Future Biomass-based Transport Fuels

Summary and Conclusions from the IEA Bioenergy ExCo67 Workshop

This publication provides the summary and conclusions from the workshop 'Future Biomass-based Transport Fuels' held in conjunction with the meeting of the Executive Committee of IEA Bioenergy in Helsinki, Finland, on 10 May 2011.

The purpose of the workshop was to provide the Executive Committee with perspectives on the likely contribution of biomass-derived transportation fuels. The aim was to stimulate discussion between the Executive Committee, Task Leaders, invited experts, and various stakeholders and thereby enhance the policy-oriented work within IEA Bioenergy.

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INTRODUCTION

Transport has been the sector most resistant to efforts to reduce CO_2 emissions due to its strong dependence on fossil fuels and steady growth offsetting the considerable vehicle efficiency gains achieved. Total CO_2 emissions from transport in the European Union (EU) have increased by 24% from 1990 to 2008, representing 19.5% of the total EU greenhouse gas (GHG) emissions. Without decisive action, it is expected that worldwide energy-related GHG emissions will more than double by 2050. The EU objective is an overall reduction of CO_2 emissions of 80-95% by 2050.

Easily accessible petroleum (cheap oil) – the main feedstock for conventional liquid fuels – supplies nearly 100% of current road, air and ocean transport fuels, and is expected to be depleted by 2050 if not sooner. Energy efficiency in transport can substantially contribute to reduced emissions. However, the ultimate solution to achieve almost complete decarbonisation of transport is the substitution of fossil sources by CO_2-neutral alternative fuels.

Biofuels provide a way to reduce oil dependency and contribute to decarbonisation of the transport sector, often with minimal change to vehicle stocks and distribution infrastructure. They will need to play a significant role in replacing fossil fuels suitable for planes, marine vessels and heavy duty road transport. Production and use of biofuels can also provide benefits such as increased energy security by reducing dependency on oil imports and reducing oil price volatility. In addition, biofuels can support economic development by creating new sources of income in rural areas leading to better social infrastructure, creating higher qualified jobs and ultimately, requiring better educated employees.

At present, biofuels only provide around 2% of total global transport fuel, but emerging transformative technologies offer considerable potential for growth over the coming decades[1]. Governments are aware of this situation and have started developing and implementing long term developmental programmes:

- USA is working to deploy cellulose-based fuels and power.
- SE Asia promotes a wide range of biofuels.
- Brazil and African countries are taking the ethanol (EtOH) and biodiesel track.
- Europe is focussing on the whole range of alternatives.

In the shorter to mid-term, biofuels might be a bridge for vehicles in urban and sub-urban areas until electric vehicles and their requisite power infrastructure are readily available. But even in the longer term, biofuels (including liquid biomethane) are the best options for long haul transport and for heavy duty vehicles where it is difficult to envisage using electric systems and hydrogen. There is general acceptance that conventional technologies such as ignition engines will continue to play a major role until at least 2030. However, during this period oil-derived fuels will increasingly be replaced by biomethane, sugar, starch, or oil crop-derived fuels at first and by advanced technologies for biofuels later.

Even though these general directions are being discussed all over the world, there are fundamental differences in national strategies. A number of assumptions are segregating the different approaches, for example the availability of cheap oil or electricity, the preference for a certain form of biomass and the corresponding technology for its transformation and finally estimates of the sustainability of the process chosen.

Besides sustainability aspects, policy makers need to answer even more important questions dealing with energy security, rural development, environmental pollution and food security. The biofuel pathway is one of the strategies that can be implemented both in industrialised and developing countries. In summary, the main drivers that motivate policies towards biofuels are:

- The rapid growth in demand for transport energy.
- The depletion of easily accessible supplies of oil.
- The ever higher costs of oil extraction and refining.
- Concerns about climate change.
- The necessity to achieve energy security.
- Concerns about development of rural areas.

In the light of several important publications produced in 2011, including IEA's Roadmap on Biofuels[2], EU's White Paper[3], the report of an expert group on 'Future Transport Fuels in the European Union'[4] and the Roadmap for a Low Carbon Economy of the EC (TEN-T programme)[5], the Executive Committee decided to hold a workshop on biomass-based transport fuels. This is one of the key themes in the work of the Implementing Agreement – viz. to demonstrate the production and market deployment of environmentally sound, sustainable transport fuels and energy from biomass resources. Six Tasks are involved in the production of energy or fuels from biomass: Task 32 (Combustion), Task 33 (Gasification), Task 34 (Pyrolysis), Task 37 (Biogas), Task 39 (Liquid Biofuels) and Task 42 (Biorefineries).

The objective of the workshop was to provide the Executive Committee with perspectives on the likely contribution of biomass-derived transportation fuels both from the producer and consumer point-of-view.

Mr Esa Härmälä of the Finnish Energy Department, Ministry of Employment and the Economy opened the workshop with an overview of the energy situation in Finland. This was followed by four sessions which addressed the following topics (session facilitators in parentheses):

Session 1 – Strategic views (Birger Kerckow, Germany)
Session 2 – Biomass for road transport fuels (Pearse Buckley, Ireland)
Session 3 – Biofuels for air and maritime transport (Paul Grabowski, USA)
Session 4 – Biofuels in first full-scale applications: The Finnish way (Kees Kwant, the Netherlands)

The main points made by the speakers and the questions raised during the discussions are summarised in this document. The presentations can be downloaded from IEA Bioenergy's website *www.ieabioenergy.com.*

[1] Thermal pre-treatment of biomass for large-scale applications; *www.ieabioenergy.com*

[2] IEA Roadmap on Biofuel for Transport Fuel; *www.iea.org/papers/2011/biofuels_roadmap.pdf*

[3] White Paper: Roadmap to a single European transport area; COM(2011) 144 final *http://ec.europa.eu/transport/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf*

[4] Future Transport Fuel; Report of an European expert group 2011; *http://ec.europa.eu/transport/urban/cts/doc/2011-01-25-future-transport-fuels-report.pdf*

[5] *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0112:FIN:EN:PDF; http://tentea.ec.europa.eu/en/home.htm*

Cover Picture: *Triple biofuels dispenser. Courtesy NREL, USA*

OPENING REMARKS

The Energy Situation in Finland – Mr Esa Härmälä, Finnish Energy Department, Ministry of Employment and the Economy, Finland

Finland is a country rich in biomass (bioenergy potential), but it faces some important challenges in energy consumption. These are:

- Finland is one of the largest European countries but has a very low population density so transport distances are large.
- Finland has a large number of energy intensive industries.
- Finland has harsh long winters, as in 2010/2011 – however, regular business never stops despite the severe climate.
- Finland has a population of 5 million, with 500,000 summer cottages as well as regular housing – all consuming energy.

Due to the long distances and widely dispersed population, transport is one of the most challenging sectors. At present, less than 5% is based on non-fossil fuel. It goes without saying that a combination of high efficiency biofuels and electricity are therefore mandatory for the future. But is this enough? It can be assumed that besides energy efficiency, individual transport must be reduced. Commuting must switch to public transport if it cannot be reduced or eliminated. With today's technology, working at home is possible and should be promoted. Office time should be reduced to the necessary minimum.

In Finland renewable energy (20% of energy consumption) is mainly biomass from the forests. Its total consumption is 35 TWh corresponding to 48% of the renewable energy (Figure 1). Two-thirds of biomass is used for industrial purposes and for power production, about one third in small-scale combustion.

There is no need to invest in new infrastructure for the forest industry. Everything is in place – forest equipment, harvesting supply chains and general conversion facilities (power plants). Finland focuses therefore on 2nd generation technology.

Because transport is crucial in Finland, the government has set a national target for renewable fuel at 20% by 2020, which is double the target set by the European Commission. The NER 300 projects of the EC, with financial contributions in the order of up to €10 million, are therefore important for Finland. Finland applied for several projects for biodiesel, which counts double for the RES target and is also engaged in the SET plan for the production of renewable fuel.

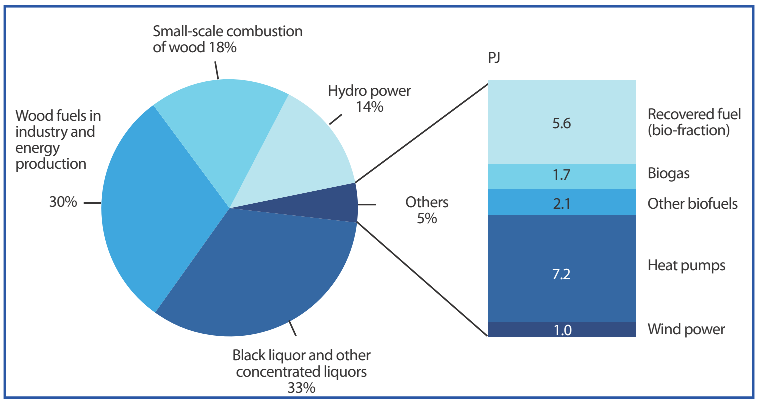

Figure 1. 2009 consumption of renewable energies in Finland. Source: Kai Sipilä adapted from Finnish energy statistics 2010.

SESSION 1 – STRATEGIC VIEWS

Fuel Strategies for Short and Long Distance Transport – Dr Thomas Garbe, Volkswagen, Germany

There is no doubt that the car industry invests in new engine technologies with new types of fuels. There are several major drivers for doing that. A push effect is created by governments asking for oil substitutes and reduction of GHG emissions, but there is also a pull effect from customers asking for new, better, cleaner – yet still affordable – cars. Apart from the limited availability of cheap oil and the CO_2 emissions, there is also a logistical and at the same time a security problem. The major oil fields are in unstable regions and often the supply chain must pass through problematic areas. Decentralised alternative fuels offer the chance to solve these problems.

There are other challenges to be overcome which influence fuel consumption and subsequently emissions, such as steadily growing mega-cities, customer requirements (that are changing all the time) and last but not least unstable political support for industry. A significant investment by the industry requires a stable political environment as well as incentives. This is equally true for Europe, the USA or Asian countries.

The targets to achieve an optimised sustainable mobility include increased efficiency (of engines and of fuel production), the decarbonisation of fuels, and low emission engines that are also economically sustainable (Figure 2). However, they also include optimisation of the mobility system *per se*, e.g. there is a good chance that in large cities individual traffic will have to be phased out and replaced by public transport.

Decarbonisation of fuels: Decarbonisation of vehicle fuel and emissions reduction is the option with the greatest public and political support. However, technically it poses quite a challenge, because the progress achieved with conventional fuels in past years has been impressive. Today, a diesel car produces less than 5% of the emissions that it used to 20 years ago.

The choice of the energy source and (even more) of the energy carrier, that is the fuel, is therefore of high importance. Electric cars certainly have the lowest emissions locally; however the crucial issue is the means of electricity production. Electricity can be produced using all sources of primary energy, including oil, coal and gas. The ecological leaders today are electric cars with batteries charged by renewable electricity (wind). These have the least environmental impact according to the latest results from IFEU[6]. However, they are still in the range of 60-80g CO_2 eq/km.

Volkswagen (VW) has set a goal to limit the emission of CO_2 eq/km to 20g or less by 2050 (Figure 3). Until then progress will mainly be achieved with conventional combustion engines using alternative fuels. A major switch to electric vehicles will only occur after 2030.

[6] Helms, Lambrecht and Rettenmaier, 2011. The renewable challenge – biofuel vs. electric mobility

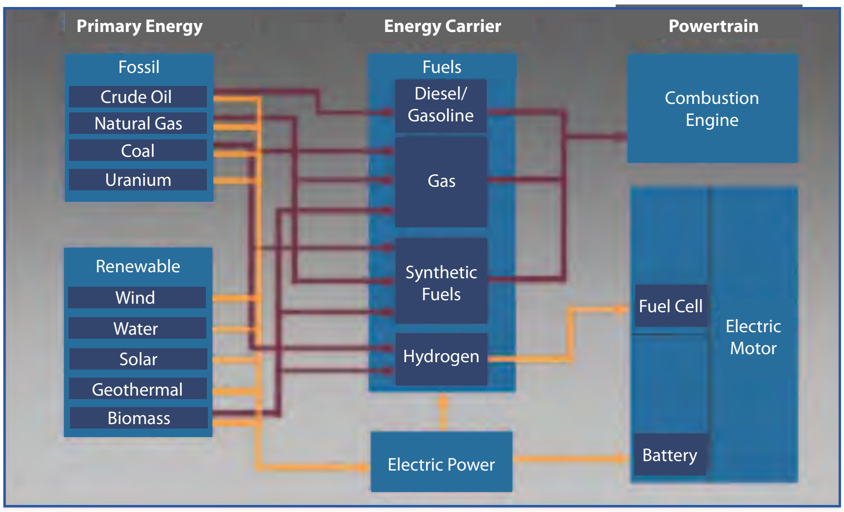

Figure 2. Pathways to power trains.

The intention is go down the road of plug-in hybrids, and extend the range of battery powered vehicles. Although fuel cells are not mentioned in Figure 3, Volkswagen does have developments under way (Tiguan Hymotion[7]). Initially, combustion engines for both biofuels and electric cars will be developed in parallel.

For the market, as a first step combustion engines will be improved for the use of biofuels. A high priority will be to ascertain which of the biofuels has acceptance amongst consumers and politicians. For the latter a positive LCA is important. It is therefore crucial for car manufacturers that LCA methodology is standardised, with only one set of data used in comparable LCA models all over the world. Neither fuel producers nor the car industry can afford to follow different calculations leading eventually to different results and therefore different technical developments. Biomass-derived fuel should not only have a good ecological footprint but the feedstock should also be available in sufficient quantity.

Once the fuels are chosen, they will determine a number of factors (Figure 4). In addition, the fuel should be compatible with existing vehicle technology, be safe, and have a high energy density. Most importantly, it must be mixable at any ratio with fossil fuel, provide a high level of energy efficiency even when substituting for fossil fuels, be low cost and produce low emissions.

A comparison shows that biogas has the best qualities (Table 1) but in general gas-fuelled cars still have a limited market share. That is why it is even more important to look into the question of what the consumer expects when a new fuel or, even more important, a new power train is introduced. The consumer wants established infrastructure (refuelling, vehicle servicing, etc.), wants to understand why he or she should change and what the technical and financial advantages of the new type of car will be. Above all, the alternatives have to be financially more attractive than the corresponding fossil-fuelled cars. Ecological commitment is money driven.

