline and diesel raised the issue of which cars could tolerate what percentage of biofuels, especially when biofuel blends rose to more than 5% by volume. Originally in 2005 and 2006, the target was to increase biofuel blending into gaso-

line and diesel to 10% by volume, but soon a limit of 7% by volume was set for diesel. The launch of gasoline with 10% bioethanol (E10) originally failed in 2008 due to lack of clarity on questions of compatibility, and again in the year of its launch 2011 there was broad discussion of compatibility problems.

## ABOUT THIS STUDY ...

**This study was commissioned by Shell Deutschland with the scientific institutes IINAS and IFEU, in response to the discussion on propulsion systems and fuels of the future, and the new Mobility and Fuel Strategy (“Mobilitäts- und Kraftstoffstrategie”) for Germany. Its purpose is to examine the role of biofuels in the future fuel mix, following the introduction of Super E10. It covers not only road transport, but all modes of transport. In keeping with the tradition of previous Shell studies and scenarios, it examines all the relevant facts, identifies key trends, and shows the medium to long-term perspectives of biofuels.**

**It examines how far and under what conditions the various criticisms of biofuels are justified, covering the following questions in detail:**

- **Where are biofuels today, and what sustainable potential do they have in the medium and long term?**
- **What competition is there for use of biofuels, and how valid are the arguments of their critics?**
- **Can transport biofuels be sustainable at all? And what conclusions can be drawn for other biomass uses, including non-energy uses?**
- **Biofuels of the second or third generation were once seen as the silver bullet for sustainable mobility. But what has become of the next generation of advanced biofuels?**
- **Is vehicle technology of today and tomorrow compatible with biofuels? This question is addressed by Shell authors Dr. Jörg Adolf and Dr. Dorothea Liebig for all modes of transport and for all fuels relevant today.**
- **Finally, long-term scenarios and perspectives of biofuels are discussed, together with measures for their possible implementation.**

# 1 BIOFUELS TODAY... AND TOMORROW?

There are a large number of biofuels, production processes and biogenic raw materials available today (see Fig. 1). The main biofuels worldwide today are bioethanol and biodiesel. Bioethanol is used as a substitute in gasolines, and biodiesel in diesel fuel. Both of these fuels are mainly used in blends with fossil fuels, but they are also used straight.

**Bioethanol** is mostly made from crops containing starch or sugar, in fermentation and distillation processes. The main raw materials are maize (especially in the US), sugarcane (especially in Brazil), other cereals (wheat, rye, sorghum, etc.), cassava, and sugar beet in Europe. The use of lignocellulose based ethanol is another very hopeful candidate, with the US in particular putting a lot of effort into the ongoing development of this biofuel.

**Biodiesel** is mainly produced from vegetable oils by trans-esterification with methanol (methyl ester). The most frequently used oils come from rapeseed in Europe and canola in Canada, soybean (Argentina,

Brazil), oil palm (Indonesia, Malaysia) and sunflower, and also smaller but increasing quantities of jatropha (India, Madagascar and others).

Apart from biodiesel, **straight vegetable oil** and **hydrotreated vegetable oil (HVO)** are possible fuels. While straight untreated vegetable oil is hardly used as a fuel any more, there is a lot of interest in HVO, especially for aviation. But rapid increase is hindered by the costs and effort involved in the hydrogen needed for hydrotreating.

**Biomethane** produced from biogas and processed to CNG quality is regarded

as a promising biofuel, because it is characterised by relatively high yield per unit area (FNR 2012). But today it is often given more critical assessment because it uses maize silage as the feedstock for biogas; the prospect of growing maize monocultures gave rise to an accusation of "maizing up" landscapes. Bio-CNG also requires vehicle fleets to be designed for this purpose, which is practically not the case today.

There are other biofuel approaches as well, most of them new and not yet ready for use. For example **biobutanol**, another alcohol which is more similar to gasoline than is ethanol. Butanol can be obtained

from the same energy crops (including lignocellulose) as ethanol; but the fermentation process is less efficient, and thus more expensive.

**Dimethyl ether (DME)** is a fuel that is similar to liquid petroleum gas (LPG), and can be blended either with gasoline or diesel. The concepts for bio-DME are mainly based on lignocellulose, and also on other organic residues such as black liquor from cellulose production, which are also to be used for 2<sup>nd</sup> generation biodiesel.

**Biomethanol** is another product which can be used in various ways as a fuel or converted to gasoline (MtG process, "methanol-to-gasoline"). The technique normally used is gasification, which can in principle be applied to any type of biomass as the raw material.

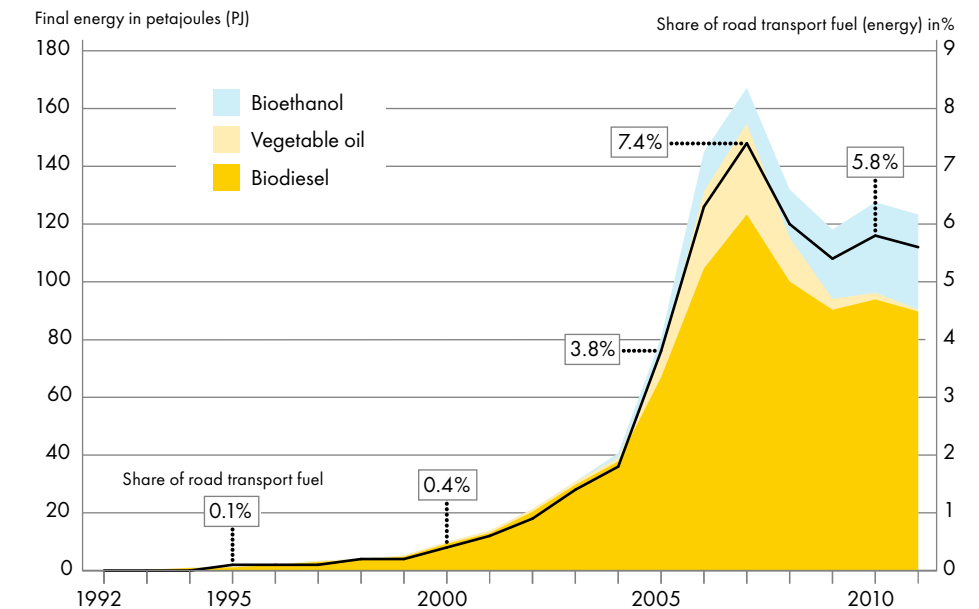
**Biohydrogen** is also in discussion as a fuel, and can be obtained from various types of biomass using different methods. In particular, there is discussion of bio-engineering processes using bacteria.

## DEVELOPMENT IN GERMANY

There are about 60 million vehicles registered in Germany today, including 43 million passenger cars and 2.5 million trucks. Diesel dominates among trucks, while 98.6% of all passenger cars are powered by diesel or gasoline engines, 1.2% by gas propulsion systems, and 0.1% by hybrid and electric propulsion systems (KBA 2012). Despite the high level of vehicle ownership, the fleet size continues to increase. Fuel sales have been declining since 1999, but demand is shifting, with diesel sales increasing and gasoline sales decreasing (MWV 2012).

In 2011 about 54 million t of fuels were used, including the biogenic components; of these, 3.7 million t (more than 120 PJ) were **biofuels, which accounted for 5.6%** of fuel consumption (cf. Fig. 2). The German biofuels boom which started in 2004 was triggered by tax exemption for straight biodiesel. A mandatory blending requirement was introduced in winter 2006/07, and the tax subsidy was gradually reduced (Adolf 2006). Biodiesel consumption is still higher than bioethanol because diesel started with a higher blending ratio (B7) and more diesel is used.

## 2 BIOFUELS IN GERMANY



Source: BMU (2012); own presentation

Since 2006/07, E5 gasoline has also been on sale, and since 2011 E10. However, **E10 had virtually no impact in 2011**. E10 was not introduced everywhere in Germany until the second half-year. The low level of demand for it has meant that E10 has so far become established only as a minor grade in the market; the leading gasoline type is still E5.

Straight biogenic fuels such as biodiesel (B100) or pure vegetable oil now have hardly any significance, not least due to vehicle engineering. It is not possible to introduce fuels with a high proportion of bioethanol (E85), because, similar to bio-CNG, only very few vehicles would be able to use them (only Flexible Fuel Vehicles).

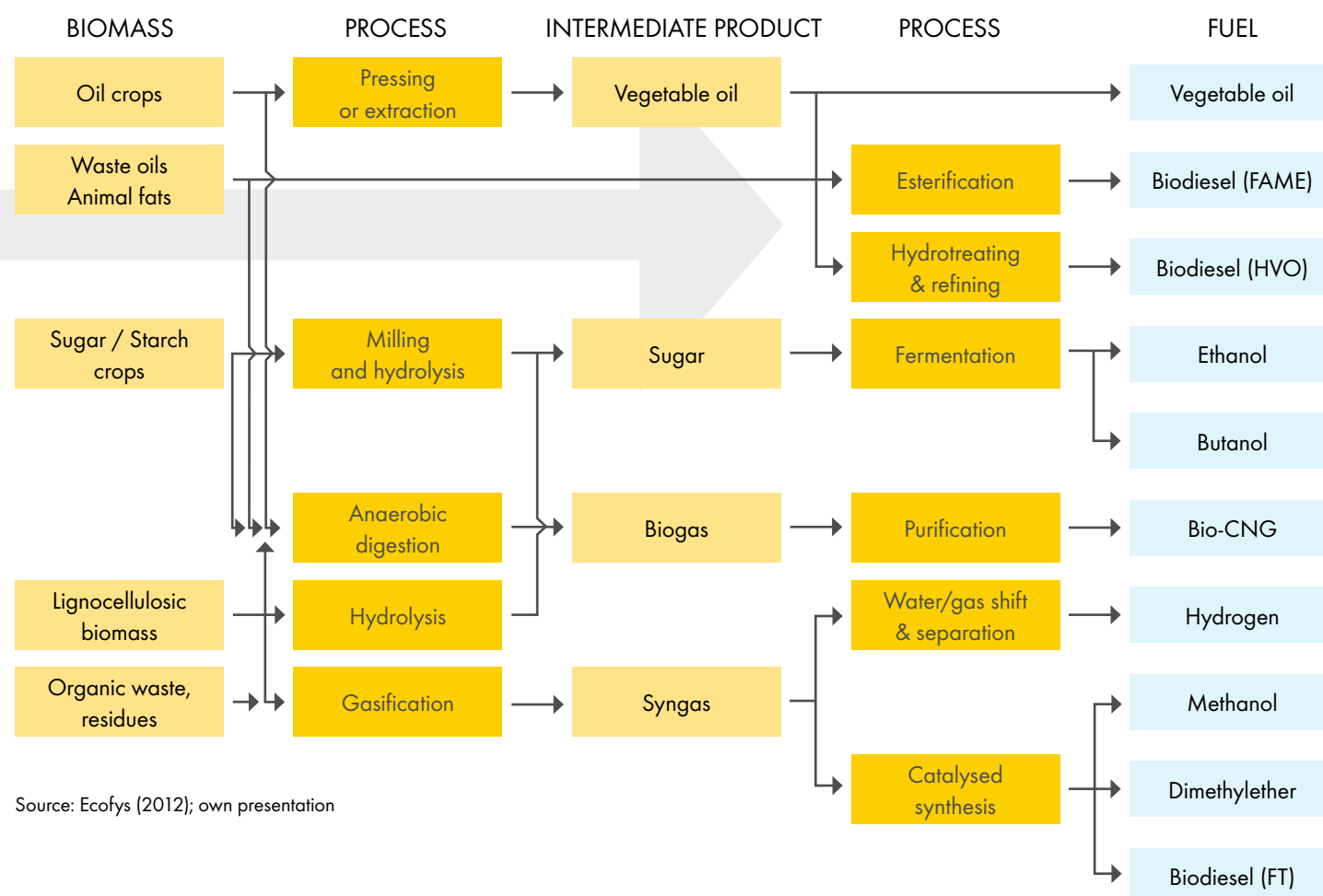
The breakdown of types and origins of biofuels which count towards the quota in Germany is shown in the report by the Federal Office of Agriculture and Food (BLE 2012). These figures come from Nabisy ("Sustainable Biomass System", the electronic data acquisition system of the BLE), and give an overall figure for transport biofuels and the liquid biofuels used for power and heat generation. They also include the quantities registered but intended for subsequent export. The figures do not therefore reflect the exact quantities of biofuels used in vehicles in Germany in 2011. The total with sustainability certification was approx. 185 petajoules (PJ), about 85% of which were

biofuels. The BLE system included 107 PJ biodiesel. However, industry association figures for 2011 show biodiesel sales of only 86 PJ (VDB 2012).

The figure for bioethanol in the BLE system was around 49 PJ, while the Association of Ethanol Producers calculated consumption in Germany in 2011 at 33 PJ (BDBE 2012). This discrepancy is to be explained mainly in exports of ethanol quantities already entered in the records. Thus in 2011 the figures for more than 10 PJ of maize-based bioethanol from the USA were entered in the Nabisy system, but later sold onward to other European countries. Another biofuel with some degree of importance was refined (hydrotreated) vegetable oils, with 12 PJ. Straight vegetable oils and biomethane played no significant role.

The **basis for biodiesel was mainly rapeseed oil (80%), followed by waste oil (15%)**. Apart from palm oil (5%), other vegetable oil types played no significant role. The situation for bioethanol is as follows: wheat was the most important feedstock (32%), followed by European maize (28%) and sugar beet (25%). Rye, barley, and triticale together accounted for another 13%. Sugarcane was not more than 2%. Indication of growing country was only on a voluntary basis in 2011, so the data were not complete for origin of the biomass. The main non-European growing country was Malaysia.

## 1 RAW MATERIALS AND PRODUCTION PROCESSES FOR BIOFUELS



Source: Ecofys (2012); own presentation



Leaving aside the USA, the dominant suppliers for Germany were EU countries, led by France, Hungary and the Netherlands (which are in some cases re-exporting).

**The use of biofuels in Germany rose sharply from 2004 onwards, but has declined again slightly since 2007. Biodiesel from rapeseed is the dominant product, followed by ethanol from grain. The feedstocks used are mostly energy crops. So far, imports play only a minor role. Success has not yet been achieved in the development of “advanced” biofuels ready for the market.**

#### FUTURE POTENTIALS IN GERMANY

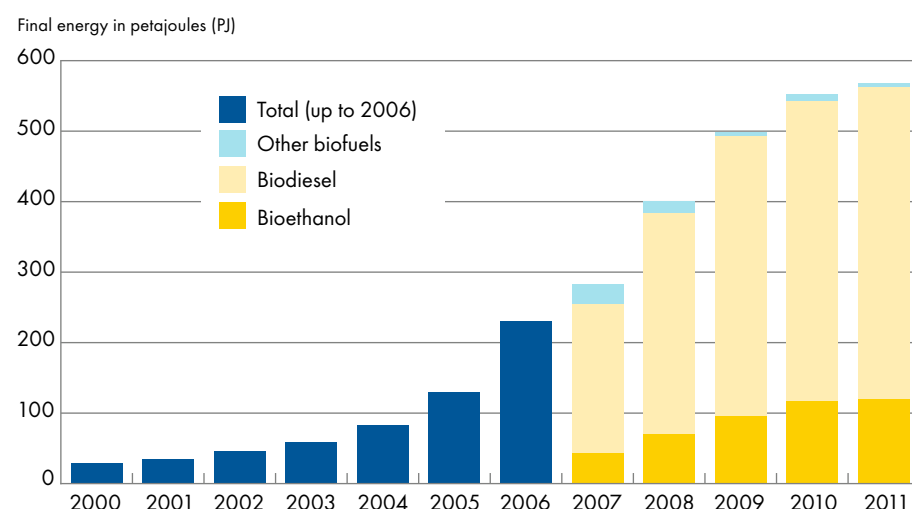
Consumption of biofuels has risen significantly since 2004, and power and heat production from biomass have increased in parallel. So how much bioenergy and biofuel can be produced in future, and where are the quantity limits?

Various studies<sup>1)</sup> indicate a sustainable potential of about 1,300 PJ bioenergy from energy crops, and about 700 PJ from biogenic waste and residuals, available in Germany at least until 2030, and in this order of magnitude also possible until 2050 (Nitsch et al. 2012). Due to sustainability requirements, the energy crops would however no longer be maize, rapeseed, etc., grown on good arable land like today, but would mainly be perennial crops (short rotation forestry, energy grasses) grown on marginal land and largely without the use of irrigation and fertilizer, for reasons of nature conservation.<sup>2)</sup>

Compared with this potential of a total of 2,000 PJ there is currently primary energy consumption of 14,000 PJ, which could be reduced to 9,300 PJ by 2030 (Nitsch et al. 2012). That means domestic bioenergy would be able to provide 20% – that is three times as much as today.

This potential is the basis for the assumption that additional bioenergy crops will be grown only on unused arable land, will not have a negative impact on biodiversity,

#### 3 BIOFUELS IN EUROPE (EU 27)



and that about 3% of agricultural land previously used for intensive farming will be placed under nature protection, one third of food production will be in organic farming, and no grasslands will be converted, but only grass cuttings used.

It was also assumed that there is no shift of biomass from biomaterial use, and that Germany will remain 100% self-sufficient in food. This potential would thus be available without competition between uses – but its development depends on the framework conditions set for energy and environmental policy.