Negative experiences must be avoided – for example, field testing of Mercedes trucks using a 5% blend of fossil diesel with biodiesel showed a reduced operating range, from 90,000 km to 60,000 km.

Unfortunately, there are also a few prejudices and misconceptions that must be fought, such as 'biofuels destroy all the forests' or 'poor people will starve when biomass is used as a fuel'. Communication is a top priority.

There are alternatives under development such as hydrogen-treated bio-oil (HVO), and oil from algae or waste material, to produce drop-in fuels. The industry is also ambivalent about butanol. Positive factors are the high energy density and consumer acceptance but it is unclear how to implement this fuel into existing systems.

On the basis that efficiency, biofuels and electricity are the pillars of a global CO_2 and energy strategy, VW has

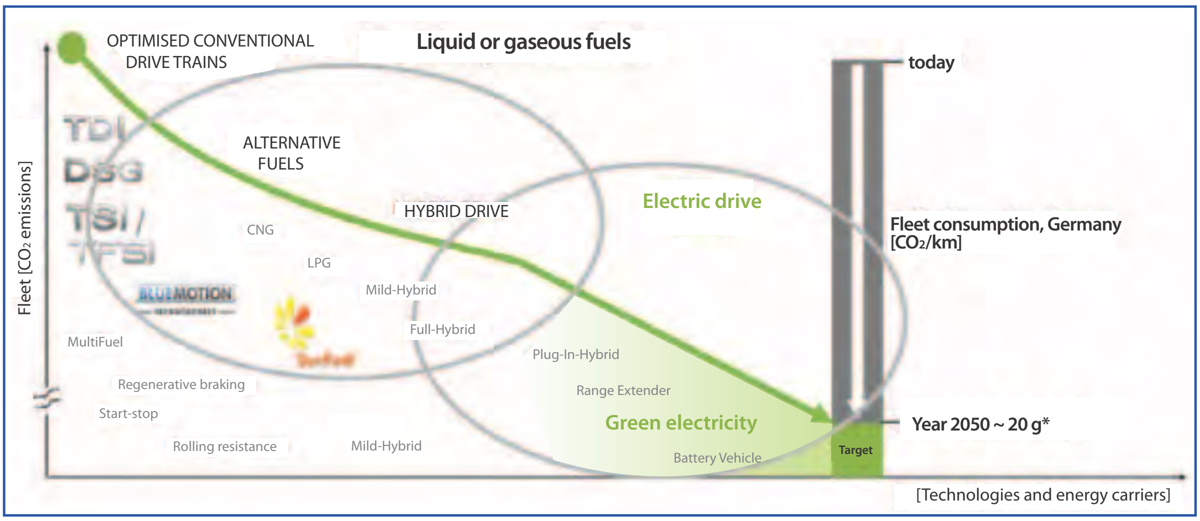

Figure 3. Roadmap to reach the 2°C target as seen by Volkswagen.

[7] Wolfgang Steiger, 2010, The future power train technology, LBBW Automotive Workshop, London

Figure 4. The fuel has an influence on a large number of parameters.

concluded that the roadmap towards electric vehicles is via liquid and gaseous biofuels. Standardised LCAs have to be developed for these fuels, in particular for the growth of biomass. Engine and fuel must work together, therefore development must also go hand in hand. The optimum preconditions for the introduction and use of biofuels – infrastructure, quality, and consumer acceptance – have yet to be created. Successful market introduction by 2020 will only be possible if critical parameters can be met. The exceptions are vehicle emissions (already fair to good) and market share, which takes longer to develop.

Technology Roadmap: Biofuels for Transport – Dr Adam Brown, IEA Headquarter, Paris, France

There is a pressing need to accelerate the development of advanced energy technologies in order to address the global challenges of clean energy, climate change and sustainable development. The overall aim is to advance global development and uptake of key technologies to reach a 50% CO_2 -equivalent emissions reduction by 2050 over 2005 levels.

To achieve this ambitious goal, the IEA is developing a series of global technology roadmaps covering 19 technologies, under international guidance and in close consultation with industry. Ten roadmaps have already been published[8] – four on renewable energies, and a fifth for biofuels[9].

The Energy Technology Perspectives model: The biofuel roadmap is based on the IEA's Energy Technology Perspectives 2010[10] BLUE Map Scenario (Figure 5), which sets out cost effective strategies to reduce greenhouse gas emissions by half by 2050 and to stabilise atmospheric GHG around 450 parts per million to limit global temperature rise to below 2°C. 23% of the emissions savings should be achieved in transport. The BLUE Map Scenario (which is the basis for all the roadmaps) envisages that biofuels could contribute significantly to GHG reduction by increasing from 2% of total transport energy today to 27% by 2050. The scenario suggests that a considerable share of the volume required will come from advanced biofuel technologies that are not yet commercially deployed. (IEA now uses the terms conventional and advanced biofuels rather than 1st and 2nd generation.)

The primary tool used for the analysis of the BLUE scenarios is the IEA ETP model, a global 15-region model that permits the analysis of fuel and technology choices throughout the energy system. The ETP model has been supplemented with detailed demand-side models for all major end-uses in the industry, buildings and transport sectors. These models were developed to assess the effects of policies that do not primarily act on price.

Even though efficiency improvements are the largest contributor to emissions reductions in BLUE Map, biofuels will be needed in particular to decarbonise heavy transport modes (planes, marine vessels and long-haul trucks) that rely on liquid fuels. In the longer term, biofuel production combined with carbon capture and storage might also become an interesting option to reduce CO_2 emissions, possibly leading to negative CO_2 emissions.

Conventional biofuels are mature technologies and are commercially produced today. The most wide-spread advanced technologies include HVO, cellulosic-ethanol, and biomass-to-liquids fuels. They are currently in a pilot or demonstration state. Novel fuels like algae and sugar-based hydrocarbons are still the subject of R&D. Conventional biofuels will disappear

Table 1: Evaluation of selected biofuels by Volkswagen

	Biodiesel	Ethanol	Biogas
Potential Availability	Small percentage Diesel Pool	10-30% increasing by lignocellulose	High percentages in actually small markets
Sustainability	Open questions	Food vs tank discussion Solution: lignocellulose	Different organic sources, use of waste biomass possible
Technical Evaluation	Slightly worse than diesel; material incompatibilities better than diesel	Slightly worse than gasoline; material incompatibilities	Slightly better than CNG
Market Situation	EU: 7% (100%/20% in niches)	E10 in Europe Customer still has open questions	Introduced, 0-100% (by certificate)

[8] *http://www.iea.org/roadmaps*
[9] *http://www.iea.org/papers/2011/biofuels_roadmap.pdf*
[10] *http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2100*

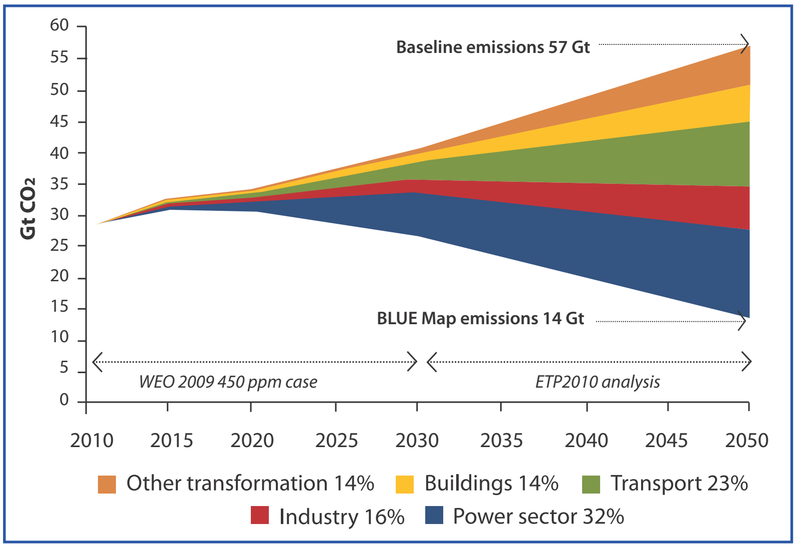

Figure 5. The IEA BLUE Map Scenario with the 2°C goal by 2050.

in the longer term due to limited land use efficiency, only moderate GHG reduction potential, and in particular due to increasing, and increasingly volatile, feedstock prices. Over the next 40 years, new biofuel technologies might come to the market, and can contribute to meet the roadmap targets.

Sustainability of biofuel production: Biofuels have been in the focus of the public during recent years, and media have sometimes drawn a black and white picture of the biofuels sector, damning conventional biofuels for causing deforestation and rising food prices, amongst others.

However, a broad range of technologies exists and it is not fair to say that conventional biofuels are all 'bad' and advanced biofuels are 'good', since the performance of biofuels depends on the choice of feedstock, the way land is used, and the energy and fertiliser inputs that are required. The key is to apply good practice in the cultivation of feedstock, and use efficient processes for the conversion of biomass to biofuels (Figure 6).

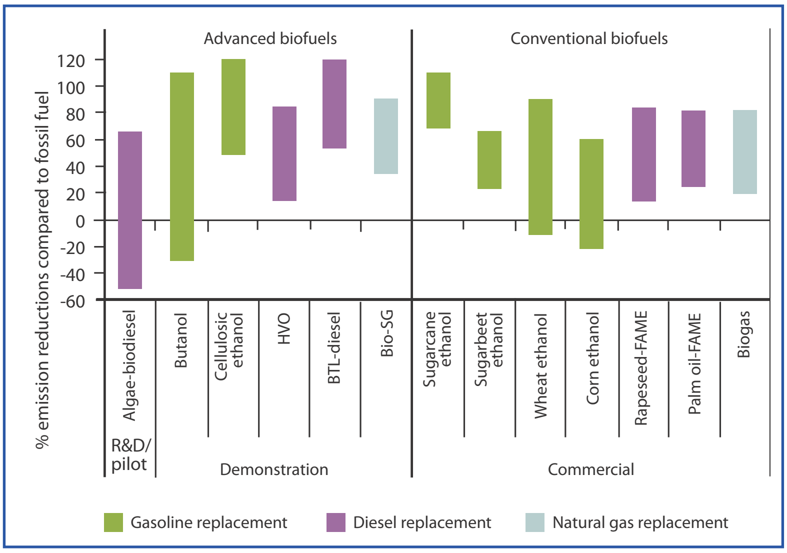

Figure 6. GHG reduction potential of biofuels.

Concerns have been raised that the GHG benefits of producing and using biofuels can be reduced or negated by carbon emissions associated with land use change (LUC). A comprehensive and up-to-date analysis of the issues involved has recently been published by IEA Bioenergy[11]. For biofuels to provide the emission reductions envisaged in the transport sector, it is essential to avoid large releases of GHG caused by LUCs. However, emissions related to current biofuel production generate only around 1% of the total emissions caused by land-use change globally, most of which are produced by changes in land use for food and fodder production, or other reasons.

While there are some uncertainties about the quantification of emissions from indirect land use change (Figure 7), it is possible to identify routes where the risks of LUC and resulting emissions can be minimised and in some cases be negative. These include:

- focus on wastes and residues as feedstock;
- maximising land use efficiency by sustainably increasing productivity and intensity and choosing high-yielding feedstocks;
- using perennial energy crops, particularly on unproductive or low-carbon soils;
- maximising the efficiency of feedstock use in the conversion processes;
- cascade utilisation of biomass, i.e. linking industrial and subsequent energetic use of biomass; and
- co-production of energy and food crops.

Cascade use of biomass means linking industrial and subsequent energetic use of biomass (e.g. using wood to produce high-quality products, afterwards low-quality products and as a last step energetic use).

In some cases, GHG reduction of more than 100% compared to gasoline/ diesel use are achieved through use of co-products (e.g. bagasse, the residue from sugarcane ethanol production, is burned to produce electricity that is fed into the electricity grid and thus replaces electricity from fossil sources). Biofuels can also have a negative LUC impact, when biofuel co-products reduce demand for cattle feed (soybean meal); the production of which would have caused deforestation. In the long-term, all agricultural and forestry products should be certified, and an overall sustainable land use management strategy should be adopted.

[11] IEA Bioenergy,2011, Land Use Change and Climate Change Mitigation - Background Technical Report *http://www.ieabioenergy.com/LibItem.aspx?id=6927*

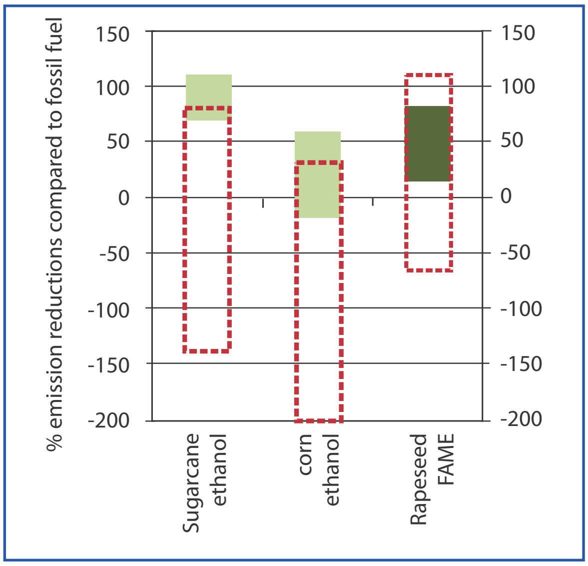

Figure 7. Impact of emissions from LUC.

Land demand: The question is whether the world has enough land to grow all the biofuels required. Currently biofuels occupy less than 1% of total agricultural land (this includes 1.5 billion hectares of arable land, and 3.5 billion hectares of meadows and pasture). And even from the 30 million ha used today, a considerable amount of co-products are produced, such as cattle feed, or bio-electricity and heat.

The 100 million ha required in 2050 are equivalent to 2% of total agricultural land today. This means that land use increases three-fold, whereas biofuel production grows 10 times in the next 40 years. Nonetheless there will be challenges to expand the area for biofuel production. The FAO assesses that food demand will increase by 70% by 2050, based on growth of the world's population to 9 billion in 2050. This will require 70 million ha of additional arable land, in addition to considerable yield increases. The 100 million ha required in 2050 assumes that 1 billion tons of residues are available. If it is more, then less land is required.

There might be a great potential for energy crops in developing countries, because they have not undertaken much research on breeding indigenous crops with the aim of producing high-yielding bioenergy/biofuel feedstocks.

Biofuels production costs: For biofuels to be widely used, they must not only be sustainable with regard to environmental and social impacts, but also with regard to economic aspects. This means that they must eventually become competitive with gasoline and/or diesel fuel. Based on the ETP BLUE Map Scenario, the IEA has developed detailed cost estimates for a range of fuels today and in the future, based on a bottom-up analysis of supply chain components.

Little detailed data on advanced biofuel production costs are available, because such information is usually confidential and there is as yet no experience from large commercial-scale production plants. For conventional biofuels today, the main cost factor is feedstock, which accounts for 45-70% of total production costs, whereas for advanced biofuels the main factor is capital costs (35-50%), followed by feedstock (25-40%).[12]

The IEA low-cost analysis shows that with increasing scale and technology improvement, biofuel production costs can be reduced and get close to those of gasoline/diesel (Figure 8). Production prices will depend on various parameters, including feedstock costs, capital costs, and the impact of rising oil prices on both. The analysis of the low cost scenario reflects a weak link between oil prices, and feedstock and capital costs. This means that increasing oil prices do not impact biofuel production costs very strongly. In an optimistic scenario most conventional biofuels could become competitive with fossil fuels around 2015-2020. Advanced biofuels could become competitive around 2030. Total expenditure on biofuels in 2010-2050 is expected to reach around US$11 trillion (i.e. 11% of total fuel costs).

In the high-cost scenario, with a stronger impact of oil price on feedstock (20%) and capital costs, most biofuels (except sugarcane-ethanol and bio-SNG also called biomethane) would remain slightly more expensive (US$0.10/litre gasoline equivalent). Hence, a CO_2 price of US$50/t would be sufficient to offset the cost difference.

Ethanol Market Overview – Mr Mark Thomas Lyra, Raizen, Brazil

A leader among countries that base their economic development on renewables, Brazil has one of the cleanest energy matrixes in the world, with nearly half of the country's

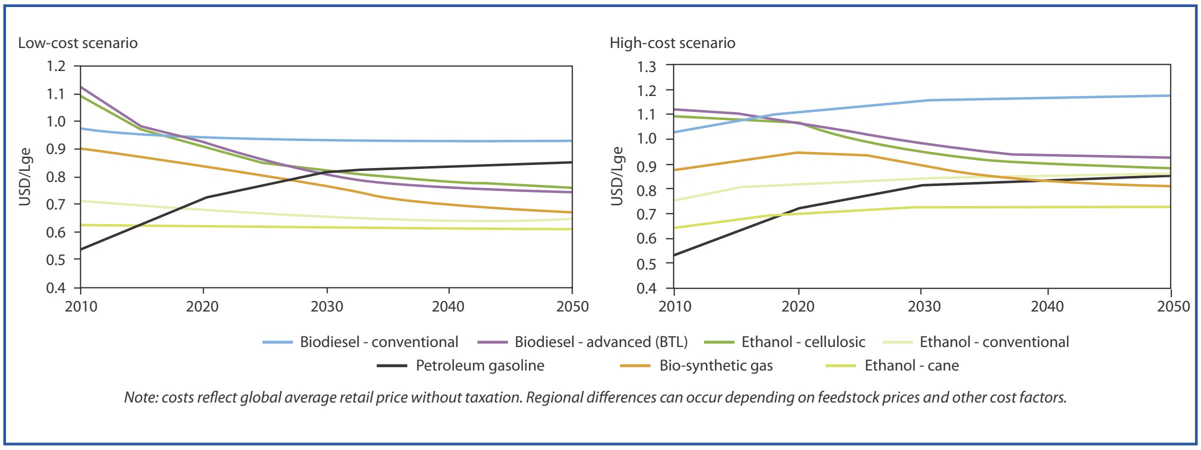

Figure 8. Cost of different biofuels compared to gasoline.

[12]IEA, 2009. Transport, energy and CO_2. *www.iea.org*

energy obtained from renewable sources. For this reason, Brazil could be a low carbon economy, but unfortunately, Brazil is currently the fourth largest emitter in the world, a negative record mainly resulting from GHG emissions from deforestation, responsible for half of the country's total emissions. While agriculture contributes 26.5% of emissions, followed by industry (8%) and transport sectors (6.3%), energy production accounts for only 1.35% of total emissions.

GHG release into the atmosphere caused by deforestation is expected to decrease in the future. Transport emissions are expected to grow by 50% until 2030. Therefore, Brazil will have to take concrete measures to promote low carbon technologies and preserve its clean energy matrix in the future.

The ethanol programme, which was put in place more than 30 years ago, helped Brazil to replace half of its gasoline consumption with ethanol today. There is no pure gasoline in Brazil anymore. By law, all gasoline sold in the country is blended with 20-25% ethanol (E20-E25). In addition, Brazil produces 100% ethanol (E100) that consumers use to fill up their Flex Fuel Vehicles (FFVs). Launched in 2003, this technology allows cars to run on pure ethanol, gasoline or any mixture of the two fuels. These cars became very popular, and five years after their introduction, they account for 25% of the Brazilian light vehicle fleet and for 90% of the new cars sold in the domestic market.

Sugarcane is now the number one source of renewable energy in Brazil, representing 16% of the country's total energy consumption, second only to fossil fuels.

Raizen is entirely dedicated to sugarcane and ethanol. It is Brazil's only fully integrated player in the sugarcane industry with activities in cane cultivation, sugar and EtOH production and trade, domestic and export logistics and retail business. Raizen is the name of a Joint Venture formed in 2011 between Royal Dutch Shell and Cosan S.A. It is Brazil's largest sugarcane producer with 4.3 million tons of sugar and the largest EtOH producer with an estimated capacity in 2011 of 2.2 billion litres in a total of 23 ethanol plants. It includes electricity co-generation from bagasse with an installed capacity of approximately 900 MW. Excess capacity of 300MW is sold to the market. The fuel distribution network includes Esso and Shell stations making it second to Petrobras.

According to the World Bank the population will continue to grow by 40% until 2050 to reach 9 billion inhabitants. With this increase energy consumption and – if business as usual continues – also emissions will grow. To fight this development, the governments in most of the countries or regions have taken measures to reduce GHG emissions. But not only governments are asking for lower emissions, the population is concerned as well.

A survey in South American and Asian countries as well as in India has shown that more than 60% of the population considers global warming a serious problem. A large number of companies, including companies operating worldwide such as Coca-Cola, McDonalds and DHL are taking measures against GHG emissions even if it is only replacement of plastic bottles by bio-plastic (30%) or driving delivery vehicles with ethanol or trucks with biomethane.

The use of fossil fuels is directly linked to the emission of greenhouse gases. The largest share in 2009 came from electricity generation with more than a third of the world's total CO_2-emissions. Transportation is the second largest emitter, with about 25% of the total CO_2-emission. This is why biofuels can play a major role in emission abatement over the next 20 years at least.

Biofuels can represent up to 30% of the transportation energy mix in 2050 (Figure 9) that compares fairly well to the 27% of IEA's BLUE map scenario. Brazilian sugarcane represents the best cost benefit option in terms of cost and carbon emission with 0.049 g CO_2eq/kcal and US$0.0064/kcal. Several factors explain why sugarcane ethanol helps to reduce GHG emissions: sugarcane absorbs 22-36 tons of

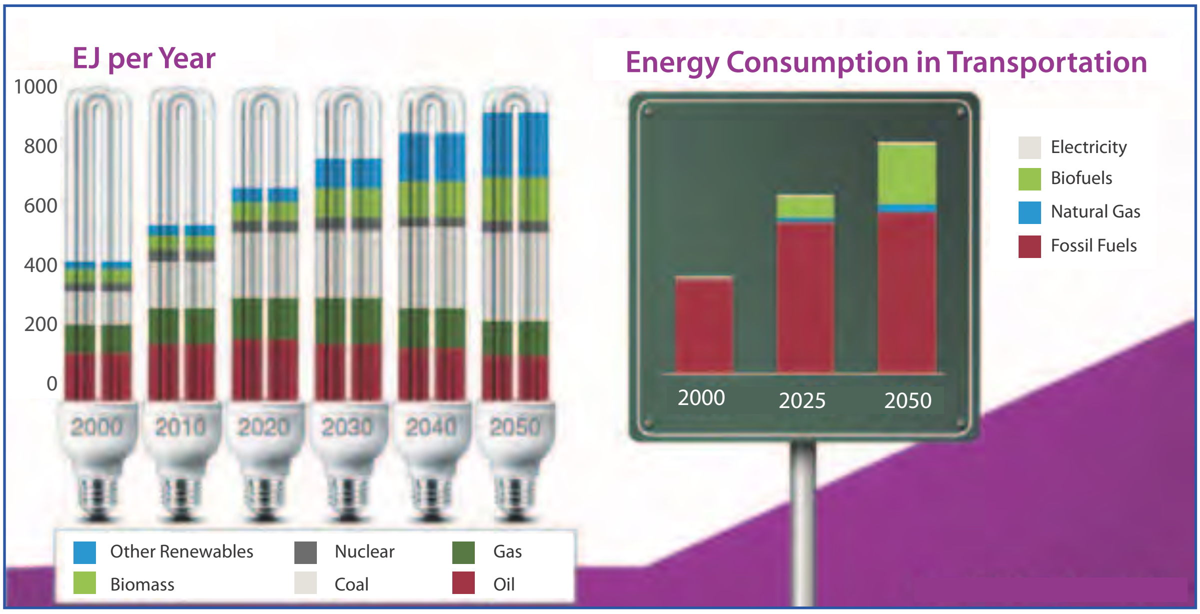

Figure 9. Potential contribution of biofuels to the GHG emission reduction in total energy consumption and transport. Source: OECD.

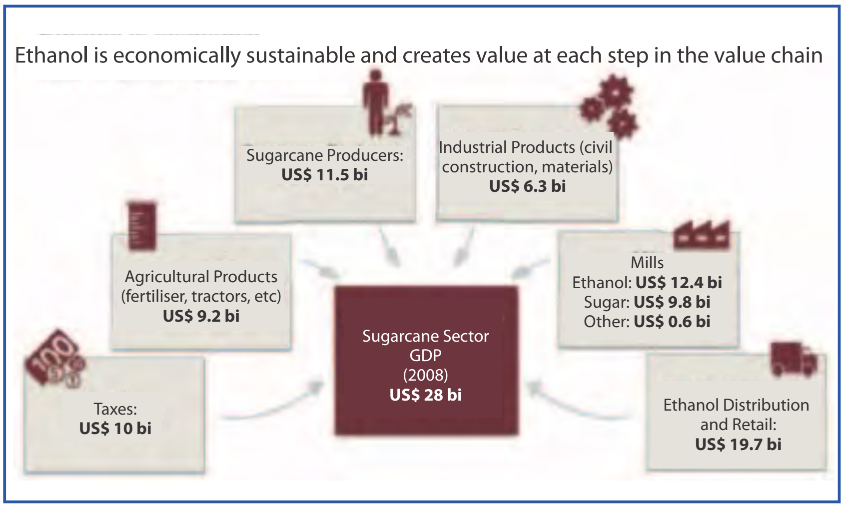

Figure 10. Ethanol adds substantial amounts to Brazil's gross domestic product.

CO_2 per hectare per year; sugarcane is a semi-perennial crop that is replanted only every six years on average, reducing the release of CO_2 following tillage. No-till techniques are also strongly encouraged, considerably reducing the amount of fuel necessary to run the agricultural machinery in the field; the use of agro-chemicals in the sugarcane sector is low compared to other crops. Sugarcane mills are net energy producers thanks to co-generation of electricity with the residues of sugarcane (bagasse).

The production of biofuels has also to be sustainable with regards to social responsibility and economy (Figure 10). In 2008, EtOH added US$28 billion to Brazilians GDP not to mention the approximately R$7.7 billion savings by customers using EtOH instead of gasoline.

As a large company, Raizen contributes substantially to social sustainability. There is less reliance on manual labour – in the harvest of 2011/2012 more than 70% of the canes will be harvested mechanically. In 2010, the Cosan Foundation benefited over 60,000 members of the communities in which it operates.

So far, Brazil is the only market where biofuel (EtOH) has a substantial share (more than 50%). In absolute figures the USA market is even bigger, however its market share is only about 10%, followed by Thailand with 5%. Hence the potential to grow these markets is significant. One of the main pre-conditions is a certification system. Brazil has been collaborating with a number of countries, in particular with Holland and the USA, to develop a common standard[13 14]. A certificate should be comprehensive, objective and transparent. It should involve all relevant stakeholders to ensure acceptability, be science and evidence-based and has to be easily measurable.

Bonsucro®[15] formerly known as the Better Sugarcane Initiative (BSI), is a London based multi-stakeholder initiative set up to develop a sustainability standard and certification system with the aim of reducing the environmental and social impacts of sugarcane[16]. Over a period of five years a certification system for the sugar industry was developed with the collaboration of NGOs and industry. As at June 2011, 1.7 million tons of cane sugar, 130 million tons of sugar and 63 million litres of ethanol, all produced at the Maracaí Unit of Raizen, in São Paulo, have been certified. The Maracaí mill is the first sugarcane EtOH producer in the world to receive the certificate, which is valid for three years.

In July 2011 the European Commission announced that Bonsucro's certification scheme had been formally recognised by the European Union. Bonsucro-certified ethanol will therefore count for the national targets the 27 EU Member States have to reach by 2020, under the RED.

SESSION 2 – BIOMASS FOR ROAD TRANSPORT FUELS

The Sustainable Expansion of Sugarcane Ethanol in Brazil and the Trends for Other Countries: The experience of ETH Bioenergia – Dr Carla Pires, ETH Bioenergia, Brazil

ETH Bioenergia is part of the Odebrecht group. It is a family holding that originally gained prominence in Brazil in the construction and engineering industry, then diversified internationally into transportation, real estate, energy, chemicals and defence. ETH got involved in the ethanol business in 2007 when they acquired two existing sugarcane mills in Brazil. Since 2009 they have started up five additional mills in Brazil and four more are under construction. They are extending into other countries around the equator with favourable climates, such as Costa Rica and Africa (Mozambique, Tanzania, Ghana and Libya). In other African countries preliminary due diligence is under way, with all these projects focused solely on ethanol and electricity production.