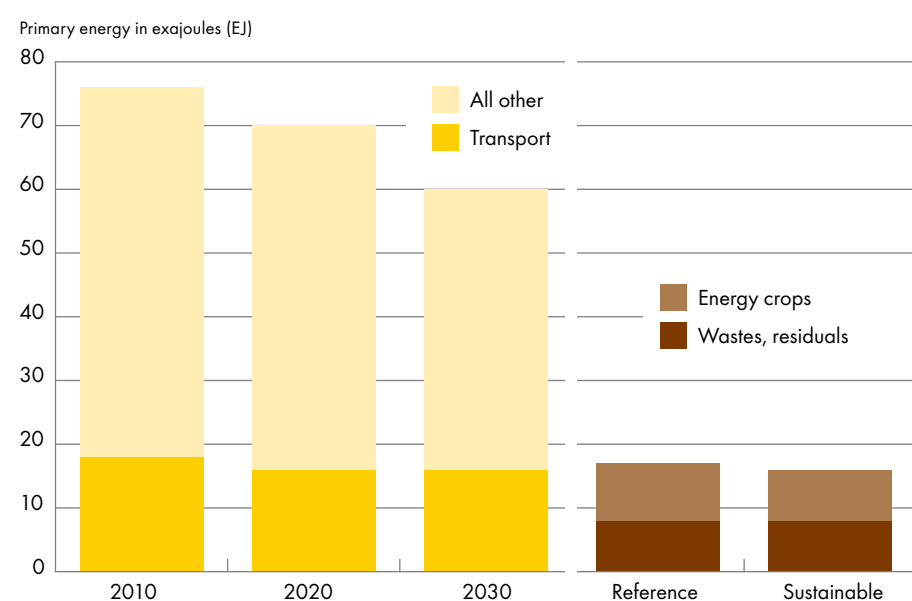
**Taking account of power and heat production from biomass, domestic**

**biofuels could meet about 20% of Germany's fuel demand by 2030, and more than 70% by 2050 (assuming a significantly lower level of demand than today).**

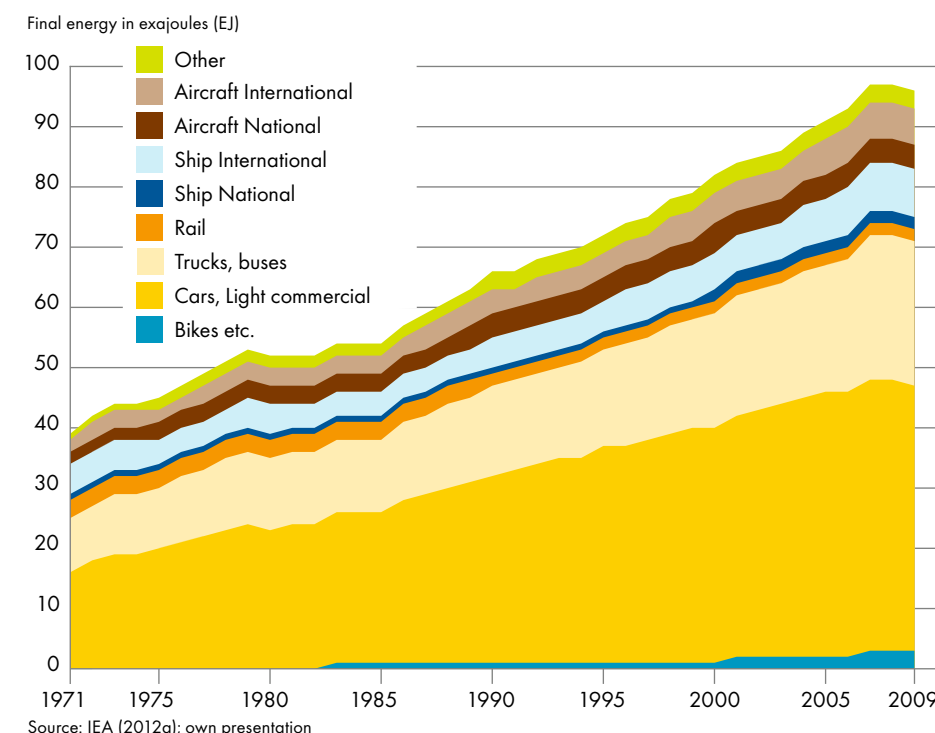
#### DEVELOPMENT AND POTENTIALS IN THE EU

The use of biofuels in the EU has increased more than tenfold since 2000. The fastest growth was from 2005 to 2009. The increase slowed down again in 2011 and reached a level of about 13 million t, corresponding to about 580 PJ (Fig. 3). Germany was the leading producer nation in the EU again in 2011, followed by France, Spain, Italy, the UK and Poland. As for Germany, there are also a

#### 4 ENERGY DEMAND AND BIOENERGY POTENTIAL IN EU27 UP TO 2030



#### 5 GLOBAL ENERGY DEMAND FOR TRANSPORT, BY SECTORS

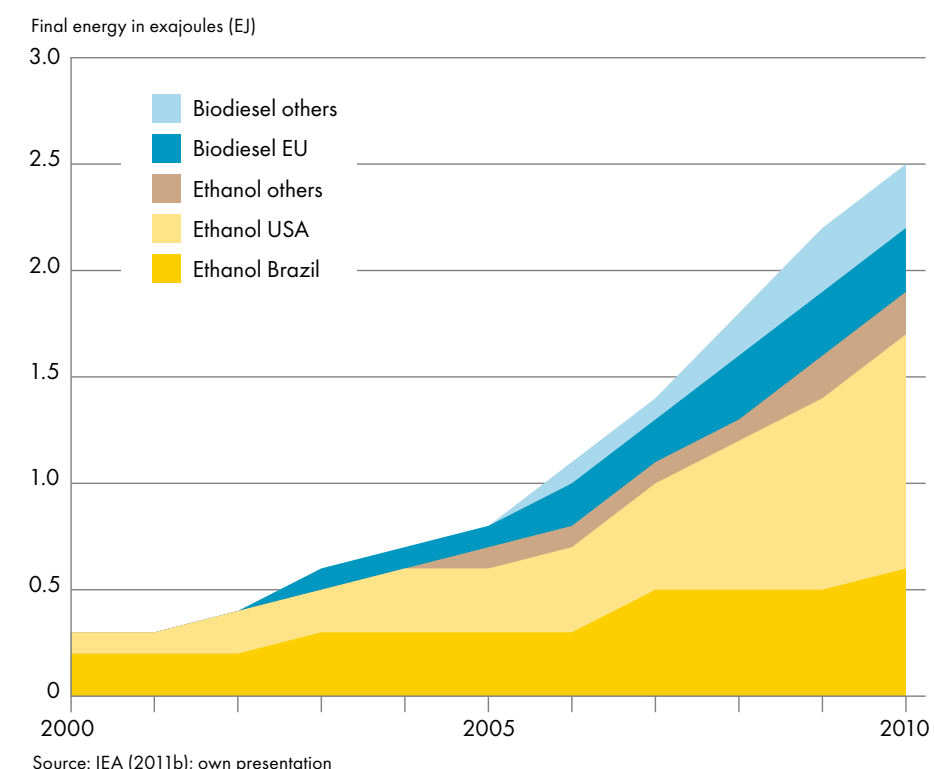


if governments implement an ambitious energy policy. Full use of the bioenergy potentials would make it possible to cover about 25% of energy demand by 2030 and about 30% by 2050.

An analysis of potentials and demands up to 2050 reached the following conclusion: assuming sustainable production, 2<sup>nd</sup> generation fuels would be used increasingly after 2020 and cover a large proportion of the fuel demand in the truck, ship and aviation sectors by 2050, while passenger cars would mainly use electric propulsion (NTUA 2012). The role of imports would be limited to 14% of all biofuels.

**The EU has sustainable bioenergy potential which could in the long term cover about one third of energy demand – and biofuels would account for a dominant share of that by 2050.**

#### 6 WORLDWIDE BIOFUEL PRODUCTION



number of studies on sustainable bioenergy potentials for the EU<sup>3)</sup> – Fig. 4 shows the latest results from the EU project Biomass Futures (IC et al. 2012), which analyses in depth the costs of bioenergy and the sustainability of biofuels. A total of 15 exajoules (EJ) of biogenic primary energy will be available in the EU27

on a sustainable basis by 2030; about 2 EJ could be used for biofuels, parallel to bioenergy supply for power and heat – that is about four times as much as today (ECN 2012). However, these would mostly be 2<sup>nd</sup> generation fuels. By comparison: the primary energy consumption of the EU27 in 2010 was about 74 EJ; it could be reduced to less than 60 EJ by 2030, and less than 50 EJ by 2050

#### GLOBAL TRENDS AND POTENTIALS

In the past few decades, energy demand for transport has risen continuously throughout the world, and is currently just under 100 EJ (Fig. 5). A slight decline has become apparent since 2008, mainly due to efficiency gains particularly in the OECD countries, but not to a reduction in transport mileage. Passenger cars and trucks account for the majority of consumption; shipping and aviation are developing dynamically.

The focus of worldwide activities in biofuels is outside of Europe. Brazil and the US have always been the leaders in terms of quantity, and underscore this with a continuing upward trend (Fig. 6). Brazil is planning to expand sugarcane ethanol on the basis of yield increase, and also aims to expand on a large scale by designating agro-ecological zones. The USA have frozen the use of corn bioethanol (i.e. ethanol made from maize) at today's level, in the Renewable Fuel Standard, but are planning to use increasing quantities of “advanced biofuels” and ethanol imports from Brazil. Emerging countries such as Argentina (biodiesel from soy oil) and South-East Asian countries are planning to boost their production significantly in future, and also to increase their own consumption. Alongside the EU, the USA and Brazil, 20 other countries have

1) Cf. DBFZ, IUP (2011); Fritsche et al. (2004); EEA (2006 + 2012); IC et al. (2012); SRU (2007); Thrän et al. (2005), WBGU (2009).

2) For detailed description of sustainable energy crop cultivation, see Fritsche et al. (2004), EEA (2012) and WBGU (2009).

3) Cf. EEA (2006+2007+2012); IC et al. (2012) and Thrän et al. 2005.

adopted binding quotas, and another 6 countries have specified blending goals in their legislation (IEA 2011b).

The global bioenergy potentials have been analysed in many studies;<sup>4)</sup> an overview of these is given by IPCC (2011). Due to the interconnections between agricultural issues and questions of land use and nature conservation, it is not possible to give "one" figure for bioenergy potential, but rather a range, taking account of questions of sustainability.

Energy crops can also be grown on marginal lands that cannot be used for agricultural production, with a positive impact on soil fertility, erosion characteristics and carbon content in the soil; and the availability of water is also a major constraint. Studies estimate a total of between 25 and 100 EJ bioenergy which can be harvested on such vacant and degraded land without negative impact on biodiversity.<sup>5)</sup>

Together with biogenic waste and residuals, which give potentials of between 50 and 100 EJ of bioenergy, a total of 75 to 200 EJ bioenergy could be available without use of agricultural land by 2050. This potential is independent of agricultural development, and its use does not result in indirect land use change (ILUC) – in fact cultivating perennial crops on formerly degraded land could increase soil carbon and thus improve the greenhouse gas inventory.

In addition, depending on the development of yield and consumption, another 200 to 300 EJ from arable and grassland could become available, no longer needed for food and feed production. This quantity is disputed because the parameters are uncertain – negative impact of climate change on agricultural yields and water availability could reduce the amount of surplus land. Comparison with global energy demand (IEA 2012a) and the fuel demand included in that (Fig. 7) shows that half of the "low" global bioenergy potential would be sufficient to replace the whole of the demand for petroleum based fuels by

2050 (approx. 54 EJ). For conversion of the bioenergy potential to fuels, a conservative level of 50% for conversion efficiency was used. Higher levels could be achieved if coupled products are used, and conversion technologies improved.

The other half of the global bioenergy potential would be available for generating power and heat, especially in emerging countries and developing countries – under the demanding condition of a huge improvement in energy efficiency worldwide, both in transport and in the other consumption sectors.

**Regardless of these bandwidths and uncertainties, the robust estimate for sustainable energy potential is between 100 and 200 EJ, to cover all demand for liquid fuels – provided that fuel demand can be reduced by massive energy efficiency improvements.**

**BIOENERGY TRADING – DEVELOPMENT AID OR IRRESPONSIBLE EXPLOITATION?** The major potentials for bioenergy and biofuels are outside of Europe, with countries such as Argentina and Brazil able to produce at much lower cost. That leads to increased interest in imports, especially from Latin America.

West and East African countries such as Mozambique also wish to develop their bioenergy potentials for export, as their local markets are limited and they can

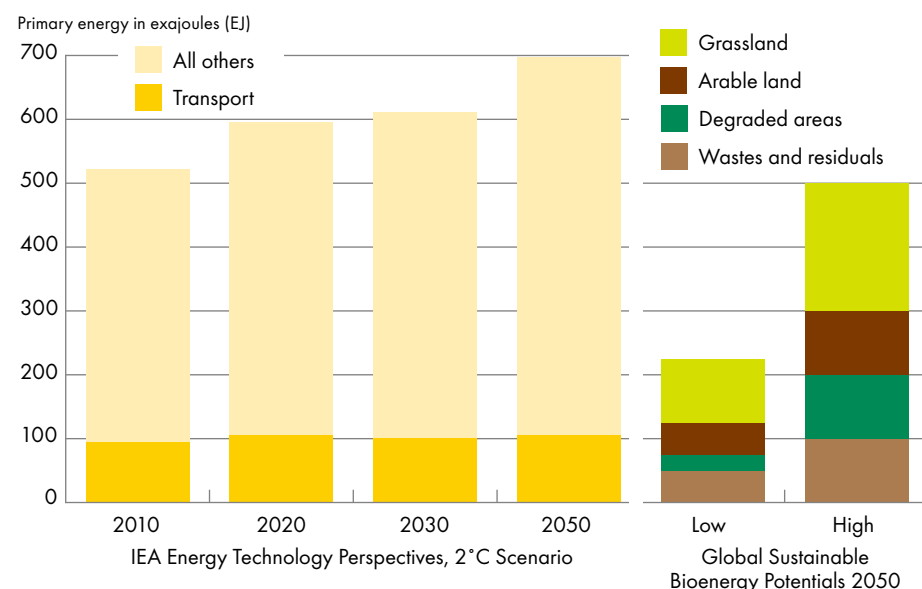
earn more revenues from exports, especially from exports to Europe. It gives rise to the question of how much biomass and bioenergy Germany could import, taking account of global equity. The "Model Germany" Study has proposed introducing "globally equitable access rights", by analogy to equal per capita CO<sub>2</sub> emission rights ("carbon equity"), setting national access rights on the basis of global bioenergy potential and population size (Prognos, ÖKO 2009).

The bioenergy potential indicated above and the population in 2050 would give a German "entitlement" of about 1.5 to 3 EJ; that corresponds approximately to the national potential of about 2 EJ. At the upper limit additional import quantities of another 50% would be "permitted", whereas at the lower limit, Germany would not be able to import any bioenergy or biofuels.

The level of future imports and the countries exporting bioenergy and biofuels will not least be a question of sustainability, in its ecological, economic and social dimensions.

**There are great differences in bio-energy and biofuels depending on country of origin, growing methods and the further processing steps, so there would be corresponding risks and also opportunities for the exporting countries.**

## 7 GLOBAL ENERGY DEMAND & BIOENERGY POTENTIALS



# 2 LAND USE AND BIOENERGY – IN COMPETITION?

**The rise of both oil prices and subsidies caused substantial increases in the use of bioenergy for power, heating and transport since the early 2000s (BMU 2012). In parallel, there has been a strong increase in the use of biomass for food and feed (FAO 2011), wood products, textiles, and pulp and paper. The conversion of biomass to chemical products and new materials increased as well (nova 2012). More access to biomass feedstocks creates and intensifies competition for its use.**

Globally, the dominant use of agricultural biomass is for feed, followed by food, while energy and material use are substantially less significant (Fig. 8). Further growth in global population, changes in nutrition habits and also the support for bioenergy will in future cause an increase in biomass demand, putting more pressure on resources such as land and water (FAO 2009; IFF 2009; IIASA 2009).

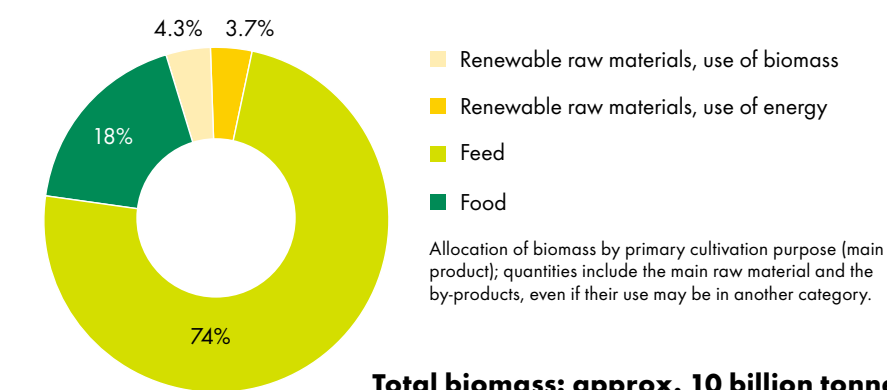
The resulting use competition could give rise to various conflict potentials. Use competition could directly lead to disputes over limited resources, or there could be disputes due to conflicting goals between the individual demand sectors, as shown in Fig. 9.

Use competition need not necessarily be negative, because it could create incentives to make more efficient use of land and water, and to optimise biomass use by replacing inefficient applications. In market economies, supply and demand are regulated by prices, which act as signals to competing purchasers on the one hand and to producers and potential producers on the other, and thus should create an equilibrium between them.

In reality, the prices are modified by taxes, subsidies, customs duties, etc. Political parameters such as quotas for agricultural products and biofuels lead to corresponding "distortions". In addition, flexibility to react to changes in price is prevented or restricted by a number of factors:

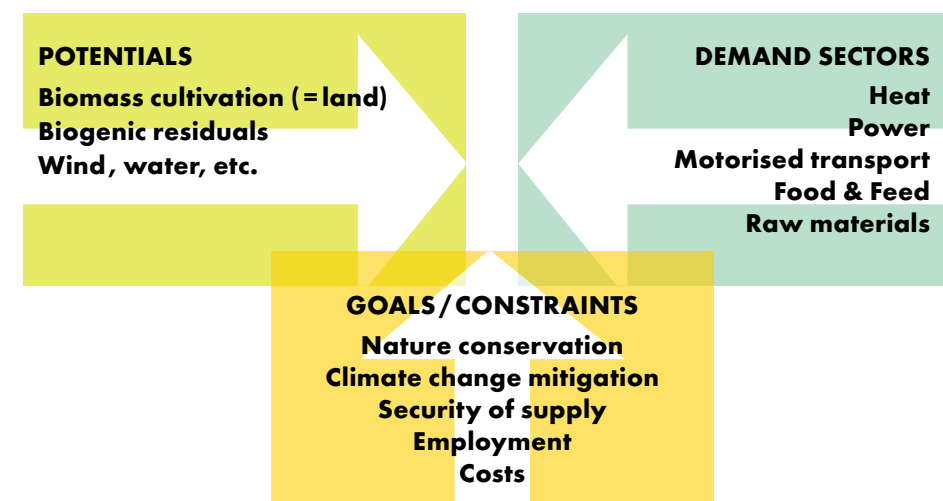
- For food, there are no substitutes available for basic needs; changes in nutritional habits and trends take time.
- The availability of capital and access to infrastructure vary; that is an obstacle to increasing supply in response to rising prices.