ETH aims to become one of the world's leading bioenergy companies. Their business model is built on competitiveness, sustainability and social activity. They start each project by directly involving the local population to create a win-win situation for the community and for ETH.

The group is fully aware that the products have to be sustainable. Expansion into foreign countries will only be successful if they first prove their business model at home, which is why ETH strongly supports the sustainability programme of the Brazilian government. This includes protection of natural landscapes, careful utilisation of water and cultivation, maximum reduction of GHG emissions, process optimisation and appropriate working conditions.

[13] Workshop 10: The impact of ILUC; *www.ieabioenergy.com/DocSet.aspx?id=6214&ret=lib*
[14] Workshop 08: Biofuels part of sustainable transport?; *www.ieabioenergy.com/DocSet.aspx?id=5886&ret=lib*
[15] *http://www.bonsucro.com/*
[16] *http://www.bonsucro.com/assets/Bonsucro_Production_Standard_March_2011_3.pdf*

ETH specialises in greenfield projects but observes sustainability criteria. In any case, because of strict Brazilian legislation the sugarcane industry has become quite sustainable and a number of problems have been mitigated.

Destruction of rain forest, wetlands and native vegetation due to sugarcane production is successfully avoided by agro-ecological zoning for sugarcane production areas. In two areas of the country, the south central and the north east, selected producer regions have been assigned to sugarcane production (Figure 11). Areas of permanent reservation and legal reserves have been determined as well. It is strictly prohibited to grow or process sugarcane in the Amazon or the Pantanal anymore, nor in any other area of native vegetation.

In fact, Amazon deforestation, which has been going on for many decades, has been caused by a set of social and economic factors completely unrelated to the expansion of Brazil's sugarcane industry. One of the main issues is the absence of clear land titles, which leaves the region exposed to rampant land speculation. More than 45% of the Amazon is officially protected and this figure keeps increasing. The rest is divided between areas that are supposed to be public (23%) and private (32%). But the truth is that only 4% of the private areas have legal titles. As a result of the lack of clear property rights and enforcement of the law, illegal logging is indeed the major 'cash crop' of the rainforest.

Displacement of food crops is another myth without real background. In 2009, sugarcane for ethanol production in Brazil occupied roughly 4.0 million hectares, or 1.1 % of the country's 350 million hectares of arable farmland (Table 2). The area cultivated for sugarcane and used for ethanol is less than one-fourth of Brazil's corn acreage, one-eighth of soybean fields, and one-thirty fifth of the land used for cattle ranching.

With only 1.1 % of its arable land dedicated to sugarcane for ethanol production, Brazil has been able to replace half of its gasoline needs with sugarcane ethanol, and generate increasing additional volumes for export. While cane production has increased from 3.5 million to about 8 million tons per year over the last ten years, food production in Brazil has grown to the same extent. The 2009 harvest for grain and oilseed reached 149 million metric tons, approximately twice that of ten years ago. Brazil is widely recognised for its diversified and highly efficient agricultural sector – it is the world's leading exporter of beef, coffee, orange juice, poultry, ethanol and sugar, to name just a few of its top commodities.

Thanks to the increase in sugarcane productivity which has almost doubled since 1970, to 85 tons per hectare, the increase in land requirement is correspondingly lower. It is expected that productivity will be as high as 170 t/ha by 2050.

According to the Brazilian National Institute for Space Research, more than 60% of recent sugarcane expansion took place on pastures, mostly degraded, in the South-central region. As such, growing sugarcane in these areas does not increase competition for new land or displace other crops; instead it leads to cattle intensification. According to a 2008 report of the University of Wageningen, 5.4 million hectares of pasture land were released for other uses between 2002 and 2006, while the cattle herd increased by 18,000 head.

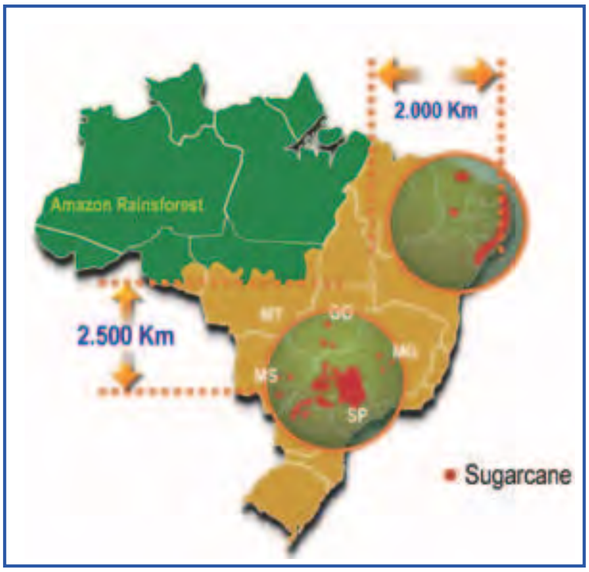

Figure 11. Agro-ecological zoning. Source: NIPE Unicamp, IBGE e CTC Preparation : UNICA.

Irrigation and water scarcity due to sugarcane production are other claims often made. In fact, irrigation has been reduced to almost zero thanks to the recycling of vinasse to the land, which is at the same time irrigated and fertilised (called fertirrigation). Only EtOH production still requires large amounts (about 20 m^3/t of sugarcane) of water, although 90% can be recycled.[17] The net water consumption has therefore dropped significantly over recent years.

Inadequate labour conditions (abuse of labourers) has certainly been a problem in earlier times, especially with small-scale farming. With market concentration, mechanisation has been introduced and working conditions improved. Besides quality of life, harvesting productivity has been increased by 20%. Never-the-less, the number of those employed has more than been maintained. The sugarcane industry is the largest employer in Brazilian agriculture with 1.2 million workers in 2010.

Intensive use of agrichemicals and loss of soil fertility might have been a problem some 30 years ago, however, since the systematic application of fertirrigation, the amount of fertiliser has been reduced as well as herbicides. Fertiliser consumption is in the same range as that needed for soy bean production but still about twice as much as for corn and wheat. However,

Table 2: Total and cultivated area in Brazil.

AREA (in million hectares)		% total	% arable land
Brazil	851		
Total arable land	354.8		
1. Area cultivated – total	76.7	9%	21.6%
Soy	20.6	2.4%	5.8%
Corn	14.0	1.6%	3.9%
Sugarcane	7.8	0.9%	2.2%
Sugarcane for ethanol	4.0	0.5%	1.1%
2. Pasture	172.3	20.2%	48.6%
3. Available area (total arable/cultivated area/pasture)	105.8	12.4%	29.8%

[17] Wellinger 2009; Waste water treatment by AD in sugar factories, Report on behalf of WWF Paraguay

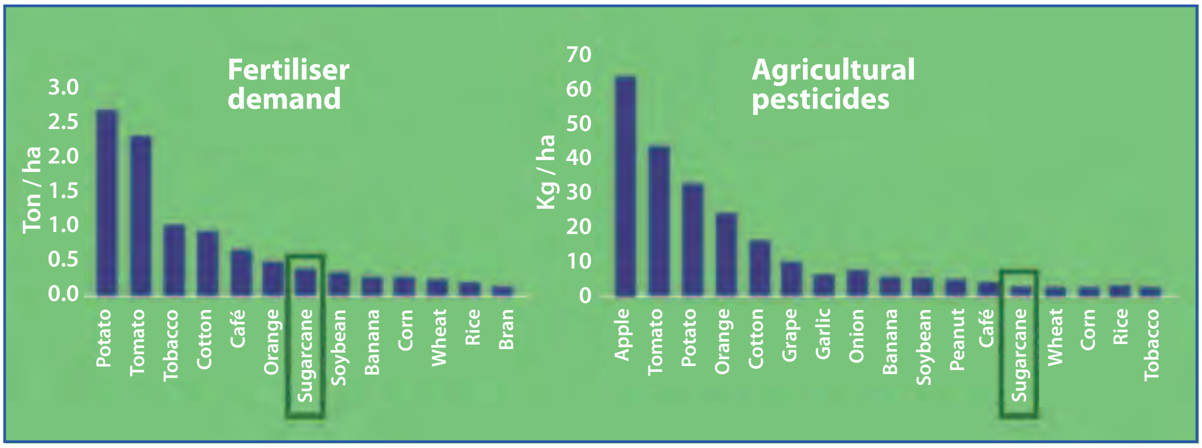

Figure 12. Fertiliser and herbicide demand for sugarcane growth.

pesticide application is at the same level (Figure 12). The claim that sugarcane production would increase the noxious effect on workers is therefore incorrect.

There is no doubt that EtOH production from sugarcane still can be improved. Biodiversity, soil conditions as well as efficiency of the industrial process still have improvement potential. But it should be pointed out that besides energy; EtOH from cane brings positive inputs to employment and rural development. Together with the excellent overall energy efficiency, EtOH from cane is the best of all renewable vehicle fuels even when compared to future advanced fuels.

What is the Future for Corn-based Ethanol and when will Cellulosic Ethanol become the Dominant Paradigm? – Jim McMillan, NREL, USA

The total 2009 energy consumption in the USA was close to 95 quadrillion BtU, corresponding to 27,400 TWh. The bulk of this energy was of fossil origin with 37% petroleum, 25% natural gas and 21% coal. Only 8% was derived from renewable energy, which is in the same order of magnitude as nuclear energy.

More than a quarter of total energy consumption is used for transport. 60% of petroleum is imported, which is why it is environmentally and strategically so important to produce renewable fuels. The major focus of the USA government in recent decades has been on ethanol production, traditional alcohol production from grains at first followed by advanced ethanol (EtOH) production from cellulosic materials.

Conventional starch-based ethanol production: Over the last three years the increase of ethanol production from corn (among the so-called '1st generation' or conventional ethanol production technologies) was indeed dramatic. In 2010, 13.2 billion gallons (50 billion litres) of ethanol were produced, up from 10.8 billion gallons (41 billion litres) in 2009 (Figure 13). However, the rate of increase is expected to slow down in the USA as there is a billion gallons/yr cap for conventional ethanol production. There are 211 production plants in operation or being constructed with a combined total capacity of 14.3 billion gallons/yr (54 billion litres). At peak there were 20 new plants built per year.

Grains for fuel ethanol are mainly processed in dry mills. In these mills, about a third of the total grain weight is recovered in the form of distiller's dry grains with solubles (DDGS). This is an excellent protein-rich feedstock especially for dairy cows. Worldwide DDGS is ranked number three in proteinaceous feedstocks, after soy beans and rape seed. In 2010, 9 million tonnes of DDGS were exported.

There will be an ongoing but relatively small import and export trade in ethanol. Imports in 2010 totalled 9.7 million gallons (35 million litres), down from 193 million gallons (731 million litres) in 2009. About 400 million gallons (1.5 billion litres) were exported in 2010, roughly four times more than in 2009.

Cellulosic ethanol production: Cellulosic ethanol production occurs in many pilot and demonstration plants but the volumes are still quite small. DOE and RFA estimate that over three dozen cellulosic biofuels pilot or demonstration plants are being built or operated in the USA. However, production volumes are still far below the targets of the 2007 Energy Independence and Security Act (EISA) Renewable Fuel Standard (RFS2; Figure 14).

Previously ambitious reduction targets were proposed of 20% for gasoline consumption in light duty vehicles (LDV) in ten years ('20 in 10'), of which 15% would come from

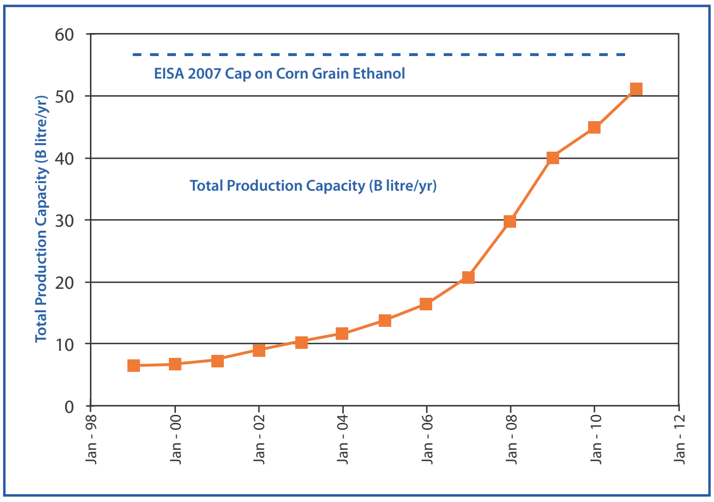

Figure 13. Grain ethanol production 1999 – 2011. Source: RFA.[18]

[18]Renewable Fuel Association; *www.ethanolrfa.org*

cellulosic ethanol substitution and 5% from higher vehicle efficiency. The more recent and now operative EISA 2007 targets production by 2022 of a total of 36 billion gallons per year (BGY) of biofuels or 136.3 billion litres per year (BLY). More than 50% of the biofuels would come from advanced (non-corn starch) feedstocks. Some envisage that by 2030, biofuels production could ramp up to 60 BGY (227 BLY), enough to displace approximately 30% of USA LDV gasoline consumption ('30 in 30').

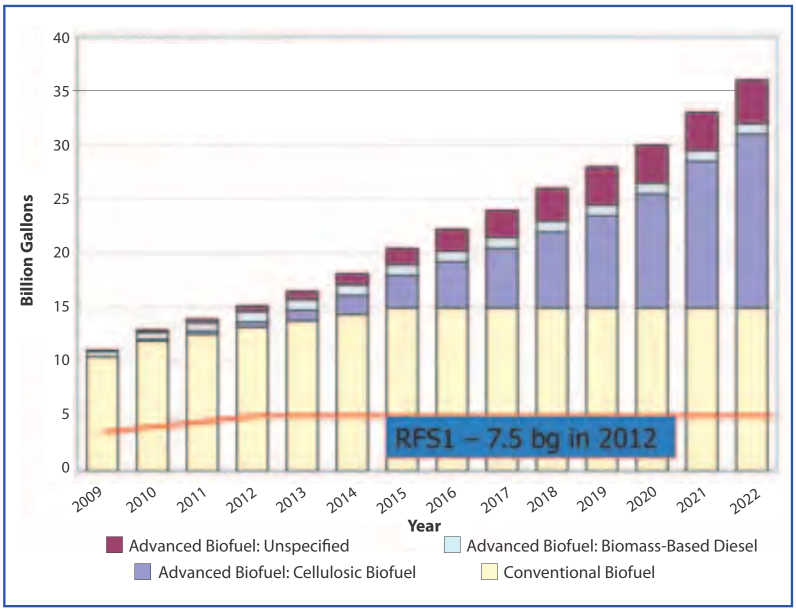

Figure 14. EISA Renewable Fuel Standard (2007).