## 8 USE OF AGRICULTURAL PRODUCTS (WORLD), 2008



Source: nova (2012); own presentation

## 9 COMPETING USES OF BIOMASS



- Environmental and global commons (such as biodiversity) currently have little or no market price, and that prevents corresponding steering effects.

The economic impact of these factors is to reduce price elasticity, and that is made worse by the differences in market access opportunities and market power of the individual players. That results in distributional problems. Use competition cannot be balanced just by price signals generated in the market without negative side effects and impact on income distribution.

## FUEL VERSUS FOOD & FEED

The public debate on competition between biofuels subsidised by governments with food and feed reached a peak in 2008. The recent shortage of maize due to a drought in the USA caused another sharp price rise in world market prices, and led to renewed disputes on the role of biofuels in the pricing of food and feed, and the consequences for food security.

Before examining that in more detail, it is important to look at the development of

4) Cf. for example Dornburg et al. (2010), IC, ERC (2011); IEA (2011b); Thrän et al. (2010); WBGU (2009).

5) Cf. Cai, Zhang, Wang 2011; ECN et al. (2009); Fritsche et al. (2010); Wicke (2011).

the prices of agricultural products in the last three decades (see Fig. 10).

The producer prices in agriculture rose sharply at the beginning of the 1980s, in parallel with oil prices, and dropped again from 1985 onwards as the oil prices went down; then after 2005 they rose again in parallel to oil prices. That was due – among other things – to the use of energy-intensive fertilizer, and the increasing use of diesel in mechanised agriculture – especially relevant for maize, rapeseed and wheat (van der Mensbrugghe et al. 2011), as confirmed by the latest analyses (USDA 2012).

Since 2005, many studies have given increasing attention to the effects of biofuels on agricultural price developments. They agree that there is now coupling between the agricultural market and the energy market, showing that apart from the factor costs, the prices of agricultural products are also determined by oil price movements (Piorr 2010; IEEP 2012). There is also agreement that the resulting additional volatility of agricultural prices has a negative impact on food security (FAO 2008; HLPE 2012b).

It is also largely undisputed that some price increases in agricultural products are caused by additional demand for biofuels, caused by subsidy policies in the EU and the US, alongside other factors

such as increased fertilizer demand, crop failures and financial speculation.

It has been shown in studies that if the specified policy goals for biofuels in the EU and the US up to 2020 are maintained, price rises between 3% and 13% may be expected for cereals and between 6% and 30% for oilseeds (JRC 2011; Fischer 2011). That could be increased by other effects such as droughts, speculation, etc., or reduced by more use of non-food raw materials for biofuel production (e.g. recycled fats, cereal waste products, lignocellulose).

Price increases in agricultural products cause more hunger, at last in the short term, for those who do not have enough income, because security of food supply is not a question of the existing food quantities, but of their affordability, availability and access (FAO 2011; HLPE 2011b). The impact is inevitably particularly hard on countries with high levels of poverty (WBA 2012).

**But low prices for agricultural products have so far not led to reduction in poverty and undernourishment** – on the contrary, low food prices are a part of the problem (Piorr 2010; FAO 2008 + 2011). Industrialised countries have undercut production in developing countries by subsidised agricultural exports, e.g. maize shipments from the US to Mexico; that has caused

agricultural production in those developing countries to decline, and they have been forced to spend foreign exchange on food imports.

High world market prices, by contrast, are a financial incentive for developing countries to increase their agricultural production. The responses to the high agricultural prices in 2008 were greater investments in agriculture, so that food production rose and prices dropped again.

The FAO is not the only organisation to see it that way (FAO 2008+ 2012a-d) – the German Ministry of Development Aid also concluded in its strategy on biofuels for developing countries that, in the short and medium term, energy use of biomass was an additional income source for agriculture (BMZ 2011).

**Biofuels can help developing countries without their own oil resources to save scarce foreign exchange at times of rising oil prices, because diesel is very expensive in rural areas there. That means biofuels would help to modernise agriculture and generate income, and thus increase security of food supply.**

But there is also a large measure of agreement that direct coupling of agricultural and oil prices via conventional

biofuels is not a long-term option – the price fluctuation induced not only has short-term negative impact on food security, but also gives the wrong signals for the development of biofuels and bioenergy as a whole.

Growing crops for bioenergy use is in direct competition for arable land, which is not only limited overall, but will tend to permit less cultivation for energy crops in future due to climate change effects, increasing food demand of a growing world population, and regional water shortages (FAO 2011; IFF 2009; IIASA 2009).

And the greenhouse gas balances of conventional biofuels, with the exception of bioethanol from sugarcane, are not favourable enough to meet the requirements of climate change mitigation. Price dynamism which induces steadily rising feedstock costs for biofuels permits no significant expansion of biofuels, especially in areas of goods transport, and shipping and aviation, which are price sensitive.

**In the longer term, the use of energy crops grown on arable land for fuel production is therefore not a viable option.**

Finally, global meat consumption is a major driver of agricultural prices, and also of land use and of greenhouse gas emissions. The production of meat has tripled since 1970 to a global total of about 300 million t, and continues to increase (OECD, FAO 2012).

In addition, China and the EU are importing more and more soybeans from Argentina, Brazil and the US for their growing production of pork, and are using considerable amounts of land for this purpose – very much more than for biodiesel from soybean oil, which is more a subsidiary product.

Meat and dairy production require large inputs of feedstocks, consuming more energy and more land, and have more environmental impact than alternative protein sources such as cereals, vegetables and aquaculture (FAO 2006; Fritzsche et al. 2012a; PBL 2011). Agriculture worldwide uses a total of about 5 billion

hectares (ha) today, of which about 3.5 billion ha are pasture for meat and dairy production, and 1.5 billion ha are used for arable farming (FAO 2011). About 1 billion ha of this arable land are used to grow feed, that is indirectly for meat and dairy production, and only about 0.3 billion ha directly for food. Arable land for biomaterials accounts for about 0.1 billion ha, and for bioenergy (mainly transport fuels) about 0.05 billion ha (nova 2012).

Thus meat and dairy production accounts for about 92% of agricultural land, whereas non-animal food accounts for only about 5%, biomaterials 2%, and bioenergy (biofuels) 1%. So minor changes in consumer behaviour with respect to meat and dairy products have major land use impact and effect on agricultural prices as a whole.

**The key to securing the future food supply security of the world is not so much the question of “fuel versus food”, but more the question of what foods are in demand, and who has enough income to pay for them.**

#### FUEL VERSUS ENVIRONMENT – LAND USE AND BIODIVERSITY

The second competition aspect in biomass cultivation is the question of land use and biodiversity. Land consumption by the expansion of housing and roads, by soil erosion and over-grazing, and by negative impacts of climate change on agricultural production, in parallel with population growth, leads to greater pressure on soils and other resources such as water, forests and biodiversity (OECD 2012).

The loss of habitats is the main factor which threatens and reduces biodiversity (UNEP 2012). To avoid further pressure from bioenergy feedstock cultivation, highly biodiverse land needs to be protected, even where the land is to be used for bioenergy crops.

The biodiversity and nature conservation issues caused by growing bioenergy crops are the same as for conventional agricultural production, because the same agricultural feedstocks are used for conventional biofuels. To stay competitive even where raw material costs increase, today's biofuels are increasingly

produced from crops which are grown in monocultures with little crop rotation, on big plantations using large quantities of fertilizers and pesticides, and in some cases also with irrigation (EEA 2012).

In Germany, renewable raw materials are mainly grown on arable land which covers a total area of about 12 million hectares. There are also 5 million hectares of grassland (producing grass), and about 11 million hectares of forest (producing forest waste products and thinnings). At present about 0.4 million hectares of land are used for growing biomass for material use, and about 2.1 million hectares for energy crops (cf. Table 11).

This area could increase to 4 million hectares by 2050, according to a number of studies (Nitsch et al. 2012; Thrän et al. 2010); one third of arable land would then be used for growing energy crops.

For the sake of nature protection and biodiversity conservation, at least 1 million hectares should be used, and grassland with a high degree of biodiversity should be taken out of intensive cultivation – that would be another 0.5 million ha.

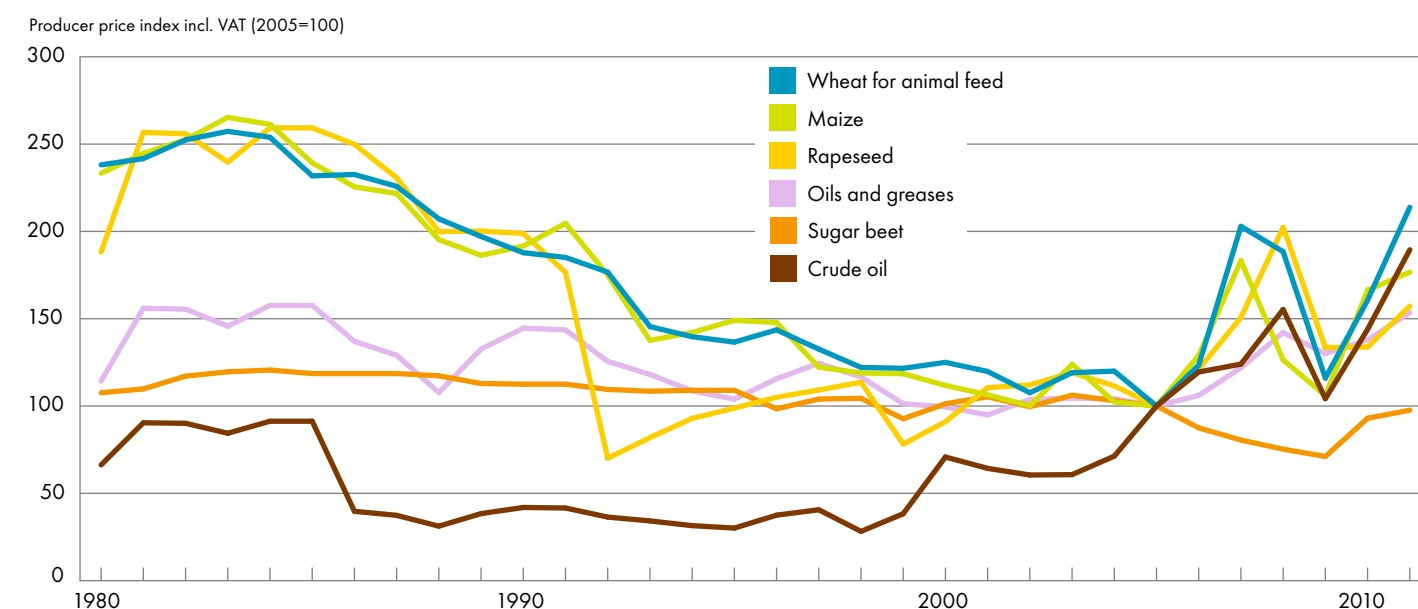
It is internationally recognised that the protection of biodiversity in nature conservation areas alone is not enough – cultivation practice on farming land is also important. So far, very few economically viable agricultural methods have been developed that minimise negative effects on biodiversity – a lot of research is needed in this area.

**Use competition between bioenergy and nature conservation can be reduced by limiting the type and extent of land use. There are also synergies between bioenergy and nature conservation, where residual biomass from landscape care activities can be used.**

#### FUEL VERSUS MATERIAL USE

In Germany, the land used for energy crops, mainly for biogas and rapeseed oil, and increasingly also for bioethanol, already substantially exceeds the land used for biomass materials (cf. Table 11). However, solid biomass will likewise be used increasingly for energy, also using wood and straw feedstocks, as bioenergy

#### 10 DEVELOPMENT OF PRICES FOR AGRICULTURAL PRODUCTS AND OIL



Source: DESTATIS, GENESIS database; border crossing prices for crude oil and oils/greases; own presentation



is increasingly used for power and heating and in the 2<sup>nd</sup> generation of biofuels. Bioenergy will thus be in competition with material use of the same biomass resources – another use conflict.

Solid biomass mainly comes from the forests – with roundwood from forestry and industrial waste wood, produced with the quality criteria specified by the market. Alongside these two categories, there are other products which normally find no use in the wood processing industry, such as waste and residual wood and thinnings, which may be of interest to the pulp and paper industry, depending on price. This material use of wood will attract more or less stable wood demand in the foreseeable future (DBFZ, IUP 2011), and can be covered by today’s forestry.

But growth is also expected for the “new” material uses, with bio-plastics, composites (e.g. carbon reinforced fibres) and bio-refineries, and also the use of forest

11 LAND FOR GROWING SUSTAINABLE BIOMASS IN GERMANY

Purpose	2011 (hectares)	2012* (hectares)
Industrial starch, sugar	170,000	257,000
Technical rapeseed	120,000	120,000
Technical sunflower and linseed oil	11,000	11,000
Vegetable fibres, medical and dyes	10,500	13,500
<b>Total raw material use</b>	<b>311,500</b>	<b>401,500</b>
Rapeseed for biodiesel, vegetable oil	910,000	913,000
For bioethanol (wheat, sugar beet, etc.)	240,000	243,000
For biogas (maize, rye, etc.)	900,000	962,000
For solid fuels (SRC, Miscanthus)	6,000	6,500
<b>Total energy use</b>	<b>2,056,000</b>	<b>2,124,500</b>
<b>TOTAL</b>	<b>2,367,500</b>	<b>2,526,000</b>

Source: FNR (2012); \*data estimated

residuals and thinnings for power and heat generating. For straw, the perspectives go beyond 2<sup>nd</sup> generation fuels, while today’s use can only be expanded in the area of “innovative” material use and in co-firing in large coal-fired power stations. The latter is somewhat improbable for straw,

in view of its combustion properties and relatively high transport cost. To avoid use competition between material and energy, a cascade concept for biomass use is to be implemented, i.e. “structure value before heating value” (Fritsche et al. 2010). That means biomass is to be used

with priority for material purpose (building materials, furniture, paper, textiles, etc.), and then, when these biogenic products have reached the end of their useful life, this is to be followed by “post-use” for energy. Further efforts will then be needed for separate collection of biogenic wastes, but cascade use is basically feasible.

**Competition between material use and energy use can be avoided by cascading.**

FUEL VERSUS POWER AND HEAT

Another possible use competition for biomass exists within energy use, that is between biofuels on the one hand and the use of bioenergy for power and heat on the other.

But today’s biofuels do not compete with bioenergy for power and heat – at present, bio-heat mainly comes from thinnings and sawmill waste (pellets), requiring no additional land for growing them (DBFZ,

IUP 2011). Power from biomass mainly uses recycled wood and waste materials from the wood industry, and in future also forestry residues and thinnings, and possibly also wood from short rotation coppices (SRC), which uses additional land. Straw is of little interest for combustion because of its high proportion of ash, producing slag and particulates, and chlorine content causing corrosion. This biomass potential could therefore be available without significant energy competition for 2<sup>nd</sup> generation biofuels, because these will use lignocellulose. Thus, competition will mainly be for forestry residues and thinnings, and in the long term also short rotation coppices.

The heating market is on a downward trend, while there is strong growth in non-biogenic renewables for power generating (solar and wind energy, possibly also geothermal energy). Competition between fuel and heat could be reduced, provided that the trend towards solid biomass in

home heating can be reversed or at least slowed down.

**There are many non-biogenic renewable energy sources available for stationary power and heat supply, so the demand for power and heat can be met by these renewables – especially if efficiency on the demand side is significantly increased. Thus use competition in energy use of biomass can be avoided in the long run.**

FUEL VERSUS FUEL

The final competitive situation is in the use of biofuels within the transport sector itself. Passenger cars, trucks, ships and aircraft have different propulsion concepts, and therefore use different biofuels. The fuels are also subject to different tax regimes, and some modes of transport are fully or partially exempted from taxes. Thus higher costs may arise at least in the short and medium term from the use of biofuels and other alternatives to fossil fuels, giving different relative and absolute cost effects. The individual users of transport services have different price elasticities (ÖKO, DLR, ISI 2012), which results in different possibilities to pass on costs.

Higher cost of fuel for passenger cars only has a dampened impact on the price at the filling station, because of the high percentage of taxes on fuel, and there are only limited possibilities for switching to other modes of transport. Trucks and marine transport have lower or far lower tax rates, and higher elasticity of demand; and the situation is similar for air transport. Passing on the additional cost of biofuels in the passenger car sector thus causes relatively little demand change, whereas the reactions may be greater for other modes of transport.

However, the longer term significance of biofuels is not in the passenger car sector, but rather in air and sea transport, and to some extent also trucks – this has to be taken into account in future development. The use competition for biofuels between the individual modes of transport is restricted, due to technical and market effects. The longer-term introduction of biofuels in aviation, heavy goods road transport and shipping calls for a proactive policy, producing the desired steering not by means of cost transfers alone.





# 3 SUSTAINABILITY OF BIOFUELS

**Sustainability depends not only on compliance with ecological requirements and environmental standards, but also on social and economic acceptability. While life-cycle assessments have been prepared for biofuels for over twenty years now, with broad coverage of the environmental area, the globalisation of the biomass market has definitely enlarged the focus to include socio-economic factors. The demand for sustainability of biofuels led to worldwide debate on the development of concrete, in some cases also binding criteria for an economic sector and for a whole product group. There are now a whole series of laws, standards, processes, criteria and initiatives aimed at improving and guaranteeing the sustainability of biofuels and bioenergy. Sustainability is to be audited by certification.**

## LEGAL STATUS AND STANDARDS

Right from the first targets set in the Biofuels Directive of 2003, there was growing criticism of the biofuels quota, on the part of many environmental and social organisations. The expected increase in land use for biomass production, especially in tropical export regions, gave rise to fears of multiple conflicts with principles of sustainability. Right from an early stage, the main fears were clearing of tropical forests and unclear land use rights (Fritsche et al. 2006).

The German Biofuels Quota Act (2006) therefore set the first requirements for sustainability for the biofuels eligible for the quota, as follows:

- 1) sustainable management of agricultural land;
- 2) protection of natural habitats; and
- 3) a certain CO<sub>2</sub> reduction potential.

Since 2009, all member states of the EU have been subject to the **Renewable Energy Directive** (RED, 2009/28/EC) and the **Fuel Quality Directive** (FQD, 2009/30/EC). These Directives contain the legally binding sustainability requirements, with the same requirements for transport biofuels and liquid biofuels for electricity or heating.

At the European level, a standardisation process was launched in 2008 within the framework of CEN (European Standardisation Committee) for “sustainably produced biomass for energy use”. This standard will be adopted in the near future, and is to facilitate and harmonise the transposition of the RED requirements for the players concerned.

Another standardisation process on sustainability criteria for bioenergy is in progress at the level of ISO (International

Organization for Standardization), independently of European legislation.

Other globally important work in this area includes the Global Bioenergy Partnership (GBEP), which reached agreement in November 2011 on a set of 24 sustainability indicators for bioenergy (GBEP 2011). The originators were the governments of 45 countries and 24 international organisations.

The special value of this process lies in the development of a generally accepted global understanding of what characterises sustainable production and use of bioenergy resources.

Fig. 12 gives an overview of the indicators. GBEP provides a method sheet giving sev-

eral pages on each of the indicators. In addition, a great many private initiatives and organisations have provided inputs for the discussion and for development of sustainability criteria. Legal requirements are set out in regulations in the USA (Renewable Fuel Standard), in the State of California (Low Carbon Fuel Standard) and in Switzerland (Mineral Oil Tax Act).

## SUSTAINABILITY CRITERIA FOR BIOFUELS

The most important sustainability criteria for biofuels are aimed at protection of the climate, biodiversity, soil and water, and at social aspects.

### Climate change mitigation

All the legal requirements and sustainability standards addressing bioenergy include among their criteria a certain

degree of reduction of greenhouse gas emissions versus a fossil reference value. This is an indicator which encompasses the whole of the life cycle. According to the RED, the calculation should include the following:

- direct land use change (DLUC );
- production or growing of the feedstocks;
- processing;
- transportation and distribution;
- use of the fuel.

The climate damaging gases to be considered are fossil carbon dioxide (CO<sub>2</sub> fossil), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and carbon stock changes. The savings criterion under RED Art. 17 (2) is a reduction of at least 35% versus a fossil reference of 83.8 g CO<sub>2</sub>-eq/MJ. Minimum savings of 50% are required from 2017 and 60% from 2018. The Directive sets out further methodological rules in Annex V, for calculation of emission reductions, and also permits the use of default values for a selection of specific biofuel paths (see Fig. 13). These values are in principle conservative, giving market players an incentive to calculate the actual values. For certain biofuels such as diesel from soybean oil, the default value is not sufficient to comply with the savings criterion. For other paths

(such as ethanol from rye), there are no default values. In these cases, a greenhouse gas calculation has to be made for every shipment of biofuels.

According to the evaluations of the Federal Office for Agriculture and Food (BLE 2012), the biofuels counted towards the quota gave savings of about 7 million t CO<sub>2</sub>-eq. That is an average of about 50% versus the fossil reference system. There are various calculation tools available to support and harmonise calculations, such as the worksheet based tools BioGrace and ENZO2 (IFEU 2012).

A key subject for greenhouse gas inventories at the present time is **indirect land use change** (ILUC). That is when land that was previously used for another purpose (e.g. food or feed crops) is changed to cultivation of crops for biofuels.

These replacement effects may occur over the whole of the global trading system (by reducing food/feed exports) even outside of a region or country, so the only way to assign that to biomass growing is by model analysis. Opinions differ widely since the start of the ILUC discussion on the question of which model approach is most suitable.

Simple, easy-to-follow models (Fritsche et al. 2008) compete with complex economic equilibrium models (CARB 2008; IFPRI 2011). The results are spread over a correspondingly wide range. But most of the model analyses show significant additional emissions.

Under the RED, the EU Commission is required to make a decision on the handling of ILUC. A large number of studies have already served for preparation of this decision, which now proposes further research, and a final decision to be made by 2017 – it needs to be seen whether the Council and the European Parliament follow this proposal. The discussion centres on ILUC factors or reward system for ILUC avoidance depending on the type and origin of the biomass (E&Y 2011). It is possible that combinations of incentives may be used, or that ILUC will still not be taken into account in future.

Regardless of the extremely divergent positions within and between the decision makers, experts, the relevant industries, environmental NGOs and other stakeholders, the appropriate control impact of the ILUC approach is of vital importance. **The majority of experts agree that bioenergy fuels with low ILUC risk must be given priority.**

## Biodiversity

Following climate change issues, environmental conflicts resulting from biofuels are mainly seen in land conversion, land use change, and the expansion of large-scale agriculture with a trend toward monoculture. The decisive criterion here is loss of **biodiversity**.

Under RED Art. 17 (3), biofuels rated as sustainable must not be made from biomass grown on land with high biodiversity value. The Directive defines that as:

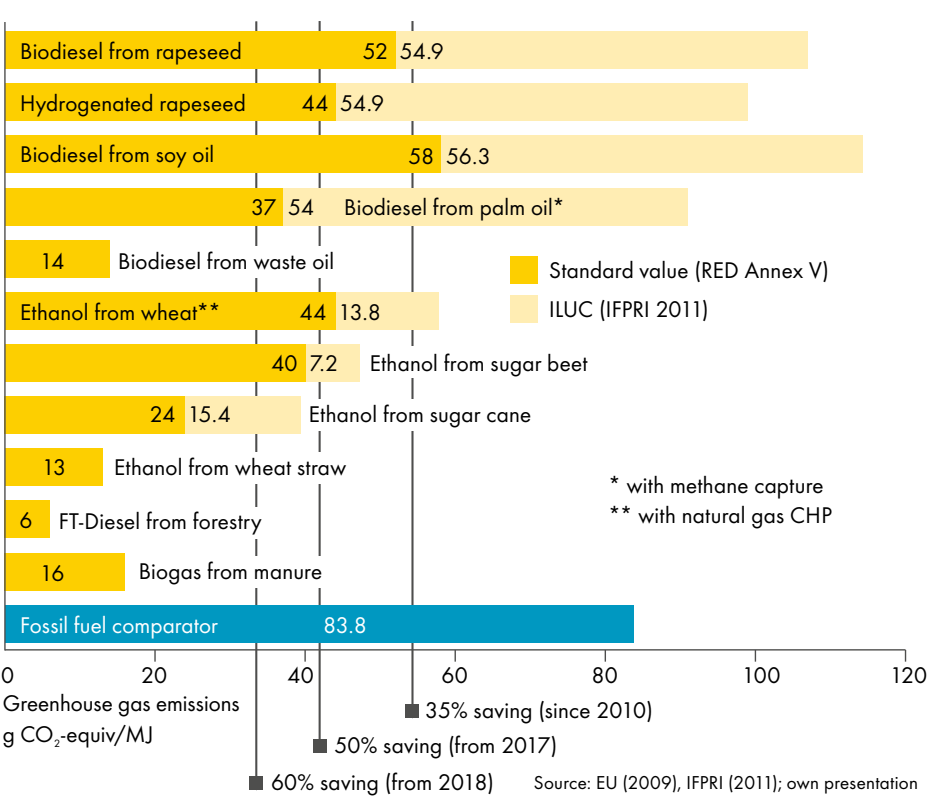
- Primary forest and other wooded land, namely forest and other wooded land of native species, where there is no clearly visible indication of human activity and the ecological processes are not significantly disturbed;
- Areas designated by law or the relevant competent authority for nature protection purposes, or for the protection of rare, threatened or endangered ecosystems

12 GBEP SUSTAINABILITY INDICATORS FOR BIOENERGY

Environmental indicators	Social indicators	Economic indicators
Life cycle GHG emissions	Allocation and tenure of land for new bioenergy production	Productivity
Soil quality	Price and supply of a national food basket	Net energy balance
Harvest levels of wood resources	Change in income	Gross value added
Emissions of non-GHG air pollutants	Jobs in the bioenergy sector	Change in consumption of fossil fuels and traditional use of biomass
Water use and efficiency	Change in unpaid time spent by women and children collecting biomass	Training and re-qualification of the workforce
Water quality	Bioenergy used to expand access to modern energy services	Energy diversity
Biological diversity	Change in mortality and burden of disease attributable to indoor smoke	Infrastructure and logistics for distribution of bioenergy
Land use and land-use change	Incidence of occupational injury, illness and fatalities	Capacity and flexibility of use of bioenergy

Source: GBEP (2011)

13 GREENHOUSE GAS STANDARD VALUES OF RED AND EXEMPLARY ILUC VALUES



or species recognised by international agreements or included in lists drawn up by intergovernmental organisations or the International Union for the Conservation of Nature);

- Highly biodiverse grassland.

The reference date is January 2008. Any land converted before that is not covered by the regulation. Exclusion of the defined types of land is regarded by many as sufficient to save the biodiversity “hotspots” from direct land use change – but that does not restrict indirect land use change.

In addition, no account is taken of the maintenance (or increase) in biodiversity of agricultural land. The protection rating for primary forests and protection of nature reserves are key components in protection of biodiversity. Many of the experts also deem it necessary to establish a minimum of nature conservancy in wide areas by legislating for appropriate methods of cultivation. In view of the feedstocks used for biofuels, there are also fears of genetic impoverishment and an increase in monocultures (e.g. maize growing).

Soil and water

These two natural assets are always key in agricultural production. Soil is a fundamental issue with respect to soil erosion and the preservation of soil fertility, and its other ecosystem services (that is the benefits of intact ecosystems for humans, such as water storage, filtering functions). Many practical standards of certification systems therefore include differentiated indicators for soil. The RED restricts itself in this respect to compliance with the minimum requirements for good agricultural and ecological condition, in accordance with EU Regulation (EC) 73/2009 (common rules for direct support schemes for farmers, cross compliance).

These are minimum requirements which are intended to help avoid negative consequences for agriculture. But the RED sets these requirements exclusively for production within the EU. Biomass produced outside of the EU is not subject to any soil-related criteria.

Water is relevant in various ways in the production of biofuels. Firstly, the avail-

ability of sufficient water is the basis for growing biomass crops intended for high productivity. If there is not enough rainfall, irrigation has to be used, which may have considerable impact on the water inventory of the catchment area. Biomass production may also cause pollution of groundwater and surface water by the use of fertilizers and pesticides.

The necessary conversion facilities for production of biofuels normally require input of water, and also result in waste water which requires extensive cleaning to prevent water pollution. The usual standards of the certification systems therefore also include differentiated indicators for water.

The RED deals with water as follows in Art. 18 (3) para. 2: the member states are required to impose an obligation on biofuel producers to report on and document measures for soil, water and air protection, and for avoidance of excessive water consumption in areas where water is scarce. That means no concrete, binding criteria are implemented here. The protection of groundwater from agricultural contamination is in turn implicitly covered by the above mentioned obligation to set minimum requirements for good farming and ecological status.

Social aspects

Social criteria have been in the foreground since the beginning of the sustainability debate on biofuels, and are demanded in particular by church institutions. As biomass imports from developing countries increase, fair trade with exporting countries as well as internationally accepted labour and land tenure conditions in producer countries are fundamental requirements for sustainable imports. All these criteria are covered in established certification systems.

Other social implications of bioenergy could be land availability and food price developments, both impacting on food security.

The RED also takes up these concepts in Art. 17 (7), whereby it imposes not on the producers but on the EU Commission an obligation to report “every two years on the impact on social sustainability in

the Community and in third countries of increased demand for biofuel”. The focus is on:

- the availability of foodstuffs at affordable prices;
- wider development issues;
- respect of land use rights;
- ratification and implementation of the core standards of the International Labour Organisation (ILO).

Compliance with social criteria is not a binding requirement. The aim is rather to introduce the social aspects and reporting requirements on an indicative basis, and thus to exert indirect pressure for their implementation at national level.

Direct requirements are avoided in the social context, as are criteria for soil and water, because they would be regarded under the rules of the World Trade Organisation (WTO) as interference in areas of national sovereignty, and would most likely trigger legal action, with good chances of success.

Climate and biodiversity on the other hand are assets with global impact.

Compatibility with these aspects may be demanded as a binding characteristic in trade products (Hermann et al. 2009).

SUSTAINABILITY CERTIFICATION

Certification systems aimed at sustainability have been in existence for several decades now. The SAN label of the Rainforest Alliance has been used since 1992 to certify environment friendly agricultural products from tropical regions. FairTrade labels have long since become established in coffee (for example Utz Kapeh).

The first quality labels in the timber trade were introduced in 1994 in response to the clearing of primary forests and forest management techniques which led to deterioration. The number of labels which contain sustainability requirements for agricultural and forestry biomass goes into the hundreds.

New systems have been developed with the introduction of the RED sustainability requirements for biofuels, in order to

cover these requirements in full. The main innovation in these systems was the greenhouse gas inventory.

The EU Commission has now recognised 11 systems which are appropriate to demonstrate compliance with the RED requirements for biofuels over the whole of the supply chain (cf. Table 14).

There are considerable differences between the systems in terms of their independence and in terms of the scope of their criteria. Systems such as the Roundtable on Sustainable Biofuels (RSB), which was developed on an international basis without direct relationship with the RED in an ambitious multi-stakeholder process, address not only the RED requirements, but also many other ecological and social criteria, and are already markedly independent due to the structure of their Boards.

The International Sustainability & Carbon Certification (ISCC) scheme developed in Germany also has a wide-ranging, differentiated checklist of criteria. At the other end of the scale is the REDcert, which restricts itself precisely to certification in accordance with the RED requirements. But it is likewise an independent system.

By contrast, systems such as RBSA of Abengoa are very much lacking in transparency, because they are designed on a purely company-internal basis. It is questionable how these systems intend to demonstrate independence and thus credibility.

How to evaluate the effectiveness of certification?

The systematic implementation of proof of compliance with the RED criteria for biofuels is to be regarded first of all as progress towards reducing the presence of non-sustainable products in the European market. Importantly, the criteria as such bring a “quality label” and awareness of compliance with it into the market.

The effectiveness of the demand for self-declarations by farmers is evident in all parts of the market, regardless of the actual use of the agricultural products. But it is not yet clear whether the sectoral certification, addressing the EU market, will effectively reduce non-sustainable production. There are no mechanisms available

14 CERTIFICATION SYSTEMS RECOGNISED BY THE EU COMMISSION

System	Country, Scope
ISCC (International Sustainability and Carbon Certification)	Developed in Germany, for all types of biofuel
Bonsucro EU (formerly BSI Better Sugarcane Initiative)	Multi-stakeholder initiative, exclusively for ethanol from sugarcane
RTRS EU RED (Roundtable for Responsible Soy)	Multi-stakeholder initiative, exclusively for soybean oil and biodiesel from soybean oil
RSB EU RED (Roundtable on Sustainable Biofuels)	Multi-stakeholder initiative, for all types of biofuel
2BSvs (Biomass Biofuels Sustainability voluntary scheme)	Developed by industry in France, for all types of biofuel
RBSA (Abengoa RED Bioenergy Sustainability Assurance)	Corporate initiative, for all types of biofuels produced by Abengoa
Greenergy Brazilian Bioethanol verification programme	Developed by industry in Brazil, exclusively for ethanol from sugarcane
Ensus voluntary scheme under RED for Ensus bioethanol production	Developed by industry association in the UK, for ethanol produced in the UK
Red Tractor (Red Tractor Farm Assurance Combinable Crops & Sugar Beet Scheme)	Developed by industry association in the UK, for biofuels produced in the UK
SQC (Scottish Quality Farm Assured Combinable Crops (SQC) scheme)	Developed by industry in the UK, for biofuels from wheat, maize, rapeseed
REDcert	Developed in Germany by various industry associations, for all types of biofuel (focus on production in Germany and Central Europe)

to prevent a split in the market – certified products to Europe, non-certified products to the rest of the world.

Another side-effect could be that certification leads to a shortage of biofuels which are eligible to count towards the quota. The stricter the requirements, the more the flow of goods will split off into markets which do not require certification. For example, Brazilian ethanol from sugarcane which meets all the RED criteria may find easier access to the US market, which does not require certification.

What can be expected from international initiatives?

The risks resulting from increased production and use of biofuels will not be restricted on a global scale until more or less equivalent standards are implemented globally. The initiatives from GBEP and ISO could develop in that direction. Though both of these institutions are based on the introduction of voluntary requirements, they do put the subject matter in all its relevant aspects up for

discussion at international level. The ISO standard would show producers throughout the world what globally agreed principles, criteria and indicators have to be observed for sustainable bioenergy. No producer could then use non-sustainable methods on the grounds that there are no generally applicable sustainability standards.

The GBEP indicators in turn give guidance to governments, so that they can examine their own bioenergy policy. Continuous further activities of the governments and organisations in GBEP give the great opportunity to continue playing a part in the dynamic discussion of bioenergy, understanding any discrepancies between the interests of the different countries, and moving solutions forward.

EXTENSION OF SUSTAINABILITY CRITERIA TO ALL BIOENERGY – AND ALL BIOMASS?

The EU adopted the policy in the RED to double the percentage of renewables to 20% of gross final energy consumption



(EU 2009), with bioenergy playing a major role:

- About 80% of the expansion goals in the heating sector are based on bioenergy;
- Achieving the RED goal will require more use of wood, which will increase the pressure on European forests, and also on international forests because of imports;
- Demand for wood is raised by increasing co-firing in coal-fired powerplants to reduce greenhouse gas emissions, which itself increases international trade;
- The future 2<sup>nd</sup> generation biofuels will likewise increase demand for wood.

The RED already contains binding sustainability criteria for biofuels and bioliquids; but these requirements apply only to liquid bioenergy sources and biogas and biomethane in the transport sector, and to solid biomass only where it is used to make biofuels.

The increasing direct **use of solid biomass** for power and heat has not so far been regulated; the Commission only recommends member states to apply the RED requirements to solid biofuels on a voluntary basis (EC 2010).

In addition, there are no European regulations in the forestry sector for “good professional practice”, as are set by the EU minimum environmental requirements for management of agricultural and forestry

land. The demand has therefore been raised to set legal sustainability criteria for solid biofuels, too – both for products made in the EU, and for imported solid fuels. The European Commission, the European Parliament and some of the member states are discussing this, for example in a series of joint workshops, in the light of increased imports of solid biomass (Fritsche et al. 2012b). Regulations for this can be drawn from existing certification systems such as FSC and PEFC, which give good principles for sustainable forestry products, but largely omit the questions of use of thinnings and harvest residues for energy purposes. The “Initiative Wood Pellet Buyers” (IWPB) introduced by industry develops a voluntary sustainability standard for pellets (IWPB 2012a+b) and is an important step on the way to EU-wide regulation. WWF has likewise submitted general recommendations for sustainability requirements for bioenergy from forests (WWF 2012a).