Process technology for cellulosic ethanol (and other cellulosic biofuels) has improved significantly over recent years, with substantial progress made in the core technologies (e.g. hydrolytic enzymes, fermentation strains, integrated processing) as well as in advanced biofuels techno-economic assessment. Some larger scale cellulosic ethanol demonstration plants are operational (Iogen, Inbicon, KL Energy, etc.) although the rate of progress on commercial-scale demonstration is slower than previously projected.

Despite ambitious targets and substantially ramped up government funding, commercialisation is still struggling. Many large strategic investors (e.g. Abengoa, BP, DuPont, DSM, Poet, Shell, Total) are making substantial investments in pre-commercial RD&D, but investment in commercial-scale production facilities lags. It is expected that a few commercial-scale plants will be operating by 2012, but the RFS2 volumetric targets are unlikely to be met. Actual production is only a few million gallons per year (MGY) instead of the target of more than 100 MGY.

The USA's ambitious EISA 2007 (Figure 14) cellulosic ethanol targets have been waived for the last two years (2010-2011) and the volumetric cellulosic biofuels credit will expire in December 2012. Fragmented government policy and financial support has been insufficient to motivate large-scale commercial investment.

Investment challenges: There are a few additional challenges hindering major private investment. First, the capital costs for cellulosic biofuels are high, estimated to be in the order of $300-600 million for a commercial-scale cellulosic ethanol demonstration facility. This corresponds to a capital cost of $5 or more per annual gallon of installed capacity. Second, the technology still has performance risks and is not yet proven at large-scale.

Furthermore there is no market pull by consumers. For an average tax payer there is no difference, i.e. no incentive, in driving a gasoline or an ethanol car, except that EtOH is more expensive and typically requires more frequent fill ups. Environmental concerns are obviously not strong enough yet to compensate for the higher fuel cost. On top of this, there is some insecurity concerning the fuelling infrastructure, because only new cars (manufactured after calendar year 2000) and flex fuel vehicles are allowed to be driven on E15 without voiding the cars warranty. Older cars can use E10 only, making it necessary (but so far economically prohibitive) for fuelling stations to offer multiple levels of ethanol blends.

There is also no market push in the form of regulatory mandates or forcing mechanisms and the future market for renewable fuels, especially ethanol, is uncertain because a consistent long-term policy framework remains elusive. For example, in the mid-2000s, the governmental focus was on accelerating development and deployment of advanced ethanol technologies but by the end of the 2000s it was switching to emphasise biomass-based hydrocarbon fuel products and support for incentives to deploy ethanol were waning. Similarly, there are discordant messages from the administration and the Houses of Congress. Presidential candidate George W. Bush initially indicated an interest in regulating carbon, then as president he didn't. A bill to regulate carbon was more recently being considered by Congress but is now 'off the table'.

Above all, investors want policy stability as was shown by the Global Competitiveness Report 2010-2011[19]. However, there are more factors hindering investment. The ability to invest was impacted by the economic downturn in 2008, and the 2011 downturn will also have a pronounced effect. On top of high investment requirements combined with significant financial risk, the discussion of whether or not there is enough (sustainably produced) biomass feedstock available for large-scale biofuels production has also impacted on biofuels investment. In addition, the technology has been oversold, in particular in terms of how fast it can deliver, at least in the initial phase. Simply put, big investors don't yet see an extremely compelling value proposition.

Spurring Cellulosic Ethanol Investment: There are at least three components of policy governments could use in order to help investors regain the market confidence required to make large investments in advanced biofuels such as cellulosic ethanol. These comprise:

- A tax component to directly motivate investment, e.g. extending the production tax credit or creating a blender's credit.

[19]2010 World Economic Forum

- An infrastructure component to enable increased demand and use, e.g. by supporting greater production and use of flex fuel vehicles (FFVs), promoting E85 or expanding the installation of blender pumps.
- A policy component to stimulate supply, e.g. within the existing RFS2 framework, properly allocate risks to focus the market (and any incentives) on those biofuels that get produced at acceptable cost.

The collective impact of current barriers is that only a few of the companies that have invested in advanced biofuels RD&D in the USA are currently going forward with large-scale commercial deployment.

This presentation included content adapted from Jeff Passmore of Passmore Group, Inc., USA.

Does Sustainable Biodiesel have a Future? – Elmar Baumann, German Biofuel Producers Association VDB, Germany

In Germany there are two associations active in the promotion of biodiesel: Biodiesel eV is a quality assurance association whereas VDB is politically active. VDB has 25 members – 23 biodiesel producers with 70% of the market share and two ethanol producers with 30%. As a lobby organisation, VDB is fully convinced that biodiesel has a bright future at least in the mid-term.

The role of VDB has become increasingly difficult because the consumption of biofuels has dropped dramatically, for two reasons. First the debate on food versus fuel considerably reduced consumer interest in biofuels, then second, and more importantly, the introduction of a tax on biofuels in 2008 halted the steady increase of pure biodiesel consumption. Total biofuel consumption dropped from 3.3 million tons per year (tpy) in 2007 to 2.5 million tpy in 2009 and levelled off in 2010 thanks to the mandatory quota of 5.25% introduced in 2009, increasing to 6.25% in 2010 (Figure 15). The biodiesel market was hurt far more than the ethanol market. The share dropped from 7.2% in 2007 to 5.5% in 2009.

Permitting the blending of 7% of biodiesel in 2009 slightly broke the downward trend, however it could not compensate for the reduction in 100% biodiesel consumption. The sale of B100 dropped from 1.84 million tpy in 2007 to 0.3 million tpy in 2010. At the same time the number of fuelling stations selling B100 dropped from 1,900 to 200.

While media discussed the irritation of the population at not knowing whether their cars would be suitable for a 10% blend (with the discussion adding substantially to the increase in consumer uncertainty and therefore to the reluctance of clients to use E10 or B10), the really big issue about the introduction of B10 and E10 was the fact that there is a limited volume of biodiesel and ethanol available. The oil industry used that as an excuse because it was not really interested in an increase.

In reality, if all the countries who had announced the partial replacement of fossil fuels moved quickly into sustainably produced biofuels, internationally there would be a shortfall in dedicated biomass. This is why VDB is working hard on certified energy crop production in Germany by improving the processes and reducing GHG emissions.

As a result of the EU Renewable Energy Directive, in January 2011 the German sustainability ordinance was put into force, asking for a reduction of CO_2 emissions by using 35% biofuels now and increasing up to 60% by 2018. This regulation at least partially halted the discussion about food versus fuel. Germany's biofuel industry was prepared to fulfil the requirement. It has introduced the ISCC's audit (one of the seven models accepted by the European Commission[20]) to give proof of a positive LCA. However, when all countries have transcribed the RED into national law and start importing biomass according to the National Renewable Energy Plans, then the import of certified feedstock will become limited and hence prices will increase, creating another hurdle for the market introduction of biofuels.

Apart from the quantitative aspects and sustainability, the technical compatibility of biofuels is another important consideration. Biofuels must be adapted to the requirements of modern combustion engines, such as emission requirements (Euro 6) and power train durability (160,000-750,000 km). For high engine efficiency fuels must be compatible with high pressure injection and turbo charging. Therefore as a first step the phosphor content has to be reduced, and as the second step the chain length has to be reduced in order to narrow the boiling range.

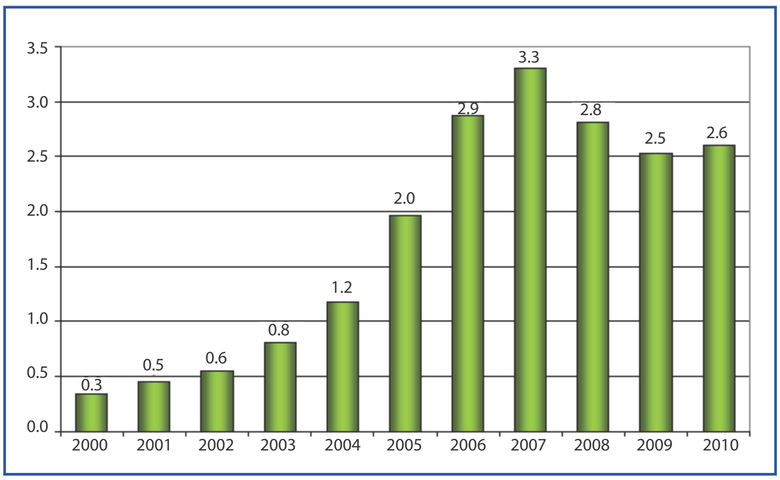

Figure 15. Biodiesel consumption in Germany (in million tons per year).

The car industry is asking for uniform international standards for new fuels and blending components well ahead of new engine developments. New fuel specifications should be established long before vehicles can be developed to these new specifications. In general the time gap between specification and market introduction is at least five years. Last but not least, the relative price of a biofuel is important against other renewable sources:
- FAME vs. gas oil
- FAME vs. HVO and advanced fuels

If all regulations were in place, ultimately the price per ton of GHG

[20] *http://europa.eu/rapid/pressReleasesAction.do?reference=IP/11/901&format=HTML&aged=1&language=EN&guiLanguage=en*

saved becomes decisive because mineral oil companies buy biodiesel primarily to fulfil their reduction standards.

In the end the development of biofuels demands political support, but the industry's image has to be improved to convince hesitant politicians. They should first support the 2020 EU policy and then develop a policy beyond 2020. Without firm goals and regulations there will be no investment in further development by the industry as has already been pointed out by Jim McMillan. Today, 2nd generation fuels have a far better image than 1st generation, but this will likely change as 2nd generation comes online.

Worldwide there is increasing demand for biodiesel but without quality improvement biodiesel will never achieve significant market share. Other biofuels such as HVO have better properties (lower threads) for modern engines, but HVO supply is currently limited. There are 25 major biodiesel producers competing on the market but there is only one HVO producer in Finland. For small-scale fuel companies there is at present little prospect of providing HVO at a reasonable price.

From Waste to Wheels: Biogas Creating the Future – Jacky Joas, Greenfield, Switzerland

Greenfield was formed in 2001 through a merger of Sulzer Burckhardt, whose high pressure division specialised in gas compressors, and Mannesmann Anlagenbau who focused on hydrogen installations. In 2007 Greenfield was acquired by Atlas Copco. Greenfield's specialties are high pressure gas compressors and dispensing systems. More recently they also acquired the Dutch biogas upgrading company CIRMAC.

The company strongly believes in biomethane as one of the major alternative fuels. Biomethane is either produced through anaerobic digestion, forming biogas that is subsequently upgraded to biomethane, or through gasification of ligneous biomass followed by a methanation step.

Production of biomethane from biogas is a well-established process in Europe, with some 150 plants currently in operation, and is increasingly applied in northern America. The production of biogas offers a unique opportunity to integrate waste management solutions, either in dedicated plants or in landfills, with the production and use of a clean burning, low carbon fuel which can also be used as a non-fossil renewable vehicle fuel. Biogas from waste is key to sustainable waste treatment (Figure 16).

Raw biogas production from organic waste produced in a city with 4-5 million inhabitants can be typically 40 million m^3 per year. Once purified and upgraded it would become 20 million m^3 of high quality biomethane, equivalent to natural gas. This amount is sufficient to fuel some 1,000 vehicles, buses or garbage trucks running on CNG, creating an almost perfect recycling loop.

In upgrading processes, CO_2 is removed from raw biogas, yielding natural gas quality which can be injected into the natural gas grid or filled into swop bodies allowing the gas to be shipped to filling stations where a gas grid is not available. Raw biogas contains mainly methane and carbon dioxide, but also small amounts of hydrogen sulphide and ammonia that has to be removed (cleaned) prior to the upgrading process.

The greatest energy efficiency with biogas is achieved in a combined heat and power unit (CHP) with an electric efficiency of up to 42% and a thermal efficiency of up to 50%. However, this is an optimal solution only as long as the heat can be utilised. Otherwise upgrading and injection into the grid offers better opportunities. Injected gas can either be used in a distant CHP where the heat can be utilised or, preferentially, be applied as vehicle fuel. Biomethane has an energy content of approximately 10 kWh, corresponding to one litre of petrol.

An important advantage of biomethane over other blended biofuels is the fact that it can be mixed with natural gas at

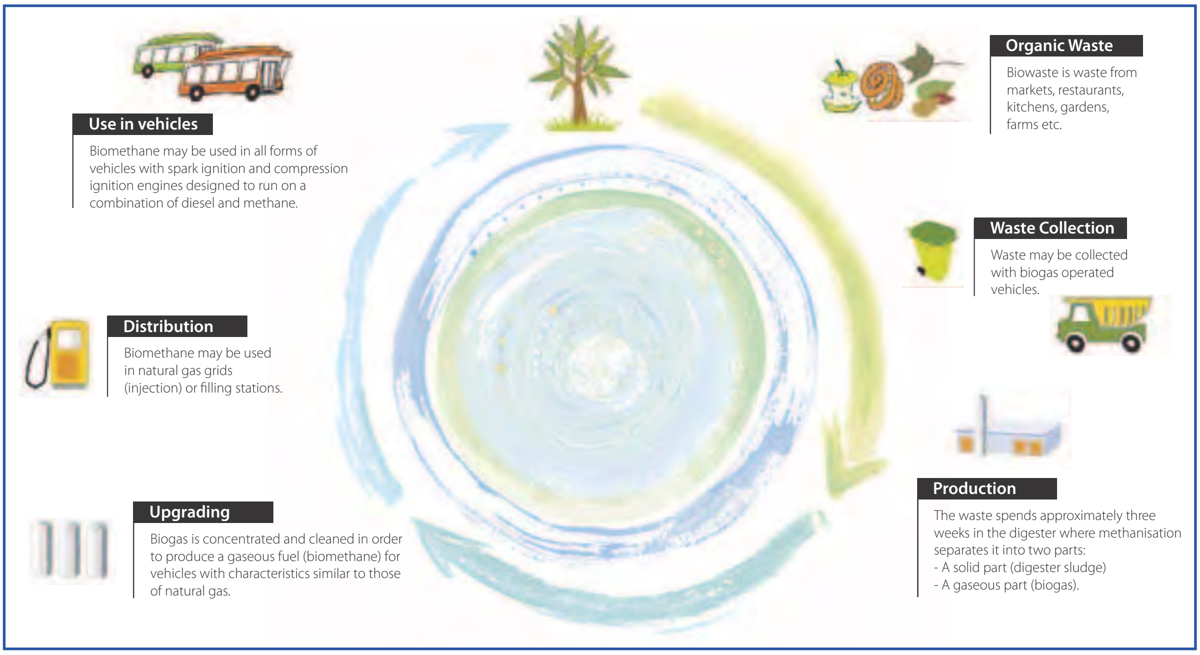

Figure 16. The carbon neutral cycle of waste treatment. Source: Biogasmax.[21]

[21] *www.biogasmax.eu*

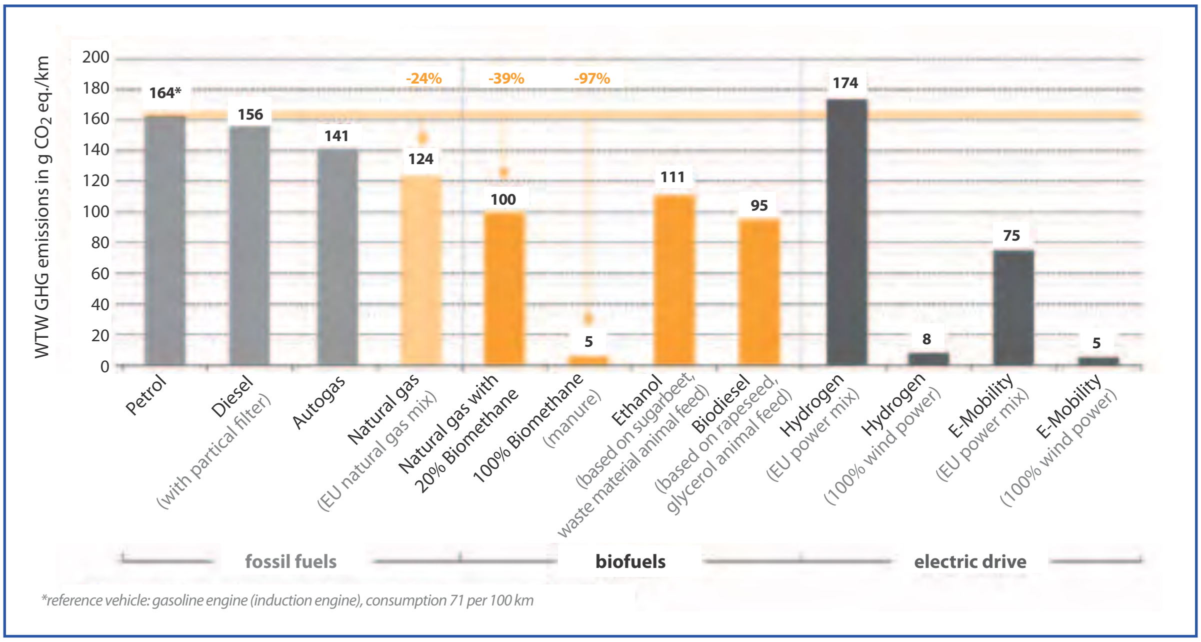

Figure 17. Carbon foot print of vehicle fuels. Source: Dena.

any ratio. There is no blending barrier or car restriction. Even more, in the absence of gas filling stations, today's OEM light duty vehicles automatically switch to petrol without noticeable effect while driving.

Switching from petrol and diesel to vehicle gas can reduce CO_2 emissions by 20%, respectively 30% for natural gas and to about 95% for biomethane (Figure 17). Only electric vehicles driven with wind power achieve comparable CO_2 reductions.

Other environmentally relevant compounds such as particles or non-methane hydrocarbons are absent when biomethane is used. Using biomethane as a fuel in diesel buses leads to a reduction of 80% in particles (without particle filter), 80% in sulphur compounds and 70% in nitrogen oxide.

When injecting biomethane into the gas grid, an injection plant is required, consisting of a gas analyser to determine the Wobbe index and guarantee the absence of sulphur and oxygen, a compressor and a flow meter. In some countries the addition of propane is required to adjust the calorific value of the gas and - if injected in a distribution or medium pressure grid – the gas has to be odorised.

When used as vehicle fuel, the gas is typically compressed up to 250 bar or even 350 bar and stored in pressurised bottle packs. A compressed natural gas (CNG) station is set up, consisting of gas filter, dryer, intermediate storage packs in three banks (low, medium and high pressure) and a control unit.

Public fuelling stations are always equipped with a fast filling dispenser whereas for fuelling of buses e.g. for public transport or garbage trucks in countries like France slow filling stations are usually used, designed to fill all vehicles overnight. Volatile organic carbon (VOC) emissions are virtually zero because the filling nozzle is tight and remaining gas in the pressure hose is recovered into the blow down vessel. The compressors are built to work leak free. Except for Italy, dispensers are usually integrated into conventional fuelling stations and can be operated in self-serve mode.

Today, gas vehicles are amongst the cleanest and most up to date of cars. With the Passat Ecofuel 1.4 TSI, Volkswagen built the first and only car on the European market to achieve five stars in the ADAC-Eco-Test - better than the hybrid Toyota Prius. In the Scirocco car race the biomethane-driven 275 HP model won the series.

Apart from Volkswagen, a whole series of factory mounted CNG makes and models are available. The majority of the European car manufacturers such as Fiat, Renault, Mercedes, Opel and Skoda, are building passenger NGVs. Others e.g. Volvo and Ford allow modification by certified garages with a full guarantee. There are also excellent delivery vans such as the Mercedes Sprinter, IVECO Daily or Fiat Ducato.

Today, worldwide there are about 13.5 million NGVs in operation – in Europe about 1.4 million of which 270,000 are heavy duty trucks and buses. Even though smaller in numbers they consume over 70% of the gas.[22]

SESSION 3: BIOFUELS FOR AIR AND MARITIME TRANSPORT – WHAT'S HAPPENING NOW?

UOP/Honeywell Development of Green Jet Fuel Technology – Stan Frey, UOP Honeywell, USA

Global aviation currently accounts for more than 2% of global carbon dioxide emissions and rising demand for air travel, especially in Asia, will only increase emissions. The International Air Transport Association (IATA) has set an ambitious goal of reducing climate-altering emissions from global aviation by 50% by 2050.

Fourteen organisations from throughout the world plan to assemble at the Paris Air Show 2011 to showcase achievements in the emerging field of alternative aviation fuels, among them UOP Honeywell. This enthusiasm for alternative fuels is not altruistic. Fuel prices have been on the

[22] *http://www.ngvaeurope.eu/statistical-information-on-the-european-and-worldwide-ngv-status*

rise, increasing more than 40% in the past year. Come January 2012, aviation also will be included in the European Emissions Trading Scheme (ETS), a move that IATA estimates will result in the equivalent of a 19% increase in fuel expenses by 2020. Biofuels could represent an opportunity for airlines to meet their emissions targets and reduce overall fuel costs.

UOP's vision is to advance as fast as possible from existing technology of 1st generation oxygenated biofuels like ethanol or biodiesel to advanced real hydrocarbon biofuels from lignocellulosic biomass or algae, replacing diesel, jet fuel or gasoline. Eventually the development passes over oil from non-edible fruits like *Jatropha*, *Camelina* or halophytes. UOP wants to produce real 'drop-in' fuels instead of fuel additives/blends. In order to lower capital costs, minimise value chain disruptions, and reduce investment risk they leverage existing refining and transportation infrastructure for liquid fuels.

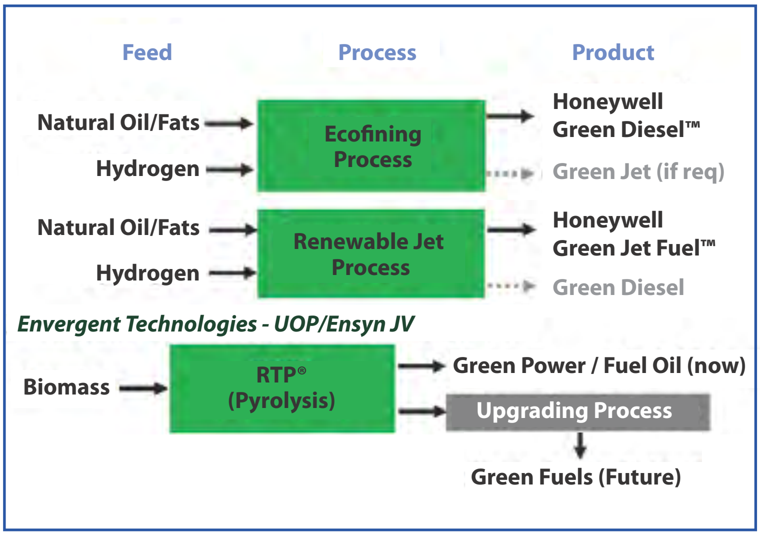

Figure 18. The three basic UOP processes.

The UOP/Eni Ecofining™ process to convert plant-derived oils by hydrogenation to fungible, drop-in diesel fuel was first licensed in 2006. UOP then extended this technology to create the UOP Renewable Jet process technology to produce renewable jet fuel from the same source plant oils. Since the introduction of the UOP Renewable Jet process, a number of advanced feedstocks have been certified. A 200 bpd demonstration-scale production plant producing diesel and jet fuel was built. In 2010 UOP produced over 400,000 gallons of Honeywell Green Jet Fuel™ for ground testing, military and commercial aviation demonstration and test flights. There is an ongoing effort to have Synthetic Paraffinic Kerosene (SPK) certified.

A joint venture between UOP and Ensyn, Envergent Technologies, LLC, has provided a pyrolysis conversion platform to produce fuels from lignocellulosic biomass. Various degrees of upgrading the pyrolysis oil allow for electricity generation, fuel for furnaces, and in the future, upgrading to transportation fuels (Figure 18).

The first large-scale (10,000 bpsd) Ecofining process unit is under construction and scheduled to come on-line in 4Q 2012. The Envergent technology, Ensyn's RTP™ fast pyrolysis process is operating at eight installations in the USA and Canada, the largest of which processes up to 100 tons/day of biomass.

The Ecofining process includes a deoxygenating and isomerisation step in a two stage process by adding hydrogen. Normal paraffins are produced from triglycerides and any included free fatty acids in the first stage, with propane, CO_2 and water being formed as side products. As a final step the paraffin passes over a catalytic process where isomerised green diesel and renewable jet fuel as well as naphtha are formed.

The product of the UOP/ENI Ecofining Process is a high cetane diesel blending component that enables control of the cloud point. Green jet fuel can meet all the key properties of petroleum derived aviation fuel (Table 4). There is increased demand for green jet fuel driven by the inclusion of the aviation industry in CO_2 legislation in Europe

With jet fuel from inedible plants and seed oils and algae, a large series of demonstration flights have been accomplished with Boeing aeroplanes from Air New Zealand, Continental, JAL and KLM as well as with Airbus from TAM and Interjet. Oil from *Camelina* and *Jatropha* was used and mixtures of *Jatropha* with algae. Algae oil can be provided from a number of sources – Aquaflow (wild algae), Sapphire (enhanced algae strains), and Solazyme (heterotrophic algae). Solazyme is working with sugars with a view to using lower grade, more economic sugars in the future.

In 2010 a large series of test flights was done with the US Air Force with military jet fuel quality Honeywell Renewable Jet Fuel for all types of aeroplanes from helicopters to large transport planes. Even ships were operated in collaboration with the US Navy using Green Diesel.

Table 4: Comparison of UOP's product qualities with the required standards. A) Green Diesel compared to FAME and petroleum standards; B) Green Jet Fuel compared to Kerosene specifications.

A	Petroleum	Biodiesel (FAME)	Green Diesel
Oxygen content, %	0	11	0
Specific gravity	0.84	0.88	0.78
Cloud point, °C	-5	-5 to +15	-15 to 0
Cetane	40	50-65	70-90

B Sample Attribute	Freeze	Flash	Density g/cc	Heat Content
JP8 Specification	-47°C	38°C	0.775 – 0.840 g/cc	42.8 MJ/kg
UOP Bio JP-8	-50°C	54°C	0.779 g/cc	43.4 MJ/kg

The focus of RD&D today is on the fast pyrolysis of advanced fuel generation. A joint venture has been established with Ensyn, one of the leading companies in the field. The pyrolysis oil upgrading process in development, deoxygenates the pyrolysis oil and produces oxygen-free hydrocarbon fuels which can be separated into jet, diesel and gasoline fuels.

If algae were the feedstock the remaining fraction of algae after oil recovery could be used to feed cattle, however there are usually not enough cattle nearby to eat all those extracted algae. As a result, the algae debris would be pyrolysed together with corn or mixed woods. Jet fuel needs an aromatic component anyway, which is why pyrolysis could be a good solution.

There are still huge challenges inherent in producing jet fuel via pyrolysis:

- Fuel characteristics have to be tested with regard to trace contaminants such as thermal stability, gums, TAN, colours, etc.
- Fuel certification requires that all perceived differences between petroleum jet and jet biofuel, such as distillation curve, low temperature behaviour etc., will need to be reviewed by all stakeholders. Extensive certification reviews will also be crucial due to the critical reliability of air travel. UOP will have to engage with turbine and aircraft manufacturers, airlines, military and governmental regulatory agencies.
- Process improvement is needed for the several routes of biomass conversion to jet fuel. For example, for pyrolysis the challenges are the stable operation of the hydro-processing upgrading step of pyrolysis oil that might be contaminated with trace metals, nitrogen's, and chlorides. For gasification selective tar cracking is an issue. For paraffin-producing and mono-component pathways aromatics content and smooth distillation curves are an issue.