The greenhouse gas emission reductions and (direct) land use changes regulated in the RED can also be transferred to solid bioenergy, though it would be necessary to determine the greenhouse gas balances of forest products, because these are not necessarily CO<sub>2</sub> neutral (cf. Fritsche et al. 2012b).

It is also important to protect high-biodiverse forests, adding criteria for sustainable forest management, limit extraction rates of wood, and for safeguarding nutrient cycles and soil quality. This extension of the sustainability requirements to solid biomass

would be an important step for reduction of the problems from rising pressure of use in forests, at national and international level (IFEU 2011).

But it must be noted that non-energy use of wood creates pressure on forests – especially from the pulp/paper and wood materials industry – and a “bio-economy” (including biorefineries and biomaterials) also uses forestry biomass (EC 2012b). That causes negative market effects such as land use change (indirect effects) if only one form of the use of biomass is regulated by sustainability requirements. First activities are under way to develop sustainability criteria for **non-energy use of biomass** and to extend them to all agricultural products. The Coalition Agreement of the present German Government explicitly sets out this goal in the European context.

Going beyond bioenergy and biofuels, the increased use of **biogenic feedstocks in all sectors** therefore requires sustainability rules which take account not only of factors such as climate protection and biodiversity, but also questions of efficient use of land and resources, and social criteria. The basis for that has already been created with the criteria put forward for extension of the RED (Fritsche et al. 2012b) and the indicators adopted by the GBEP.

**In the medium term, consistent rules are needed for the sustainability of all forestry products – and in the longer term also for all agricultural products and thus for all biomass.**

## 4 THE NEXT GENERATION: ADVANCED BIOFUELS

**More than 99% of all biofuels produced today fall into the general category of “1<sup>st</sup> generation”. That means biofuels obtained from starch, sugar or vegetable oils, from crops grown especially for energy (IEA 2008). The feedstock and land requirements for these fuels are in direct competition with other possible uses. That is why new, advanced biofuels are needed, i.e. second or even third generation biofuels.**

### THE SECOND GENERATION

The 2<sup>nd</sup> generation of biofuels is aimed at using different feedstocks in order to access a broader range of raw material potentials. These are mainly lignocellulosic materials, a mix of different proportions of cellulose, hemicellulose and lignin, depending on the characteristics of the initial material. They may be agricultural residual materials (e.g. straw), residues from forestry, or biomass crops such as grasses (e.g. switchgrass) or wood from short rotation forestry.

The term “2<sup>nd</sup> generation” biofuels is defined mainly on the basis of the feedstocks and conversion technology. However, there is no precise definition, so some biofuels cannot be allocated to a particular “generation” (e.g. biomethane), while other products are claimed to be third or even fourth generation (fuels from CO<sub>2</sub> fixing bacteria).

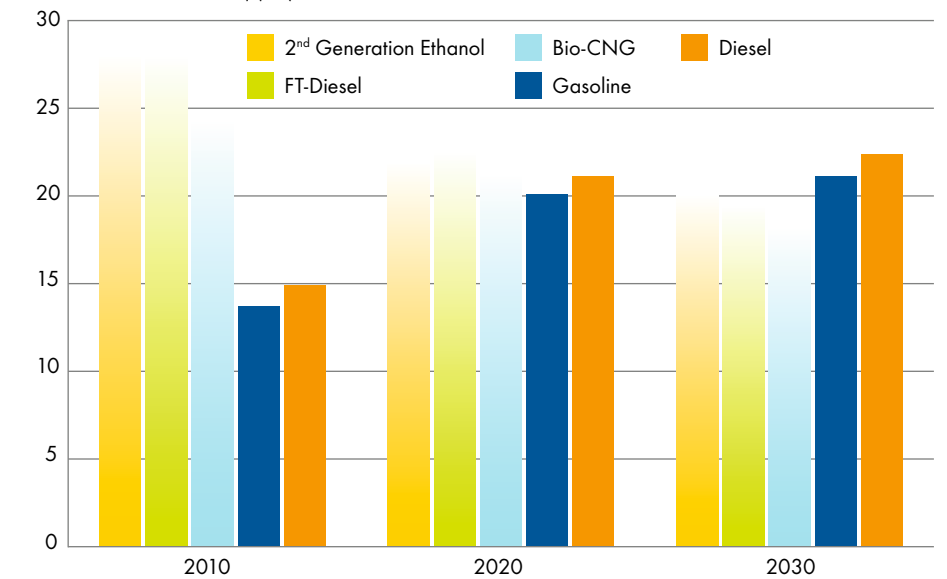
In summary, the processes may be described as follows:

**Hydrotreated vegetable oils (HVO)** are strictly speaking not 2<sup>nd</sup> generation, because the raw material is (currently) 1<sup>st</sup> generation. The process uses hydrotreatment to convert vegetable oil, which is problematic for diesel engines, into high-quality fuels comprising pure hydrocarbons. This process can be used to convert the usual vegetable oils such as rapeseed oil or palm oil, and also waste oils, recycled fats and similar.

**HEFA fuels** (Hydrotreated Esters and Fatty Acids), also referred to as BioJet, are also based on hydrotreated vegetable oils, for first applications in aviation. Alongside the stand-alone facilities for hydrotreatment of vegetable oils, there are also concepts for co-processing of vegetable oils in existing refineries. The vegetable oil is blended

### 15 POSSIBLE COST DEVELOPMENTS FOR BIOFUELS UP TO 2050

Production costs excl. taxes (€/GJ)



Source: IEA (2012a); own presentation

with the conventional crude oil upstream of the cat cracker, and further processed with the conventional streams. The fuel products diesel and gasoline then contain corresponding biocomponents, which are indistinguishable from the rest of the fuel.

#### Cellulosic ethanol:

Chemically, there is no difference between cellulosic ethanol and conventional bioethanol; but the raw material comprises cellulose, which is converted to sugar by means of chemical/biochemical pre-treatment (use of enzymes and strong acids) and fermented to ethanol. This method can produce between 160 and 250 kg of ethanol from one tonne of straw.

#### FT diesel (Fischer-Tropsch):

This is synthetic biodiesel, which is obtained from lignocellulose and other organic raw materials via synthetic gas production and subsequent Fischer-Tropsch synthesis to obtain liquid fuels. Its advantage is good fulfilment of the requirements of modern engines. How-

ever, this technology is still at the development phase.

Another technical development uses catalytic reforming processes to convert sugar, starch and all forms of lignocellulose into targeted short-chain carbon compounds. A particular advantage of this method is the process-related generation of hydrogen. Fig. 15 shows the potential longer-term cost development of 2<sup>nd</sup> generation biofuels versus gasoline and diesel.

In Germany and the EU, the share of diesel will continue to rise, which makes 2<sup>nd</sup> generation biodiesel particularly relevant. By contrast, Brazil and the US use mainly gasoline as road transport fuel, so 2<sup>nd</sup> generation bioethanol is particularly important there.

**The 2<sup>nd</sup> generation biofuels are in principle available, but there is still much work to do before they are ready for market – and their costs will continue to be relatively high in future.**

Short rotation coppice



## BIOFUELS FROM BIOREFINERIES?

The term “biorefinery” came into use in the early 2000s, by analogy to the functioning principle of crude oil refineries, for processes used to increase the efficiency of using biomass (Realf, Abbas 2004).

It is now understood to mean sustainable processing of biomass to a range of marketable material and energy products. It involves the production of food and feed, chemicals, materials, fuels, power and heat in an integrated way, with the goal of maximising the value added from the biomass feedstock input (cf. Fig. 16).

Various studies put forward arguments of the great industrial importance of these fuels for Germany (VCI, DIB 2010), the EU (Star-colibri 2011a+b) and worldwide (WEF 2010). In Germany, a significant proportion of bioethanol and biodiesel demand could be met by biorefineries by 2030 (Arnold et al. 2011).

That means biorefineries give long-term potential for decarbonisation of material usage and avoidance of use competition.

However, that applies only if coupled production is successful in the sense that a number of marketable products really are created in one process, and the expenditure is justified in terms of finance and energy resources.

The Federal Government recently presented a “Biorefineries Roadmap” which sees the need for a lot more research and development (BuReg 2012).

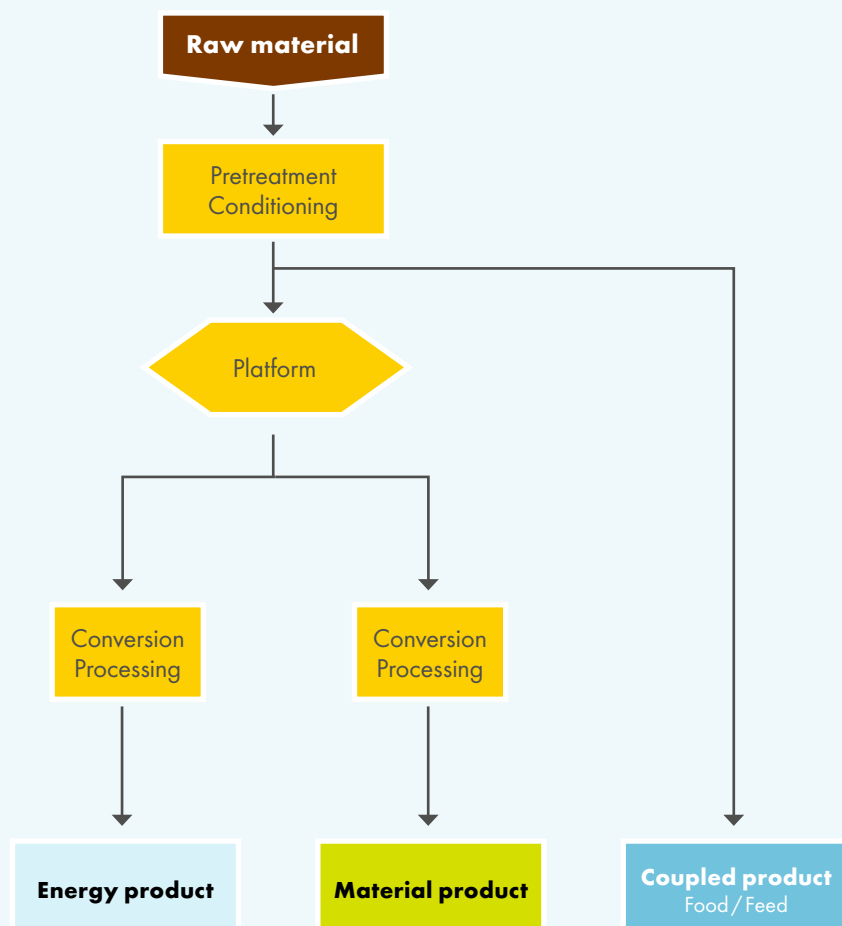
**Biorefineries are a longer-term option for sustainable biofuels – however, their economic viability still has to be demonstrated.**

## BIOFUELS FROM ALGAE AS “G3”?

For some years now, algae have been regarded as promising new feedstock in the global discussion of biofuels, and biofuels produced from them are sometimes described as “3<sup>rd</sup> generation”, because they would no longer require the use of land.

It is possible in principle to produce bioenergy (for example biogas) and biofuels from algae, but it is also important how the feedstock is obtained:

## 16 HOW A BIOREFINERY WORKS



Source: Arnold, Fritsche, Maga et al. (2011)

■ **Macroalgae** such as seaweed are cultivated almost exclusively in the sea, or harvested from natural stocks. They are mainly used for food & feed and as an industrial feedstock. Macroalgae can be used to produce biogas and bioethanol, but the yield has so far been small.

■ **Microalgae** are used for high-end cosmetic and medical applications, and their global production today is just a few 10,000 t. They are grown in open tanks or closed photo-bioreactors, and contain certain percentages of oils for biodiesel production, while the rest of the biomass can in principle be used for ethanol and biogas production.

The reason given for the worldwide interest in algae is that yield per unit of area can be up to ten times higher than for plants on land. But that is based on laboratory results, and transferability to production is questionable, because in practice factors such as light utilisation

and shading reduce the high yields per unit area. The energy use of algae is still at the research and development stage, with outstanding questions such as genetic drift and the effort needed to extract the biomass, with correspondingly high cost (IC 2011b; IEA BioT39 2011).

The cultivation of microalgae requires water and energy inputs for circulation and cleaning, which may cause considerable greenhouse gas emissions (IC 2011a; Murphy, Allen 2011). The use of genetically modified strains is critical, because even closed systems cannot prevent genetically modified algae from getting into the environment, with corresponding risk potential (Snow, Smith 2012).

**It will take at least 10 years before algae could make a contribution to providing biofuel feedstock. That will require major improvements in cost-effectiveness, and in the energy and water balance.**

# 5 TECHNICAL COMPATIBILITY OF BIOFUELS

**Biofuels are similar to fossil fuels for transport. They are normally liquid, or in some cases gaseous<sup>6)</sup> and release energy in a combustion process, as do fossil fuels. So in principle they can be used wherever energy is converted by combustion – especially in vehicles with internal combustion engines, and also in ships, diesel locomotives and aircraft.**

**But though the product characteristics of biofuels are similar to those of fossil fuels, they are quite different in some respects. So for technical reasons not all biofuels are suitable for all means of transport. Fig. 17 shows which types of fuels are used by which means of transport today. Passenger cars and commercial vehicles are the largest fuel consumers – and so far they are almost the only users of biofuels. The most important types and characteristics of biofuels are presented and discussed here, indicating which means of transport can be run on biofuels and which cannot.**

## (BIO)FUELS – TYPES AND CHARACTERISTICS

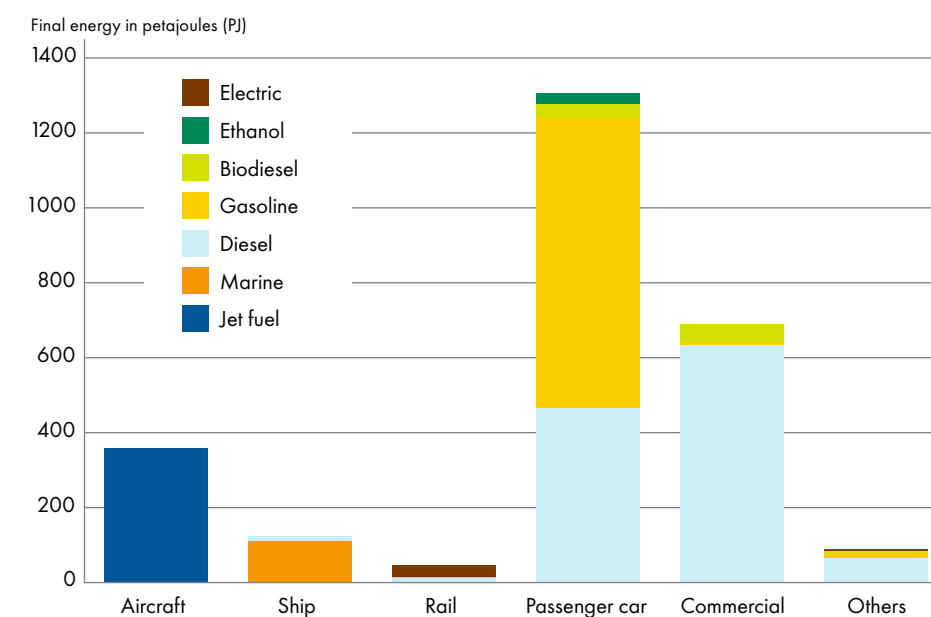
In order for biofuels to be used in today's propulsion systems, their technical characteristics must not be significantly different from those of conventional fuels. Depending on fuel type, they can completely replace conventional fuels, partially replace them, supplement them by means of blending, or not replace them at all. Where biofuels can completely replace conventional fuels, or can be used almost seamlessly in existing vehicles, fuels and supply infrastructures, they are also called “drop-in fuels”.

Fuels are made from crude oil in refineries. They are used in road transport, aviation and shipping. They are made by heating (distilling) the crude oil in multi-stage processes and use various other treatment stages (conversion) to make petroleum products.

Fuels manufactured in refinery processes are multi-substance blends. A distinction is made on the basis of their boiling range and energy density between light distillates (gas and gasoline), middle distillates (jet fuel, diesel, and marine diesel) and heavy distillates (heavy fuel oil). The boiling point characteristic gives information on how precisely a fuel is defined – for example, with strict requirements for jet fuel.

The boiling points of the biocomponents bioethanol and biodiesel are significantly different from their fossil counterparts – bioethanol, used for blending with gasoline, is a pure component; it evapo-

## 17 ENERGY DEMAND FOR TRANSPORT IN 2010



Source: Federal Environment Agency UBA (TREMOT), DESTATIS; own presentation

rates completely once its boiling point is reached. That is why an increase in the evaporated fuel volume can be observed in blends of ethanol and gasoline at 78°C (shown in Fig. 18 for E10). Biodiesel has a very flat boiling point curve; its boiling temperatures are considerably higher than those of fossil diesel. If combustion is not complete, this may cause problems in the engine (such as dilution of the engine oil). The heavy fuel oil used by ships is much heavier than the other fuels shown, with a very wide boiling point range.

Depending on the application, a wide range of other quality parameters are defined for the various fuels by national standards such as DIN in Germany or by international fuel standards of the EU,

or by other international standardisation bodies (such as IMO, ASTM International). For reasons of safety, minimum requirements are set for flashpoint and freezing point of fuels. Requirements are also set for aromatics and sulphur contents in order to reduce emissions of sulphur dioxide and particulates.

Fossil fuels give a number of advantages compared with other energy sources, for example high energy density, storage stability, ease of handling, etc., which is why many transport modes have established them as the main fuel.

Biofuels give ecological benefits, for example they can contribute to reduction of pollutant emissions (at the local level).

<sup>6)</sup> Gaseous fuels are liquid petroleum gas (LPG), compressed natural gas (CNG) and liquefied natural gas (LNG), which likewise supply combustion engines with energy. They can play a long-term role in the transport sector, but today they mainly have niche functions. In principle, it is possible to use biogas or biomethane as a substitute for gaseous fuels.



But to be suitable for use in today’s vehicles and supply infrastructures, biofuels need to have chemical properties which are at least similar to those of fossil fuels. The commonest types of biofuel used today are:

- bioalcohols (such as **ethanol** and **butanol**);
- (straight) **vegetable oils**;
- FAME (fatty acid methyl esters), **biodiesel** obtained by esterification of vegetable oils;
- HVO (**hydrotreated vegetable oils**) and synthetic diesel from biomass.