There are a number of other R&D opportunities including:

- Biomass intermediate product dissolution and separation processes.
- Low water biomass source development.
- Logistical studies of biomass delivery to the processing plant.
- Hydrogen transfer of renewable hydrogen to product hydrocarbons.
- Process economic studies that address competition from 'next best alternative' use of biomass and intermediates.
- Processes that produce complete jet fuel (paraffins and aromatics).

Developments and Visions of Environmental Friendly Ships –Patrik Rautaheimo, STX Europe, Finland

STX Europe includes France, Finland, Norway and Romania and belongs to the STX business group headquartered in Korea. It is a conglomerate with 40,000 employees specialising in ship building in 10 different ship yards. They consider themselves highly innovative ship builders, and have built the two largest cruise ships in the world. All together STX covers 20% of the market share of cruise vessels, 40% of cruise ferries and 60% of ice breakers.

Emissions from cruise ships are an important issue particularly in terms of NOx, particulate matter (PM), CO_2, SOx and other GHG. Apart from stack emissions they create noise, waves and waste, etc. (Figure 19). The long term goal of STX is to build ships without emissions.

The major drivers for emission control, apart from environmental concerns, are fuel prices and the increasing strength of regulation, e.g. it is no longer possible to use heavy oil, which is the cheapest fuel. The International Maritime Organisation (IMO), as the main regulatory body for shipping, has in recent years devoted significant time to regulating shipping energy efficiency in order to control marine GHG emissions. IMO has developed a number of technical measures that include:

- The Energy Efficiency Design Index.
- Limits of CO_2 emissions per ton or passenger mileage.
- Energy Efficiency Operational Indicator (voluntary).
- Ship Energy Efficiency Management Plan.

In ships, energy is mainly used for propulsion.

Other than energy efficiency measures, IMO has also released regulations to limit GHG emissions, e.g. emission of SOx to 3.5% (by 2012) and 0.5% (by 2020). In the Sulphur Emission Control Areas the SOx emissions were even reduced (from 1.5% in 2006) to 1.0% in 2010 and 0.1% by 2015. In addition, emission of NOx is increasingly limited in new ships larger than 130kW (as a function of power expressed as engine rpm) from 14.4 to 7.7 g/kWh by 2011, and further to the range of 3.4 to 2.0 g/kWh. The guidelines also include regulations for ozone-depleting substances, volatile organic compounds, shipboard incineration, and fuel oil availability and quality.

The directives of the European Union are far stricter, with a 0.1% sulphur content limit for EU ports as of 1 January 2010. In addition, port dues are set depending on the volume of emissions.

Because absolute emissions are a function of energy utilisation it is worthwhile to reduce the energy consumption quite apart from minimising the fuel costs. This can be achieved by reducing propulsion energy but also the rest of

Figure 19. Cruise ship emissions.

the energy needs on a cruise ship i.e. passenger hosting, A/C compressors, auxiliaries and also through improved heat recovery.

New energy efficient cruise ship concepts have already been developed. The 'Independence of the Seas' built in 2008 is currently the most energy efficient cruise ship of its size. With new and improved technology, even significantly better energy efficiency levels are feasible – as much as 20-30% less when compared to the 'Independence of the Seas' and more than 40% when compared to other large cruise ships.

By reducing the energy requirements together with improved waste heat recovery and optimised total energy flow, propulsion alone may count for 12-15% of the reduction. Today's large ships have electric propulsion systems. The question is how to produce the electricity as efficiently as possible and preferably with a choice of fuels allowing purchase of the cheapest in a volatile market.

In a steam boiler there is no problem using different fuels simultaneously in any mixing ratio. The down side is that large amounts of fuel are needed, as the thermal efficiency of propulsion steam turbines is low, with an average efficiency of 25%. Heavy fuel oil (HFO) is still the cheapest oil today. However, due to restrictions on emissions and price increases it will disappear over the next few decades. Independent of regulation it has been argued that at some stage within the next 30 years HFO will lose its status as the cheapest marine fuel due to improved cracking processes in the refineries converting more and more crude oil into distillates. These improvements will leave less refinery residue available. Residual fuel oil produced from a barrel of crude has decreased by about 4.6% per decade since 1990.

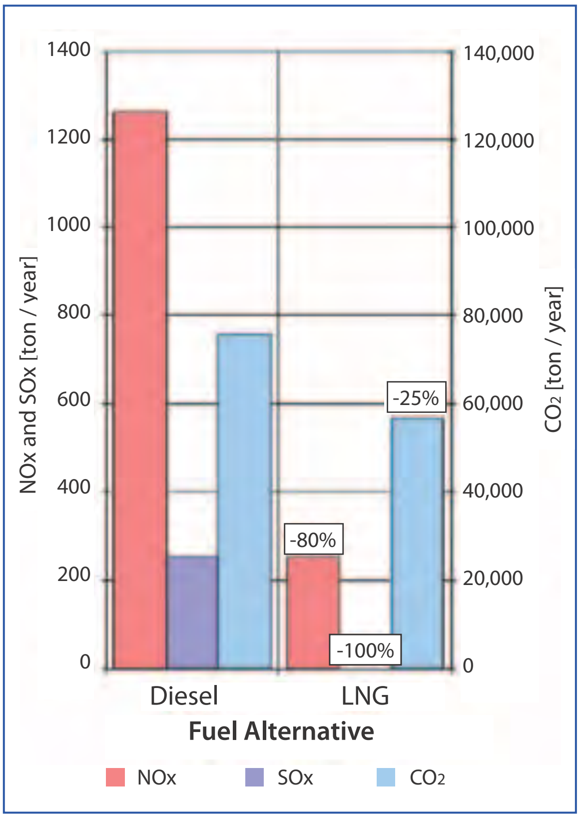

Figure 20. Annual emissions of a cruise ship powered by diesel or LNG.

Things are a bit different with a dual fuel (DF) diesel engine, as it is a derivative of a pure diesel engine. In gas mode, for which the DF engine is optimised, it uses gas fuel and combustion is initiated by a small amount of marine diesel oil (MDO) pilot fuel being injected into the cylinders. The thermal efficiency of the gas operated engine is about 47%. The compression ratio has been lowered slightly to avoid irregular combustion. However, this lower compression ratio has a negative effect on the thermal efficiency in liquid fuel mode.

In liquid fuel mode, the DF engine operates on MDO or HFO, but the thermal efficiency is reduced to about 43%. This in turn leads to a 39% thermal efficiency for the entire electric propulsion system from prime mover to propeller, which is still much better than the performance of the steam turbine drive system.

The fuel flexibility of the dual fuel diesel, combined with its high thermal efficiency, seems to offer the best possibility for reducing the transportation cost of LNG. The fuel flexibility allows the operator to select the cheapest fuel available, within the emission constraints of the charter agreement and proper management (Figure 20).

For ferries LNG storage is not a problem because transportation distances are usually short and regular refuelling is possible. LNG as the major fuel on LNG carriers is not a problem either because they use the boil off natural gas to operate the generators. Bunkering is more problematic in large cruise ships and they are still based to a large extent on diesel fuel.

As an alternative to fossil diesel, biofuels or blends of biofuels with diesel are being introduced. Biofuel powered ships have been operating for a number of years in the Great Lakes region of the USA. Biofuels are sulphur-free, thus the use of biofuels will remove the SO_2 problem from shipping. In addition, emissions of particulate matter will be significantly reduced resulting in a reduced health risk. Only renewable CO_2 will be emitted during combustion, and even though there are some GHG emissions during production of the biofuel, the climate change gas reductions will be substantial when changing from fossil fuels to biofuels.

STX built Aura 2, the world's first dual fuel MGO and liquid biofuel powered ship for their customer Gaiamare Oy. It is designed as an ice breaker and for transport of special transport cargos. Gaiamare Oy's subsidiary Sybimar is planning to produce the biodiesel in their own refinery (FAME from slaughterhouse waste from fish and chicken production). The solids from the waste are separated and used for biodiesel production or as feed.

There are also concepts being developed to use fuel cells for electricity production on a cruise ship, however only for 20-50kW, which would cover roughly 5% of total energy consumption. The fuel cell would be powered by biogas produced in an on-ship digester using the food waste from catering.

SESSION 4: BIOFUELS IN FIRST FULL-SCALE APPLICATIONS: THE FINNISH WAY

Market Introduction of Next Generation Biofuels: Industrial View – Ari Juva, TransEco, Finland

TransEco is a Finish research programme (2009-2013) on energy efficiency and renewable energy in transport. It is designed to develop, demonstrate and commercialise technology for improved energy efficiency and reduced emissions in road transport. The programme, which was initiated by VTT Technical Research Centre of Finland, provides tools for adapting the Finnish road transport system in a cost-effective way to national and EU-level climate and energy targets.

The background of the TransEco research project is the European Renewable Energy Directive 2009/28/EC requiring that 10% of transport fuel energy be covered by renewable energy (biofuels and electricity) by 2020. Waste-derived fuels or fuels from non-edible biomass count double. In Finland this target was voluntarily increased to 20%. In 2010 transport fuel consumption was some 3.8 Mtoe, and thus 20% would be equivalent to some 760 Ktoe.

The Fuel Specification Directive (2009/30/EC) defined a 'blending wall' with a maximum of 10% EtOH by volume in petrol (corresponding to 6.7% in energy) and a FAME content by volume of maximum 7% in diesel (corresponding to 6.4% in energy). TransEco designed an example of future vehicle fuel composition in Finland (Table 5) achieving 20% RES in transport by 2020. BTL production via gasification and Fischer-Tropsch (FT) is therefore not expected before 2017. E85 produced from sugarcane will be imported from Brazil or any of the other large-scale producers outside Europe. HVO will be produced via the Neste Oy process predominantly in Finland but could be imported from another plant. Neste Oy currently has a total production capacity of two million tonnes per year in the following sites:

- Porvoo 1: 200,000 tonnes (2007)
- Porvoo 2: 200,000 tonnes (2009)
- Singapore: 800,000 tonnes (2010)
- Rotterdam: 800,000 tonnes (2011)

Table 5: Example of a solution to cover 20% energy in fuels of Finland.

Type of Fuel	Ktoe CO_2eq	% of energy
2011: 6% energy = 225 kte/a		
Gasoline 50%E5 + 50E10 (mean E7)	80	2.1
FAME Diesel B0-B7 (mean 1%)	10	0.3
HVO	135	3.6
2020: 20% energy = 750 kte/a		
Gasoline 80%E10 + 15E20 + 5%E85 (mean E12)	165	4.7
Biomass 10 kte/a (x2)	20	0.5
FAME Diesel B0-B10 (mean 1%)	15	0.4
BTL Diesel 200 kte/a (x2)	400	10.7
HVO	140	3.7

HVO demonstrates a number of advantages over conventional biodiesel:

- It can be blended at any ratio with fossil diesel.
- It has excellent cold properties between -5°and -35°C.
- At 100% it yields low exhaust emissions: NOx -10%, particles -30% when compared to fossil diesel.
- It fulfils CEN CWA 15940 paraffinic diesel standard.
- It requires less maintenance (lube oil; injection system).
- There are long intervals between particulate filter replacements.
- There are many raw material options: vegetable oils, animal fats, waste, side streams, algae and bacteria oils.

Table 6: Environmental tax system starting in 2011 (expressed in €/litre). Biofuels eligible for double counting are exempted from CO_2 tax.

	Energy	CO_2	Supply Sec.	Total
Gasoline	50.36	11.66	0.68	62.70
Ethanol	33.05	7.65	0.68	41.38
Diesel	30.70	13.25	0.35	44.30
Paraffins	24.00	12.51	0.35	36.86

Like FAME diesel, biogas as vehicle fuel is regarded as a minor source that will be applied in some large-scale installations only. Biogas is only considered as a good option for countries with extended gas grids but not for Finland.

Finland has a taxation system which takes into account energy content, carbon intensity and local emissions. Paraffinic diesel fuel and methane get a tax reduction for reduced local emissions, €0.05/l for paraffinic diesel. The CO_2 tax component is coupled to the RES Directive:

- Bio-components which do not fulfil minimum sustainability requirements are charged with full CO_2 tax (adjusted for energy content).
- Bio-components fulfilling minimum requirements get a 50% CO_2 reduction.
- Bio-components eligible for double counting are exempted from CO_2 tax.

The figures in Table 6 clearly indicate that Finland is promoting paraffinic diesel. For Neste Oil this is an advantage because they have already built HVO plants. Overall this preference fits the Finnish support system which always favours industry and not so much the individual consumer.

Biofuels End-use Aspects: Maximising Impact and Performance – Nils-Olof Nylund, VTT, Finland

This summary covers results of three different end-use projects:

- Optimising E85 (Refuel RE85) composition for use in cold ambient conditions.
- OPTIBIO: Paraffinic renewable diesel for buses.
- The IEA Bus project.

The first two are national projects with industry and government cooperation. The IEA Bus project is an international activity funded by three Implementing Agreements – Advanced Motor Fuels (AMF), Bioenergy, and Hybrid and Electric Vehicles. The national projects focused on end-use performance in the specific geographic (huge, sparsely populated country) and climatic conditions (close to the Arctic Circle) of Finland and did not necessarily reflect the situation throughout Europe or North America. The IEA Bus project has a truly international dimension.