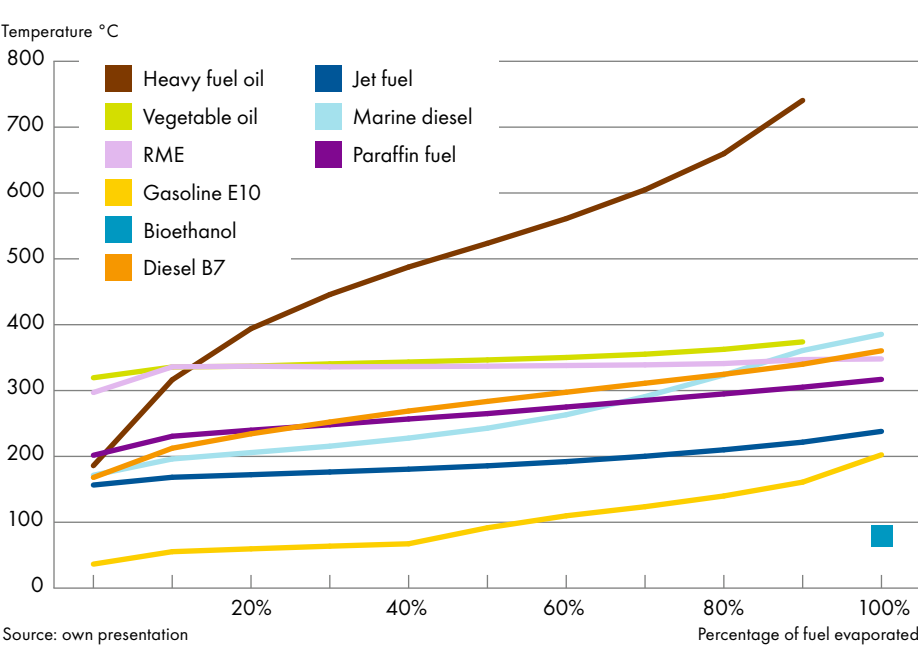
Unlike crude oil or fossil fuels, bioalcohols are not blends of many substances, but are pure chemical substances with clearly defined physical properties. Depending on the vehicle technology used, they may be a restricted substitute or a complete substitute for gasoline. Selection of the materials with which the fuel has contact must be appropriately adapted in order to avoid corrosion of plastics and metals (Bauer, Margraf, Kulikowski 2011). The different evaporation properties of ethanol and gasoline-ethanol blends also require modification of engine management systems.

The available alternatives for middle distillates are more varied. They range from straight vegetable oil, to 1<sup>st</sup> generation biodiesel (FAME), to HVO (hydrotreated vegetable oils) and synthetic diesel from biomass. All the currently available diesel substitutes are based on vegetable oil.

Not all vegetable oils and their derivatives are equally good substitutes for middle distillates. In terms of quality, a distinction can be made between 1<sup>st</sup> generation biodiesel (FAME) and 2<sup>nd</sup> generation biodiesel (hydrotreated vegetable oils and synthetic diesel from biomass); sometimes the term “generation zero” is also used for straight vegetable oil. Only 2<sup>nd</sup> generation biodiesel products are very similar to fossil fuels. They can be used as drop-in fuels, not only in vehicles, but also in aviation, at least within certain limits.

In addition, there is a series of other biofuels (such as dimethyl ether (DME), or butanol), which have not so far been able to establish themselves as fuels for various reasons, not even as niche fuels. The two

18 BOILING POINT CHARACTERISTICS OF FUELS



Source: own presentation

bioalcohols methanol and butanol can be used in today’s vehicles, at least in low blending percentages, similarly to ethanol. DME by contrast is gaseous at normal ambient temperature, and requires a pressurized gas container as its tank.

(Bio-)hydrogen can be used either in vehicles with high-efficiency fuel cells, or in internal combustion engines. Hydrogen also needs a special tank system, requiring substantial modification of the vehicle.

ROAD TRANSPORT

Internal combustion engines are dominant in road transport worldwide today. Two different types of engine concept are used – gasoline engines and diesel engines. Throughout the world, passenger cars (and motorcycles) are mainly powered by gasoline engines; commercial vehicles, especially trucks and buses, are mainly powered by diesel engines.

Modern diesel engines are no longer inferior to gasoline engines in terms of comfort, cleanness and performance. Compared with gasoline engines, diesel engines have higher efficiency on the basis of their operating principle, and that means lower fuel consumption. Especially in Europe, passenger cars with diesel engines are now in widespread use; in some countries, diesel powered passenger cars account for more than 50% of new car registrations.

Passenger cars with gasoline engines run on gasoline (petrol); vehicles with diesel engines run on diesel fuel. The most important quality parameters for fuels in European road transport are specified by the current **EU Fuel Quality Directive** (2009/30/EC). It is applicable throughout Europe, and has now been adopted as a model in other regions of the world. In addition, automotive manufacturers today almost all operate globally. It is in their interest to get high-quality fuels, defined on a standardised basis, which can be used in engine concepts worldwide. The guidelines for fuel qualities, depending on the respective market requirements, are set out in the World Fuels Charta (WFCF 2006).

All in all, the fuel requirements have been tightened up significantly in the last 20 years – in Europe, and also in other countries. Modern vehicle technology has also become more and more sophisticated and sensitive.

The environmental requirements for automobiles have become so much tougher that it became necessary to reformulate fuels. The fuel qualities and exhaust gas limits were re-specified for passenger cars and commercial vehicles in the 1990s by means of the **European Auto Oil Programme**, in order to improve air quality. Today, Germany and the EU are among the toughest markets with the strictest exhaust gas limits, as per the World Fuels Charta.

The minimum requirements for gasoline are defined in the European Fuels Standard EN 228. Gasolines are light fuels with a density of 720 to 775 kg/m³. They have a very low freezing point, and thus good cold-running properties. Basically, various types of engine gasoline are distinguished, depending on their octane number (anti-knocking properties); the main gasoline type is Eurosuper with 95 octane.

The contents and properties of diesel fuel are specified in the fuel standard EN 590. Diesel fuel has a high density of 820 to 845 kg/m³. Diesel – like all middle distillates – has a high flashpoint compared with gasoline. Every diesel fuel must have a cetane number of at least 51; but for synthetic diesel (such as Gas-to-Liquids) the cetane number may be significantly higher. Diesel fuels can crystallise at low temperatures, so the standard defines special cold-flow requirements for the various climatic regions in Europe. The cold-flow properties of diesel are set accordingly in the refineries.

Alternative fuels

Substitution potentials for conventional propulsion systems and thus also energies in road transport are available most readily in passenger cars and light commercial vehicles. But at present there are no alternative propulsion systems in sight for goods transport, especially long-haul goods transport (Shell 2010). One of the main reasons for that is the low energy density of alternative energy sources (such

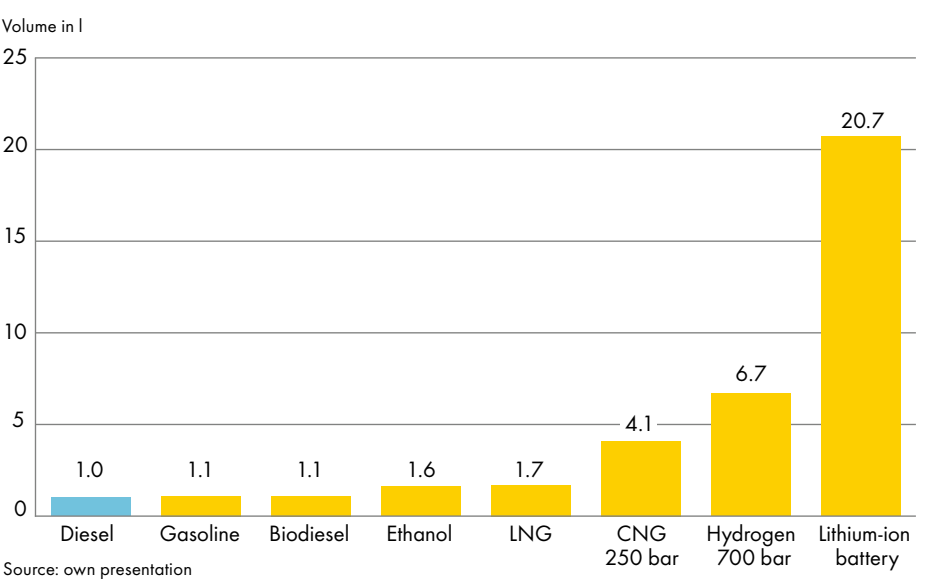
as CNG, hydrogen, or electricity from batteries).

The batteries available today would require twenty times as much space to provide the same energy as is provided by a litre of diesel fuel. Even considering that electric motors are much more efficient than combustion engines, an electric system would still mean a much bigger space requirement and much more weight, both of which reduce the payload. The only alternative energy source which gets close to gasoline and diesel is biofuels (and to some extent LNG). Vehicles with gasoline engines can alternatively or additionally be run on bioalcohol. The commonest bioalcohol available today is biogenic ethyl alcohol, that is ethanol. Compared with conventional gasoline, ethanol has a lower boiling point, a higher octane number, and lower energy density due to its greater oxygen content.

Normal gasoline engines are approved nowadays for blends of up to 5% by volume of bioethanol (E5) without further technical modification (WFCF 2009b). Gasoline fuels may therefore contain up to this amount of bioethanol without indication to the customer. Blending of bioethanol up to 10% (E10) is regulated in the German fuel draft standard E-DIN 51626-1 and has been permitted in Germany since the beginning of 2011.<sup>7)</sup>

7) In addition, bioethanol can be blended with gasoline indirectly as ether (ethanol tert-butyl ether, ETBE); but indirect blending is limited by fuel specifications (for example oxygen content).

19 VOLUME FOR STORAGE OF ENERGY CONTENT OF 1 LITRE DIESEL



Source: own presentation

Not all vehicles registered in Germany today tolerate E10, but more than 90% of them do. Despite this high level of compatibility, consumer acceptance of E10 is still limited, even if the trend is upwards.

Today’s gasoline engines are not approved for higher gasoline-alcohol blends than E10. This limitation is described as a “**blend wall**” – gasoline with more than 10% ethanol content requires special adaptation of the vehicle. Flexible Fuel Vehicles (FFVs), which can take any blend of gasoline and alcohol, are mostly available only in South America. Such vehicles can use E85, a special transport fuel defined by fuel standard DIN 51625.

Diesel engines can in principle run on biodiesel or other diesel substitutes. A distinction has to be made between straight vegetable oils, conventional biodiesel (1<sup>st</sup> generation) and synthetic diesel.

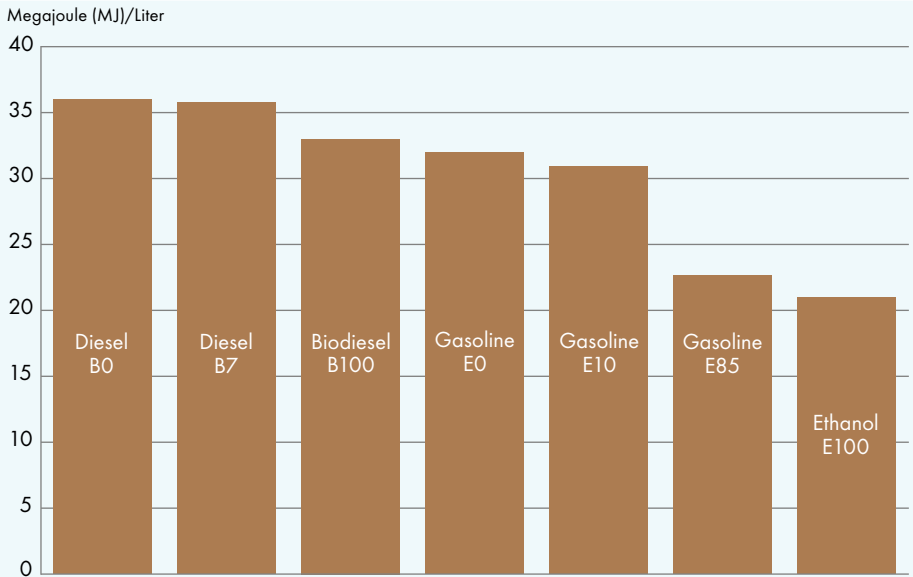
Vegetable oil is the simplest biogenic fuel, because it is not further processed. As a rule it can only be used in modified, specially equipped diesel engines, because vegetable oil has significantly different properties from diesel fuel – it has a longer ignition delay (lower cetane number), and greater viscosity especially at lower temperatures. It has good biodegradability, but poorer storage qualities.

Vegetable oil has a higher evaporation temperature, which means that it accumulates in the engine oil, and this can lead to the formation of lumps. The properties of vegetable oils differ depending on the type of plant. The quality standard DIN 51605 specifies vegetable oil fuel from rapeseed oil. Pure vegetable oil is a niche fuel today; it is not suitable for today’s modern diesel engines with their sensitive fuel injection systems.

The commonest diesel substitute today is conventional biodiesel. Biodiesel is obtained by esterification of rapeseed, soy or palm oil or of recycled grease or animal fats with methanol. The general technical term for all biodiesel fuels today is FAME (fatty acid methyl ester). Biodiesel has a higher flashpoint than diesel, and is somewhat heavier with comparable viscosity. Its freezing point varies depending on the raw material used. Biodiesel is specified by the European diesel standard



20 ENERGY CONTENT OF BIOFUELS



Source: EU (2009); own calculations

**The energy content of biofuels differs in some cases significantly from that of fossil fuels. The energy content of bioethanol is only about 66% versus gasoline, while biodiesel is about 92% versus fossil diesel (in each case on the basis of volume / litres). Whereas fuel standards are normally based on volume (percent by volume, that is percentage per litre), legislation and political programmes set targets for energy content (and in future also greenhouse gas reduction). In order to get 10% by energy in gasoline, about 15% by volume bioethanol have to be blended; to get 10% by energy of biodiesel in diesel fuel, about 11% by volume have to be blended.**

EN 14214; biodiesel made from straight soybean or palm oil does not comply with the standard because of poorer resistance to cold.

Biodiesel is better adapted to today’s engine technology than straight, untreated vegetable oils. However, biodiesel may also accumulate in the engine oil because of its higher evaporation temperature – and biodiesel can likewise harm plastic components in the engine. The sophisticated propulsion and exhaust gas cleaning systems set a blend limit of 7% by volume for biodiesel (B7) in Europe. B7 is tolerated both by older vehicles and new vehicles, and requires no special labelling, and no provision of a “protection grade” for older vehicles.

Many modern diesel passenger cars do not tolerate higher contents of FAME. The main reason for that is their exhaust gas treatment. Trucks conforming to older emission categories were considerably better able to tolerate biodiesel; some truck fleets even used up to 100% FAME. Euro VI trucks are just coming into the market now, and currently have approval only for B7. Finally, from Euro VI onwards, compliance with the emission limits has to be demonstrated again for every fuel type allowed by the vehicle manufacturer. The problems occurring with use of biodiesel are engine oil dilution with biodiesel, lower storage capability, and catalyst poisoning (metals) in biodiesel (WFCC 2009a); that can normally be

remedied by increased maintenance work and quality inspections. Higher quality biodiesel compared with FAME can be obtained with synthetic diesels made with Fischer-Tropsch processes (FT diesel) and hydrotreated vegetable oil (HVO). These fuels, and GTL fuel manufactured from natural gas, are covered by the CEN Working Agreement (CWA 15940) as **paraffinic diesel**.<sup>8)</sup>

These diesel types have very favourable fuel characteristics, even exceeding those of conventional diesel fuel. Synthetic biodiesel / HVO fuels have lower density and considerably higher cetane number than conventional diesel or FAME. They contain no oxygen, so their energy content is higher than for FAME fuels. Synthetic biodiesel and HVO are also described as “drop-in fuels”, because they can be used almost in any percentage with conventional fuels, not only in road transport. However, HVO is currently only available in limited quantities commercially, and synthetic diesel from biomass is not commercially available.

AVIATION

Aircraft used in civil aviation are almost exclusively powered by jet engines or turboprops (where the turbine engine drives a propeller). Light aircraft for amateur and sports use are normally

powered by reciprocating engines, mostly gasoline engines; but engines operating on the diesel cycle are also increasingly used. Jet and turboprop engines use jet fuel as their energy source (also known as aviation fuel or kerosene). The fuel has to meet high quality standards because of the tough requirements of the engines. It is regulated by comprehensive, internationally standardised quality specifications. The leading standardisation organisations for jet fuels are the Ministry of Defence (MOD, UK) and ASTM International (formerly American Society for Testing and Materials).

International civil aviation uses almost exclusively the **Jet A1 or Jet A specification**. Jet A1 is defined by the standards DEF STAN 91-91 and ASTM D 1655. Jet A1 has a density of 775 to 840 kg/m³ – somewhat lighter than diesel. Its boiling point characteristic is very flat (cf. Fig. 18); in other words, Jet A1 is a very narrow fraction of crude oil distillation, optimised for combustion in jet engines.

Other essentials for jet fuels are favourable cold-flow properties, because commercial aircraft normally fly in the upper region of the troposphere at outside temperatures of about -50°C. Thus Jet A1 has a freezing point of at least -47°C or lower, and a flashpoint of at least +38°C or higher.

Apart from jet fuel, **aviation gasoline (avgas)** can also be used in aircraft.

Avgas is a special gasoline for aircraft with internal combustion engines. Some of these aircraft are also approved for high-octane gasoline. However, it is not permitted to obtain this from filling stations because of the compulsory blending of bioethanol, and also because of stricter safety regulations.

Alternative aviation fuels

At present there are no alternatives in sight to liquid hydrocarbons as propulsion fuels for aviation. That is why the aviation industry is increasingly trying to make use of alternative liquid fuels. Possible candidates are synthetic kerosene fractions from the Fischer-Tropsch process (e.g. Gas-to-Liquids from natural gas) or hydro-treated vegetable oils (HEFA / BioJet).

The special interest of aviation is directed at biogenic aviation turbine fuels; sustainable biofuels can help to reduce the greenhouse gas emissions from aviation. But alternative jet fuels have to meet the strict quality and safety requirements of conventional jet fuels – and conventional 1<sup>st</sup> generation biofuels cannot do that (ATAG 2009). Blends of up to 50% of approved alternative fuels are now permitted (HEFA/BioJet; FT ), as they differ very little in their chemical composition from conventional jet fuel (IATA 2011).

SHIPPING

Ships are mainly used for carrying freight; they play only a minor role in passenger transport. Ships have very good transportation performance in comparison with other modes of transport. They can carry large quantities of goods over long distances with low specific energy consumption. Shipping is by far the most energy efficient mode of transport (BSH 2011).

The dominant form of propulsion in shipping today is diesel engines, normally using liquid fuels, though individual series can also use gas as their fuel. They have to meet high requirements for operating reliability and safety, because ships are designed for continuous operation and long life. Shipping is basically divided into marine shipping (on the seas) and inland navigation (on inland waterways such as rivers and lakes). Different fuels are used for the different categories, because the requirements differ between marine shipping and inland navigation.

Marine shipping

More than 80% of the goods traded in the world today are carried by sea. The global merchant fleet comprises 103,000 ships (UNCTAD 2011). Virtually all commercial ships are powered by diesel engines today. Big merchant ships mostly use slow-running two-stroke engines with an output range from about 25,000 to 80,000 kW. Their efficiency is up to 50%. There are also marine engines (smaller) powered solely or additionally by liquefied natural gas (LNG) – these are known as Dual Fuel Engines (Ecofys 2012).

Marine fuels are standardised by the International Maritime Organization (IMO), and the main quality parameters for fuels used in shipping are specified in ISO standard 8217. It distinguishes in particular between heavy fuel oils (higher viscosity), and lighter marine diesel. Heavy fuel oils are mainly produced from the residues of crude oil processing. They have high density, that is about 1,000 kg/m³, and high viscosity. Marine diesel fuels are blends of various middle distillates and lighter; they have characteristics which are typical of diesel fuel. The large diesel engines in particular use mainly heavy fuel oils for their propulsion.

The rising quality requirements for marine fuels have led IMO to reduce significantly the upper limits for sulphur content in heavy fuel oil. By 2025 at the latest, heavy fuel oils have to keep to a maximum limit of 0.5% sulphur; the maximum today is 3.5%. Special emission control areas have been designated (SOx Emission Control Areas = SECA) where the maximum sulphur content is limited to 0.1% from 2015 onwards.<sup>9)</sup> The Baltic Sea has been designated as a SECA since 2006, and the North Sea since 2007.

Many marine ships are designed to run on two types of fuel, e.g. heavy fuel oil and marine diesel, so that they can use clean marine fuels in port areas for example. New ships can easily be modified for operation purely on distillates (ISL 2010).

Heavy fuel oils are relatively low-cost fuels. Shipping has optimised machinery for

<sup>9)</sup> Vgl. International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), Annex VI: Regulations for the Prevention of Pollution from Ships.

use of heavy fuel oil in the course of the decades. And merchant ships also have long service life – their average age at the present time is 22.5 years, and many of them are decommissioned only after 30 years of service (UNCTAD 2011). Engines are often used for a period of 20 years or longer. That means alternative propulsion systems and fuels play practically no part at all in the majority of shipping. They are used only for special purposes at present (for example in LNG tankers). Nevertheless, the use of biogenic fuels would also be possible in marine shipping.

Biofuels could help to reduce local emissions (sulphur dioxide emissions) and greenhouse gas emissions from shipping (Ecofys 2012). But biofuels in marine applications pose a number of technical challenges – marine ships normally keep their fuels in storage for longer periods; so storage stability has to be ensured. The cold-flow properties of marine fuels containing biogenic components change; material compatibility has to be checked. In addition, there is very little practical experience available on the use of biofuels in marine shipping (ISO 2012). That is why the blending of biocomponents is not currently envisaged in ISO 8217. As middle distillates often contain biocomponents today, they are subject to additional requirements for oxidation stability in the Marine Fuel Specification ISO 8217 (2012).

Marine shipping is still in a phase of exploration when it comes to the use of biofuels. The introduction of alternative fuels would firstly require creation of an appropriate ISO standard for marine fuels based on biofuels. Heavy fuel oils are also very low-cost compared with other fuels. As a rule they are the only petroleum product which is cheaper than crude oil. Biofuels, on the other hand, are considerably more expensive than crude oil, and also more expensive than fossil fuels. The interest of shipping in biogenic marine fuels therefore continues to be very low at present.

Inland navigation

Inland navigation accounts for about 10% of goods transportation in Germany (measured in tonne-kilometres), with its network of some 7,300 km of inland waterways. The Rhine is by far the most

<sup>8)</sup> CWA 15940 of 2009 remains valid until implementation of the technical specification CE N/TS 15940:2012 Paraffinic diesel fuel from synthesis or hydrogenation processes – requirements and test methods.

important waterway in Germany and Europe; it accounts for 80% of the whole or part of all goods transport operations by inland waterways (Winter 2012). Most inland navigation vessels, especially for freight carriage, are powered by diesel or marine engines. Unlike marine shipping, these are mostly medium to fast running diesel engines. The output range starts at about 500 kW (sometimes less) and goes up to about 2,500 kW, that is considerably above the range for road trucks (JOWA 2007; IVR 2011).

The fuel used in inland navigation is marine diesel. The requirements for this fuel, as for road transport, are regulated by the 10<sup>th</sup> Federal Emissions Control Ordinance (10. Bundesimmissionsschutzverordnung). In the past, inland navigation vessels could use fuels of heating oil quality (corresponding to national standard DIN 51603-1). Since 01/01/2011 **only sulphur-free fuel** may be used, as stipulated in EU Directive 2009/30/EC.

By contrast with road transport, no biofuel component is specified or intended for inland navigation, either in the Biofuel Quota Act or in the fuel standards. Inland navigation is a small market, estimated most recently at 250,000 tonnes (DIW 2011), which sources much of its fuel in the Netherlands. A separate fuel, free of biocomponents, is therefore not always available. In addition, the German Inland Waterways Association recommends that its members use only conventional diesel as far as possible (to EN 590). Even if so far marine diesel is available without biocomponents, it has to be assumed that percentages of blended biogenic components are present in fuels for inland navigation, as for road transport (BDB 2010+2011).

Biofuel blends of up to 5% by volume are not considered problematic today. But depending on their type, inland navigation vessels may be more than 30 years old, or even 50 years old. There is practically no reliable information available on the use of higher biofuel percentages in the engines of such older vessels. And technical restrictions for the use of biofuels with the new exhaust gas limit category IIIb for ship engines are likely to be stricter for marine engines (similar to trucks and Euro VI). Higher biogenic percentages

require more equipment for operation of inland waterways vessels, for example for monitoring and maintenance of fuel systems, and for storage.

#### RAIL TRANSPORT

In comparison between the modes of transport, rail transport is the most widely electrified mode. Today there are only about 40% of the German rail network which are not electrified. About 90% of goods and passenger transport by rail is provided by electric locomotives and railcars (Kettner 2011).

At the same time, it is likely that, for economic reasons, there will still be non-electrified sections in the network in the future. Diesel locomotives and railcars will still be used in regional transport operation on subsidiary lines, and also in shunting.

Diesel-mechanical, diesel-hydraulic, and diesel-electric propulsion systems have been in use on the railways for a long time now. The diesel engines have an output range of about 300 kW for smaller shunting locomotives to 3,000 kW for heavy-duty diesel locomotives. Diesel engines for railcars are mostly much more powerful than truck engines; they are also subject to special exhaust gas regulations for non-road vehicles (EU Nonroad Directive 97/68/EC). The perspectives for diesel traction point towards further hybridisation, and partial electrification of propulsion systems. However, diesel locomotives have quite long service life, about 15 to 20 years or even 30 years after retrofitting. In the medium term, it is likely that there will be a slow decline, but still a relevant percentage of diesel traction in railway operations.

The fuels used in diesel operation are largely the same as commercially available diesel fuels (including bioblends). That means that a part of the distribution structure available for diesel fuel for road transport can also be used for rail. About 15% of the final energy consumption of rail transport today is diesel fuel, and about 85% electricity. Annual consumption of diesel fuel is around 300,000 tonnes at present (2010); that corresponds to about 1% of total diesel fuel consumption in Germany (DIW 2011). Thus rail transport is a very small market segment.





# 6 BIOFUELS IN SCENARIOS – THE WAY FORWARD

The previous sections have shown that biofuels have so far made only a small contribution to energy supply for transport in Germany, the EU and worldwide. But they have great potential in the medium to long term – demands for sustainability and advanced production methods could give biofuels a substantial role in future fuel supply, on condition that they are compatible with the respective modes of transport, that their feedstock supplies are sustainable, and that production costs are significantly reduced.

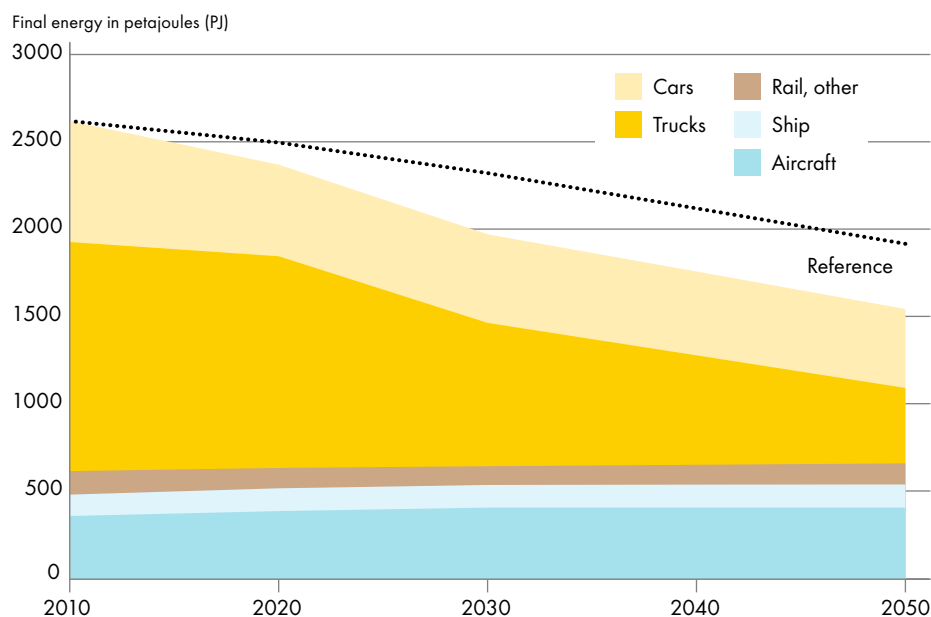
It remains to be seen how far these potentials can be realised at what times in Germany, the EU and worldwide, if the ambitious goals of climate change mitigation and conservation of resources are taken seriously. Scenarios are used to analyse this. Scenarios are not forecasts, but rather they describe possible futures, which could become reality under certain conditions. Thus technology scenarios project future developments on the basis of technological potentials (e.g. Shell 2009-2011 for transport and energy); reference scenarios extrapolate trends from the recent past. Target scenarios show possible ways to achieve specified goals. The objective here is to find out what would be needed to achieve the global 2°C climate change mitigation goal by 2050 and the interim goals for 2020 and 2030, and to determine what role biofuels could play in that.

## GERMANY

Future mobility has been addressed by a large number of studies in recent years, as a component of Germany's comprehensive "Energiewende" (Energy Transition). The most important ones are "Modell Deutschland" (Prognos, ÖKO 2009), the scenarios for the Federal Government's energy concept (Prognos, EWI, GWS 2010), the "Lead Study" of the Environment Ministry (Nitsch et al. 2012), and "Renewability" (ÖKO, DLR, ISI 2012).

The 2°C target scenarios for Germany show that up to 2020 biofuels would have to play the key role in meeting the RED goal of 10% renewables in road transport (DBFZ 2010). The scope would be greater for the period up to 2030 – depending on scenario, biofuels could contribute 250-500 PJ excluding international air traffic, and thus cover between 15 and 35% of energy demand in transport, mainly for passenger cars and commercial vehicles (dena 2011). Towards 2050, including international aviation and shipping, the scenarios present a different picture:

21 FINAL ENERGY CONSUMPTION BY TRANSPORT IN 2°C SCENARIO FOR GERMANY 2050



Source: Prognos, EWI, GWS (2010); ÖKO, DLR, ISI (2012); Nitsch u.a. (2012); ÖKO (2011); own calculations

■ Electric and hydrogen propulsion could increase substantially, especially for passenger cars; rail travel could gain shares of passenger and freight transport, and largely operate on renewable electricity, similarly local public transport systems with trams, metros and rapid transit trains.

■ Up to 2050 the contribution of renewable electricity or hydrogen generated from it would still be small for freight transport (trucks, ships) and for aviation (UBA 2010). Replacement of fossil fuels in these applications would mostly have to be by 2<sup>nd</sup> generation biofuels – for trucks nearly 100%, and for aircraft and ships up to 50%.

■ In the passenger car sector, electric and H<sub>2</sub> propulsion could provide over 40% of the energy demand (given that increased efficiency will have significantly reduced total energy demand); subject to that, more than half of the remaining demand would continue to be provided by biofuels.

Biofuels together would provide more than two thirds of the considerably reduced energy demand for transportation, followed by renewable electricity and hydrogen. Fossil fuels would then only be used in international aviation and shipping, accounting for less than 20% of total energy consumption in transport. It would no doubt also be possible to use an increased proportion of hydrogen or liquid fuels produced from renewable electricity, but from today's perspective that would be more expensive than sustainably produced, advanced biofuels. Partial electrification of heavy goods vehicles could also reduce the consumption of biofuels (SRU 2012).

Thus the scenario outlined here provides some room for manoeuvre – it is intended to show the order of magnitude of the contribution that biofuels could make under certain conditions.

**Germany's sustainable bioenergy potential is sufficient to cover the remaining demand for liquid transport fuels by means of biofuels up to 2050. Power and heating would thereby have to make use of other renewable energy sources, not bioenergy. But the key factor for a transition of transport to a more sustainable mobility is a 40-50% reduction in the energy needed for transport by 2050 compared with today.**

## EUROPEAN UNION

In 2011, the EU presented a number of "roadmaps" for future energy, climate and transport policy up to 2050. These roadmaps are in part based on quantified scenarios, and also on qualitative assessments of possible developments. As yet there is no integrated target scenario. Despite their differences with respect to the role of nuclear, renewables and energy efficiency, all these roadmaps reach more or less the same conclusions on what is needed in transport by 2050 in order to achieve the goals of "climate and resource protection" (EC 2011a+c):

- Passenger cars and commercial vehicles would be significantly more efficient and lower-emission, and rail transport, especially electrified rail transport, would be further expanded;
- Electric vehicles could account for over 65% of passenger cars, and biofuels would account for 15% of passenger car fuel consumption;
- For commercial vehicles and for shipping and aviation, biofuels would play a fast growing role, with more than 40% of fuel consumption;
- 1<sup>st</sup> generation biofuels would largely be replaced by more advanced processes from 2030 onwards, and imports would be less than 20% of demand, mainly comprising sugarcane based ethanol.

The development of the EU roadmaps for achievement of the global 2°C climate goal is in line with the long-term scenarios for Germany.

## GLOBAL PERSPECTIVES

There are more than one billion vehicles in the world today – about 750 million passenger cars and over 300 million commercial vehicles (VDA 2011). By 2050 it could be 2 billion passenger cars, because car ownership and mobility of people and freight is increasing in all emerging countries. The result of this trend would be to double the performance in passenger car transport by 2050 and to triple the performance in road freight transport (IEA 2012a).

International air traffic has grown about 5% per annum since 1980, and will continue to grow even if at a reduced pace in the coming decades, especially in Asia. A number of studies by the IEA, such as World Energy



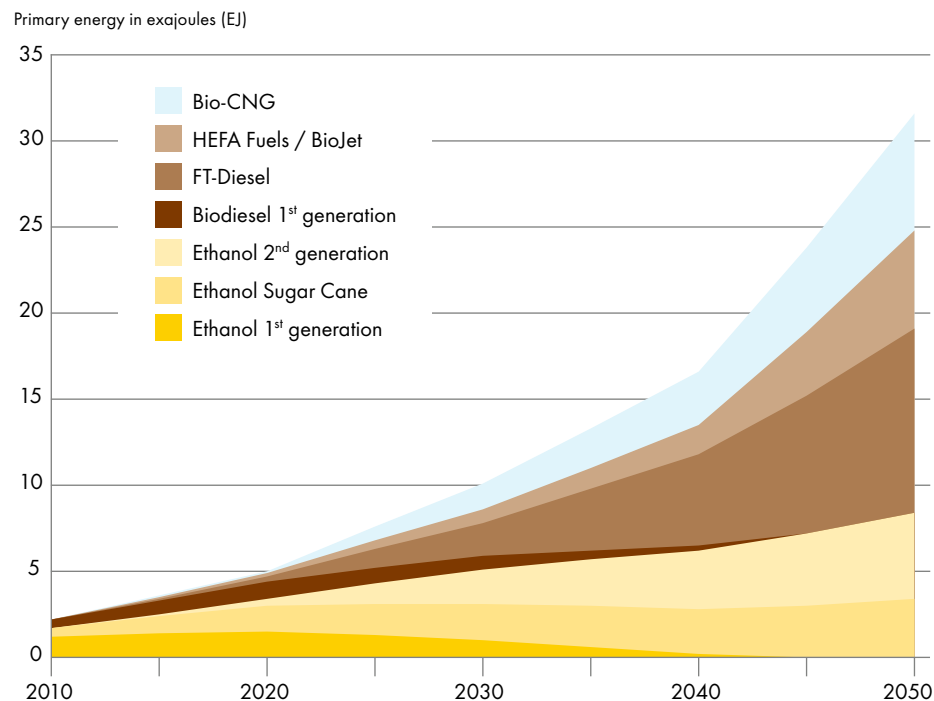
Outlook, Biofuels Roadmap 2050 and Technology Perspectives 2050, have now looked at the future from a different angle – as in Germany and the EU, it asked what future global development of transport would be assuming that the 2°C climate goal is met (IEA 2011a-b + 2012a).

The results of these studies give quite a consistent picture:

The demand for biofuels could increase tenfold by 2050 versus 2010. 1<sup>st</sup> generation biofuels (biodiesel and ethanol) would increasingly be replaced by 2<sup>nd</sup> generation biofuels from 2030 onwards. The main growth area for biofuels from that time onwards would be in commercial vehicles, shipping and air transport; in parallel to that, the use of electric vehicles would increase rapidly, and would partially replace biofuels in passenger cars.

The global biofuels demand up to 2050 determined by the IEA at some 30 EJ would utilise between 25% and 50% of the globally available sustainable bioenergy potential. Thus bioenergy would also be available for power and heating, and could replace fossil fuels there.

22 GLOBAL BIOFUEL DEMAND UP TO 2050



**On a global scale, too, biofuels could in future be a major option, provided that they are produced sustainably – and the IEA also expects a transition from 1<sup>st</sup> generation to advanced biofuels from 2030 onwards. As in the target scenarios for Germany and the EU, the key assumptions are a huge increase in efficiency in all modes of transport, successful introduction of electric propulsion in passenger cars, and a major expansion of the other renewables in the power sector.**

#### DO TARGET SCENARIOS TELL THE TRUTH?

The previous sections of this chapter briefly presented the results of ambitious target scenarios which assume fulfilment of the climate and resource protection targets. A comparison with reference scenarios which do not fulfil the targets for Germany, the EU and worldwide shows clearly the very significant challenges of implementing the target scenarios. It is by no means certain from today's viewpoint that their assumptions will be fulfilled for the period up to 2030 and beyond. So they do not represent a "truth".

The conclusion to be drawn, despite all the uncertainties, is that there remains a reasonable order of magnitude for which biofuels are still required even if successful growth is achieved for other renewables, for electric propulsion, and for a combination of fuel cells with hydrogen. If that is not achieved, and if the very ambitious goals for massive efficiency improvements in transport and heating are not achieved in parallel, the scenarios would require even more biofuels.

Conversely, for the assumptions outlined here on demand development, oil prices, technical progress and economic conditions, biofuels (apart from sugarcane-based ethanol) will enter the market only if they get significant subsidies. That is because the target scenarios contain an implicit mechanism which will moderate future rise in oil price – instead of a continued rise in oil demand in the reference scenarios, with corresponding price impact after 2020 ("peak oil"), oil demand will be reduced by the expected major efficiency improvements and the introduction of renewables, including biofuels, thus keeping oil price rises relatively moderate.

In the reference scenarios without high efficiency and renewables, oil prices are likely to rise, which in turn makes biofuels more attractive – but less the advanced (and more expensive) 2<sup>nd</sup> generation, more the conventional biofuels based on oil, starch and sugar crops. As agricultural product prices also rise with higher oil prices, and that increases the cost of conventional biofuels, there will hardly be a massive increase in biofuel use without subsidies, apart from individual exceptions (sugarcane-based ethanol). That cannot be seen as an energy transition, though.

## 7 WHAT NEXT? RECOMMENDATIONS FOR BIOFUELS

The scenarios for an energy transition in the transport sector and for compliance with the global 2°C climate change mitigation goal show that biofuels may well have a great future – in Germany, the EU and worldwide. But that is dependent on successfully meeting four key challenges for biofuels:

- **Decoupling** their raw material base from food and feed (essential for food security);
- Real **net reduction** of greenhouse gases versus fossil fuels (ILUC);
- Efficiency in use of land and resources (**cascading use** of material);
- **Cost efficiency** (vs. competing options, such as electric vehicles, renewable liquid fuels).

The following section discusses what is needed to achieve these conditions, and indicates the timescale.

#### FEEDSTOCKS AND THE FUTURE – BIOFUELS IN THE ENERGY TRANSITION

Bioenergy supplies about 90% of the alternative energies for heating and about 30% for power generation in Germany (BMU 2012). That makes bioenergy today and in the coming years an important component in the energy transition for heating and power.

It is only in the medium to long-term that bioenergy will take on real importance as a transport fuel, and only under certain conditions.

As long as fossil fuels, especially coal, are still used for power generation, and also for heating, the best use of bioenergy is not in transport, but in the replacement of coal in the power sector and in combined heat and power; this also applies at the international level (CE, OEKO 2010).

Bioenergy, especially biogas and biomethane, can take on important control and storage functions in the electricity system and help to increase the use of combined heat and power in industry (UBA 2010; Nitsch et al. 2012).

In the transport sector, the energy transition will depend on changes not only within the transport sector itself, but also in the whole energy system – the role of bioenergy will have to shift between the sectors.

To start with, much more efficient vehicles will be needed in the transport sector, which requires improvements in their technology. That will mainly be done by significant improvement in conventional propulsion engineering, and increasing electrification of the passenger car fleet (hybrid and electric vehicles), which in turn will depend on low-cost batteries becoming available.

In the longer term, liquid fuels will have to be focused on the transport sectors where there is little or no alternative to the internal combustion engine – that is heavy goods vehicles in road transport, commercial aircraft, and possibly also shipping (if LNG does not become established in the long term).

Continued dynamic growth in solar and especially wind energy would then make it possible to gradually shift energy from biomass out of power generating and into the transport sector.

The greatest bioenergy reserves are in heat production; that is where about 60% of total bioenergy is used today (BMU 2012). Rapid improvement in the energy efficiency of buildings and in solar and geothermal heating could also "free up" bioenergy from 2030 onwards; but the trend towards solid biomass in household heating would also have to be reversed.

The biomass crops used for biofuels today would change in two directions on this basis:

Priority would go to using biomass for making materials and in biorefineries, thus improving their competitiveness for biomass against bioenergy uses. The "energy value" of the biogenic products would be kept up to the end of their useful life. As wastes together with by-products from cascading use and residues from nature conservation land they would then be used as feedstock for 2<sup>nd</sup> generation biofuels.

Instead of rapeseed, maize and other annual food and feed crops, wood produced by short rotation forestry and from perennial grasses would be grown on unused arable and marginal land; that would involve enormous changeover work for agriculture.

In the course of the energy transition, heat and power generation would increasingly be provided by other renewables from 2030 onwards, so biomass could then be used for biofuels. But only if the corresponding 2<sup>nd</sup> generation technologies are available by then. Biofuels could then be the winner in the long term – initially in passenger cars, buses and trucks, and from 2030 onwards also in aviation, and finally also in shipping.

#### MAKING THE GENERATION CHANGE

This "bio-transition" in the transport sector would mean that 1<sup>st</sup> generation fuels with raw materials from Germany and Europe would be phased out – their climate and resource efficiency is unfavourable, and their feedstock base is increasingly in competition with "more valuable" uses such as food and material use.

But their successors, 2<sup>nd</sup> generation biofuels, are not yet available in the market. That is mainly because the tax conces-

sions and incentives from the European regulations (RED, FQD) are not sufficient to justify major investments in pilot plants and first (pre-)commercial plants, and those are the necessary intermediate steps for market launch. The RED provides for double counting of biofuels from waste materials and residuals, cellulose-containing non-food material and lignocellulosic material; but the FQD gives these biofuels no major support. The result is too much uncertainty about what earnings can be achieved for what quantities in the future.

The reasoning of the EU is that the binding 10% goal for renewables in the fuel market by 2020 is reasonable, **if biofuels are sustainably produced and the 2<sup>nd</sup> generation is then commercially available** (EU 2009a).

A “wait and see” policy will not solve the technical problems which still exist in the production of advanced biofuels – development is not continuing in the current market situation. Considerable investments are needed, and they will be made only if the players can calculate the expected revenues and have some degree of certainty that they can sell the products.

A combination of **three measures** is proposed in order to achieve this for advanced biofuels:

**Firstly**, RED and FQD have to require the “ecological truth” of biofuels, i.e. take account of indirect land use change (ILUC) in counting the necessary minimum GHG reduction for the 10% target for RED, and GHG reduction of all fuels for FQD. That can still be prepared in 2013, implemented by 2014, and take effect by 2017/18 at the latest, considering the transitional periods. Then additional 1<sup>st</sup> generation biofuels produced in Germany and Europe would no longer count towards the quota and there would be “room” for the 2<sup>nd</sup> generation.

**Secondly**, the sustainability criteria of the RED must be extended to include solid and gaseous bioenergy, to ensure a level playing field for the use of biogenic waste materials and residuals – co-firing (and inclusion in emissions trading) and the production of 2<sup>nd</sup> generation fuels (for RED and FQD) would then have to meet the same requirements.

**Thirdly**, a European market introduction programme for 2<sup>nd</sup> generation biofuels must be set up for a ten-year period in order to ensure security of investments; that would create the necessary conditions for production of 2<sup>nd</sup> generation biogenic diesel and bioethanol from lignocellulose, and provide sufficient incentive for it.

In addition, specific incentives for biogenic middle distillate substitutes would also be helpful, as the structure of the fuel mix in Germany and Europe moves more towards the middle distillates, i.e. diesel, marine diesel and jet fuel, whereas the European refineries are already producing surpluses of gasoline.

#### FROM RIO WITH LOVE?

Biofuels can also be imported and counted for the RED target for 2020, now that sustainability certification of biofuels has started. Until now only small quantities could be imported, due to customs duties, unfavourable foreign exchange rates, and higher prices obtained for other uses.

In the mid-term future, Argentina and Brazil in particular could also supply biofuels due to the land use regulations in force there (and the availability of suitable raw materials), meeting the sustainability requirements including the ILUC conditions. Other states, in Eastern Europe and in countries such as Indonesia and Mozambique, also have corresponding potentials of underused or degraded land, but would have to create the legal basis for compliance with the stricter sustainability requirements and for proof of compliance.

For future imports to Europe and Germany, it is essential to demand appropriate compliance with the regulations already contained in the RED and social issues such as land rights and food supply security, by conclusion of bilateral or multilateral agreements.

In addition, the approaches developed by FAO (2012a) and UNEP (IFEU, CI, ÖKO 2012) to determine food security on the project level would have to be demonstrated in practice for imported biofuels, and applied also in grant making for biofuel investments by bilateral and multilateral development banks. Such

investments should be linked with parallel modernisation funds for agriculture in the respective countries, in order to improve food and feed production; that is already a legal requirement in South Africa.

#### STRATEGIC INVESTMENTS

Substantial investments are needed for the “bio-transition” outlined here, to change the sourcing of fuel supplies towards sustainable options as part of the energy transition; the same applies to the energy transition in general – both for production of 2<sup>nd</sup> generation biofuels and for growing the necessary crops.

Major investments are being made in the energy sector, upstream and downstream. Advanced biofuels require investments in both of these areas, i.e. for a sustainable feedstock base and for modern conversion processes.

Investments have already been made by oil companies in the world’s leading biofuel markets (USA and Brazil), in companies which aim to achieve improved sugarcane cultivation and more efficient production of ethanol.

Comparable steps would be desirable for the world’s largest (bio)diesel market, that is Europe, to secure production of 2<sup>nd</sup> generation biodiesel; the framework conditions in Europe would need to be compared with and if necessary adapted to those of the leading ethanol markets.

Concepts have already been developed in cooperation with European and American NGOs to identify and use land without competing with food and feed production, and in a socially acceptable manner, to grow feedstocks for biofuels (CI 2011; Ecofys 2012).

These activities need to be stepped up; degraded land is available, but substantial investment will be needed to cultivate it with perennial plants and to establish the necessary infrastructure to market the biomass from it.

Successful implementation of these activities will then permit longer-term rehabilitation of the land for food crop production. It is therefore important not to buy the land – medium-term renting is sufficient.

#### ACCEPTANCE AND TRANSPARENCY

The petroleum industry, biofuel producers, the automotive industry, and also environmental policy makers have found to their distress that consumers react sensitively and critically to the introduction of new fuel grades, especially if the technical compatibility of fuel and vehicle is not sufficiently clarified, and there are still major issues related to the sustainability of biofuels.

At present, the B7 and E10 fuels now available in the market will be sufficient to achieve the goal of the RED and the corresponding national implementation of it until 2020, because double counting toward the quota is permitted for waste materials and residuals, and increasing electric propulsion (passenger cars and rail transport) is also eligible for multiple counting. However, the market acceptance of E10 needs to be substantially increased. It is more difficult to achieve the FQD target of saving 6% greenhouse gas emissions from all fuels used; so far, double counting has not been permitted there, and target achievement is measured exclusively by reduction in greenhouse gas emissions.

In the medium term, suitably adapted vehicle engineering, permitting higher proportions of biofuels, could help to achieve seamless integration of higher percentages of biofuel – as already done for E5, B5 and B7. Drop-in fuels will be needed in the long term, to ensure acceptance, with a view to further increases in biofuel quantities in the target scenarios after 2020.

In response to the critical opinions and concerns of environmental and consumer groups, and to regain lost trust, the sustainability certification system now established needs to be constantly revised and if necessary modified.

Another confidence building measure in addition to legal certification could be disclosure of the origin of all biofuels (by main feedstocks and countries). The evaluation reports of the German Federal Office of Food Security and Agriculture (BLE) are a first approach, but would need further development and refinement (BLE 2012). Biofuel producers and fuel suppliers could also increase the scope and detail of the sustainability reports which some of them already issue.

#### COURSE CORRECTION – YES, PLEASE!

**However robust the analysis on which the present conclusions and recommendations were based, further critical examination of their implementation is essential. The most important examination requirements and milestones are as follows:**

##### **Biomass base / availability:**

Any biofuel strategy is dependent on the availability of sufficient biomass for energy and transport use. From today’s viewpoint, robust potential is available. But it needs to be used optimally, by easing the competition for use (for example by means of cascade systems, and the use of residual materials). The existing estimates of biomass / bioenergy potentials should be reviewed about every five years.

##### **Sustainability / certification:**

The sustainability of biofuels is to be ensured by a binding criteria-based certification approach. The European certification approach is currently unique in its aims and extent. Particularly prominent aspects are the high level of greenhouse gas saving, and the protection of biodiversity. The specific details of sustainability rules can often only be determined by iteration, so the system needs to be reviewed and optimised at least once every two years, especially with respect to other relevant subjects such as water, soil and social aspects. To ensure that certification really does reflect sustainability, indirect land use changes must be effectively taken into account in the greenhouse gas calculation of the RED for biofuels, and the use of sustainability criteria must be widened to include all bioenergy sources.

##### **2<sup>nd</sup> generation biofuels:**

In the longer term, between 2020 and 2030, 1<sup>st</sup> generation biofuels must be replaced by 2<sup>nd</sup> generation biofuels. Time is needed for the mobilisation of investments for 2<sup>nd</sup> generation fuels, for biorefineries, and for sustainable cultivation on degraded and unused agricultural land by perennial cultivation systems. A period of more than five years is normally needed from planning to effective operation of large production facilities. The conditions have to be created in the second half of the present decade at the latest, in order to ensure the availability of larger market-relevant quantities of 2<sup>nd</sup> generation fuels from 2020 onwards.

##### **Sector focus:**

The use of bioenergy is spread across all sectors, currently with a main emphasis on power generating. In order to have enough biomass available for the relevant modes of transport (commercial vehicles, aircraft, ships), bioenergy use needs to be focused on the transport sector in the period 2020 to 2030.

##### **Biofuel goals:**

Currently, biofuels in compliance with the RED and FQD are meant to contribute to the 10% renewable energies in transport target, with minimum savings of 6% of greenhouse gases. With a view to the further development of the EU biofuels strategy post-2020, both of these goals have to be reviewed again towards the end of this decade, rather than just in 2021, and if necessary they have to be adapted again.

##### **Technical alternatives:**

The goals envisaged for biofuels can be fulfilled only if they are available in sufficient quantities and the necessary alternative propulsion systems and fuels are developed and introduced in the market; the contributions in these areas have to be assessed by analogy to the biopotentials and goals (requiring new assessment in each case).

Ultimately, the (bio-)energy transition in the transport sector will require regular and systematic “adjustments” by all parties involved. Course corrections are a part of the process. If major points on the above checklist are not or cannot be implemented, that would require change in the course of the whole of biofuel policy.

The long-term goal is “sustainable 2<sup>nd</sup> generation biofuels” for all modes of transport which are dependent on liquid fuels. It can be achieved.



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# GLOSSARY

1G	1 <sup>st</sup> generation biofuels
2G	2 <sup>nd</sup> generation biofuels
ASTM	American Society for Testing and Materials
B7	Diesel fuel with up to 7% by volume biodiesel blend
B100	Straight biodiesel
CO <sub>2</sub>	Carbon dioxide
CEN	Comité Européen de Normalisation (European Committee for Standardisation)
CNG	Compressed Natural Gas
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
DME	Dimethyl Ether
E10	Gasoline with up to 10% by volume ethanol blend
E85	Gasoline with 70 to 86% by volume ethanol blend
EC	European Commission
EEA	European Environment Agency
ETBE	Ethyl Tert-Butyl Ether
EtOH	Ethanol
FAME	Fatty Acid Methyl Ester
FAO	Food and Agriculture Organization of the UN
FQD	European Fuel Quality Directive
FSC	Forest Stewardship Council
FT	Fischer-Tropsch (process for manufacture of synthetic fuels)
GBEP	Global Bioenergy Partnership
GEF	Global Environmental Facility
GHG	Greenhouse gases
GTL	Gas-To-Liquids
HEFA	Hydrogenated Esters and Fatty Acids (also known as BioJet)
HVO	Hydrotreated Vegetable Oils
IEA	International Energy Agency
ILUC	Indirect Land Use Change
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ISCC	International Sustainability and Carbon Certification
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
OECD	Organisation for Economic Co-operation and Development
RED	European Renewable Energy Directive
RFS	Renewable Fuel Standard (USA)
RME	Rapeseed Methyl Ester
RSB	Roundtable for Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTRS	Roundtable for Responsible Soy
TREMOT	Transport Emissions Model
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme

**Joule (J) and kilowatt hour (kWh):**

- 1 exajoule (EJ) corresponds to 1,000 PJ
- 1 petajoule (PJ) corresponds to 1,000 TJ
- 1 terajoule (TJ) corresponds to 1,000 GJ
- 1 gigajoule (GJ) corresponds to 1,000 MJ
- 1 megajoule (MJ) corresponds to 1,000 kilojoules (kJ)
- 3.6 MJ corresponds to 1 kilowatt hour (kWh)

**Energy content and fuels:**

Diesel	43 MJ/kg	36 MJ/litre
Biodiesel	37 MJ/kg	33 MJ/litre
Vegetable oil	37 MJ/kg	34 MJ/litre
HVO/FT diesel	44 MJ/kg	34 MJ/litre
Gasoline	43 MJ/kg	32 MJ/litre
Bioethanol	27 MJ/kg	21 MJ/litre





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