All of the projects included consumer needs and the end use quality of the fuel. The cold climate is a challenge to biofuels as well as electric vehicles. Distances in Northern Finland are so long that the battery-powered electric vehicle is not a universal solution for Finland. The ordinary consumer is very conservative. This was highlighted in the introduction of E10, which is very much disliked by Finnish motorists. The rumour was spread that an American flex fuel car did not work properly with an E10 blend. This resistance (not unique to Finland) is quite surprising because flex fuel cars had been introduced a century ago. In 1908 the Ford Model T was designed with a carburettor adjustment that could allow the vehicle to run on ethanol fuel produced by American farmers. Ford's vision was to 'build a vehicle affordable to the working family and powered by a fuel that would boost the rural farm economy'.[23]

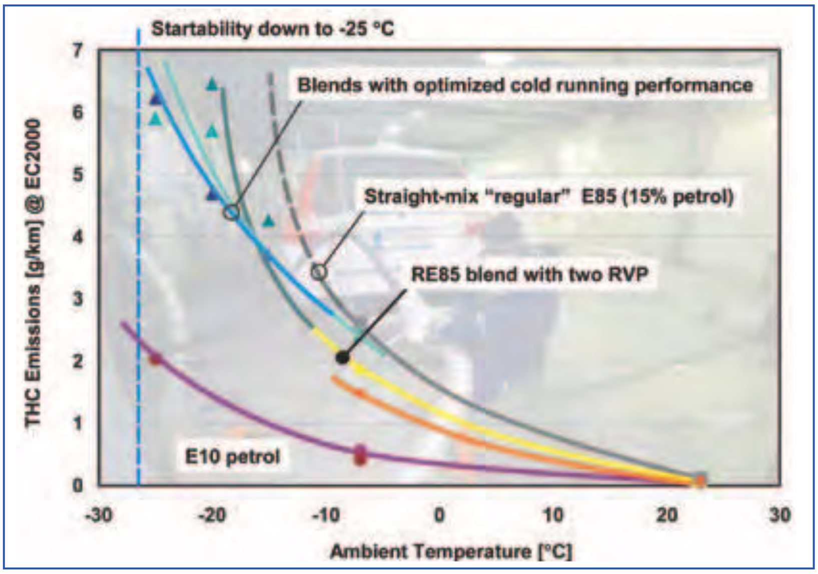

Figure 21. THC emissions of LDVs with different E85 mixtures under cold temperatures.

The E85 optimisation project tested and evaluated different high-volume ethanol fuel (E85) samples in five different makes of light duty vehicles (LDV) under low temperature driving conditions. All together five different fuel compositions were evaluated, with 70-85% of anhydrous bioethanol, the balance of 15-30% being regular petrol, or alternatively some specific components like ETBE, butane, isobutanol etc. As a reference the new Euro-quality E10 with 10% ethanol was used. Fuel vapour pressure of each sample tested was adjusted according to test temperatures to match summer or winter conditions, and ensure effortless start-up.

The tests were limited to -25°C because the temperature seldom drops below that level. However, intermediate temperatures were also used, -7°C in particular, as with the upcoming Euro6 requirements, flex fuel vehicles (FFV) need to comply also with the cold-start 'Type VI' test performed at that temperature. Test results showed that the composition of the fuel had a marked influence on the emissions and start-up limits (Figure 21, showing THC emissions). The lower the test temperature was, the more distinctive were the differences between the different fuel types. At +23°C the differences in unburned hydrocarbon emissions between 'straight' E85 composed of 85 vol-% of ethanol and 15 vol-% of regular petrol, and the test samples with other blends, were rather small. At -7°C the difference was more accentuated. Based on the progression rate of the unburned HC emissions, the authors predicted that about -15°C would be the lower limit of operation with 'straight' E85 composed of ethanol and petrol.

More 'engineered' test fuels than E85 with petrol, performed much better, and allowed starting at temperatures as low as -20°C or even -25°C, depending on the sample composition. They emitted comparable concentrations of THC and other compounds (aldehydes, ethanol) as straight E85 but at about 10°C lower ambient temperatures.

Because the starting problem of 'straight' E85 at cold temperatures is known, OEM's usually offer electric block heaters as standard equipment in their FFV models to compensate for the disability. In the tests described here when the block heater was applied for two hours before starting, the HC-emissions were strongly reduced to comparable levels with E10 fuel without preheating.

The objective of the OPTIBIO project was to demonstrate the daily use of different amounts of high quality renewable diesel fuel in reducing the toxic emissions from 300 buses in the metropolitan area of Helsinki. The project commenced with some 50 buses operated with a 30% HVO blend in September 2007 and soon included four new Scania EEV vehicles on 100% HVO entering the test in March 2008, together with two new reference vehicles operated with conventional diesel. The project was expanded to 300 buses in the autumn of 2008, most of them on a 30% HVO blend fulfilling the EN590 specifications. Three older Euro III Scania vehicles started operation on 100% HVO in April 2009 and three EEV level Irisbus vehicles entered the test with 100% HVO in February 2010.

Although for ecological reasons public transport is to be favoured over individual transport using passenger cars, older buses in particular can cause significant local pollution of particulates and nitrous oxides. The OPTIBIO project clearly demonstrated that paraffinic fuels can reduce emissions from new as well as old vehicles. In addition, contrary to conventional FAME-type biodiesel, paraffinic fuels can be used with a range of exhaust gas after-treatment devices.

In addition to emission control and total amount and distribution of particulate data, in some of the buses fuel and energy consumption, acceleration and traction power were measured comparing summer and winter diesel with 30, 50 and 100% HVO. 100% HVO reduced average energy consumption expressed as MJ/km by some 0.5%. The variation went from

[23] *http://www.nesea.org/greencarclub/factsheets_ethanol.pdf*

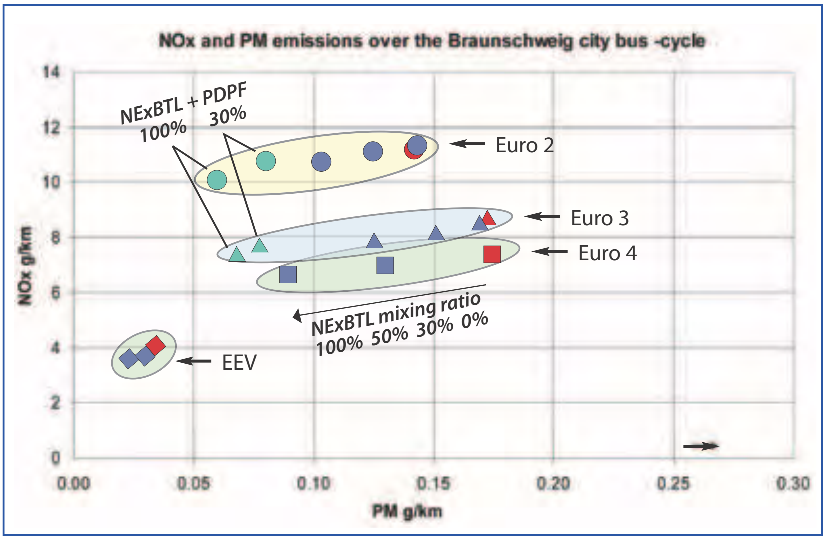

Figure 22. Effect of HVO on NOx and PM emissions. Red marks stand for EN590 diesel fuel, blue marks for 30, 50 and 100% HVO. For Euro II and III vehicles, results are also shown with retrofitted Partial Flow Diesel Particle Filter (PDPF).

+1% to -2.5%. However, in practice it can be said that HVO has no significant effect on energy consumption in vehicles using standard calibration. On the other hand, 100% HVO increases volumetric fuel consumption by 5.2% compared to summer grade diesel fuel and 3.5% compared to winter grade diesel fuel. Thus it can be concluded that volumetric fuel consumption primarily is determined by volumetric heating value.

Figure 22 presents a summary of the emission results for NOx and particulates in all the buses tested. The outcome was consistent for most of the vehicles. In comparison with sulphur-free diesel, 100% HVO will on average reduce NOx emissions by 10% and PM emissions by 30%. A relatively simple device like the P-DPF helps to enhance emission performance even further – the PM level of an old Euro II bus can be brought down close to EEV level.

Overall, the long term test was a success. In total the alternative fuel vehicles drove some 50 million kilometres, including 1.5 million kilometres with 100% HVO. No specific difficulties were recorded in the field trials, not even during the extremely cold winters in 2009/2010 and 2010/2011.

The IEA Bus Project encompasses a combination of desk studies and actual measurements on conventional and new types of buses. The goal is to provide solid IEA-sanctioned data for policy and decision makers. It aims to bring together the know-how of the seven transport related IEA agreements with the focus on fuel production (IEA Bioenergy), fuel end-use (AMF) and hybrid power trains (HEV).

The project is divided into two main parts, WTT (well-to-tank) fuel pathway analysis and TTW (tank-to-wheel) vehicle performance. As a major result, data on the overall energy efficiency, emissions and costs (both direct and indirect costs) of various technology options for buses will be provided.

The WTT analysis was based on three LCA methodologies: The GREET and the GHGenius models and the European Union RED methodology. The results demonstrated significant differences between these calculation methods. To verify the data, a literature review of 25 LCA studies of 14 different biofuel chains has been conducted. This review confirmed the huge variation in the WTT results.

For the TTW analysis 15 different vehicles have been monitored so far using the North American, European and Japanese test cycles, with a variety of different fuel blends including ultra-low sulphur diesel, oil sands derived diesel fuel, canola methyl ester, soy methyl ester, tallow/waste fry oil methyl ester, hydro-treated vegetable oil, DME, CNG and ethanol. Based on the Braunschweig bus cycle significant reductions in NO_x and PM emissions (Figure 23) as well as energy consumption could be achieved.

The results of all the projects mentioned can be summarised in a few points:

- There are still a number of challenges in producing sufficient amounts of sustainable and cost-effective biofuels.
- Blending of conventional bio-components only provides limited substitution.
- 'Drop-in' fuels or alternatively dedicated vehicles are needed to really make an impact.
- In future all fossil fuel powered cars should have a flex fuel engine.
- In buses methane delivers the lowest regulated emissions.
- When developing alternative fuels, all aspects of end-use performance, including unregulated exhaust emissions, have to be considered.

Highlights of the Next Generation Biofuels RTD&D in Finland – Kai Sipilä, VTT, Finland

In 2009 Finland produced 352 PJ of energy from renewable energy sources. This amounts to 20% of total energy production. Measured as final energy, renewable sources produced 30% of final energy consumption. Wood fuels together with concentrated liquors, account for more than 80% of the renewables (Figure 1, page 3) or 20% of the final energy consumption. That is slightly more than nuclear energy (Figure 24).

Electricity is generated at about 400 power plants that utilise varying fuels and production technologies. The electricity from renewable energy sources is mainly generated by hydropower and by incinerating forest biomass that is composed of residues from pulp and paper production and forest chips in combined heat and power (CHP) plants. The biomass plants range from 1 MWe to 240 MWe.

So far Finland has prioritised CHP plants for economic reasons. Today transport fuel is promoted by the EU, which is asking for a 10% share for renewables. Finland decided to opt for 20% with partial double counting; therefore new concepts of woody biomass for biofuels are required. Because the demand for renewable biomass-based chemicals, new fibre products and other new bio-based products to replace the use of fossil raw material is also increasing, the profitability of

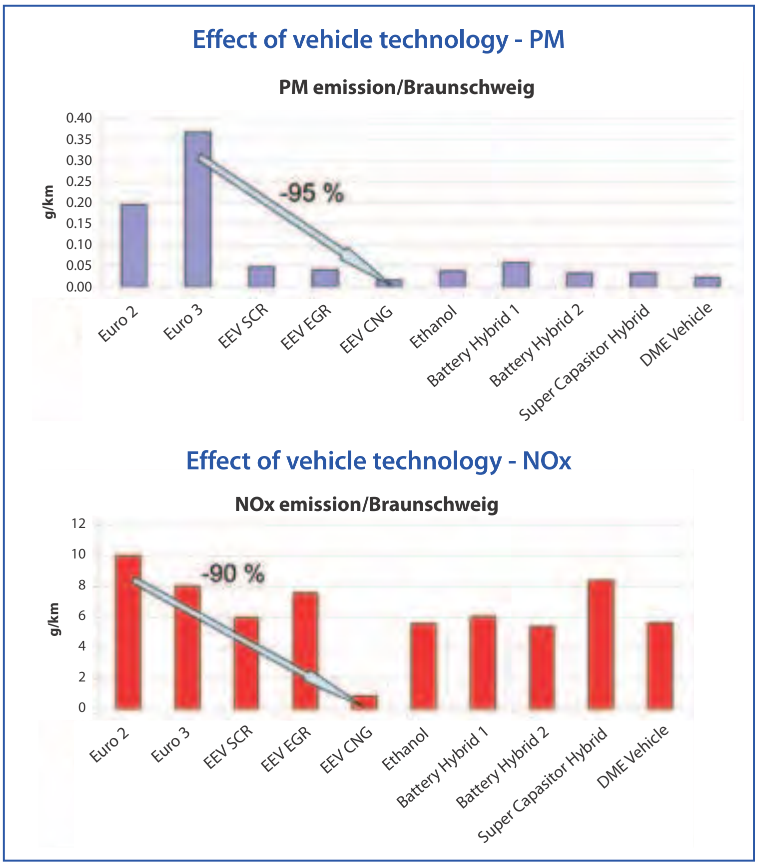

Figure 23. Emission of particulates and NO_x.

new biomass products can only be achieved by integrating the manufacture of several products into the same unit, i.e. to create biorefineries.

The history of the Finnish forest industry is full of examples of regeneration, showing the capability of the industry to adopt new ideas and business models. Many research projects in both industry and research institutes have been carried out in recent years and the results are promising. Finland has the know-how to develop new profitable biomass-based business concepts and increase the profitability of existing business.

The goal for 2020 is 7 TWh of raw material, mainly covered by wood but a few other technologies with other substrates are included, such as EtOH fermentation of lignocellulose material or biogas production from different wastes. In order to increase pulp and paper production, produce advanced biofuels at cost-competitive processes and fulfil the CO_2 targets at the same time, there is only one way to go for Finland, i.e. integrating biofuel production into existing (forest) industry. After the successful introduction of the HVO technology, the focus is now on new concepts of ethanol production and even more on HVO compatible biofuels from Fischer Tropsch. The background of the ethanol concept is the question: 'How can waste paper be used when the quality is not high enough for recycling?' The goal is to use it after de-inking, at least in part, as source material for EtOH fermentation while the rest is incinerated in a CHP plant. Such a concept, integrated with waste paper will produce – apart from EtOH – about 50,000 m^3 of biogas. It would be of financial benefit for all products. The EtOH production could especially profit from the mill's steam production from low cost waste fuels.

BTL plants in Finland are planned to be integrated into pulp and paper factories. From the annual amount of three million tonnes of wood, 50% would be used for pulp and paper production while wood diesel from gasification could be produced with the other 50% that could be further treated in refineries together with crude oil (Figure 25). The key issue for all technologies is to achieve high levels of efficiency to make them economically viable.

Three consortia are presently planning to establish 2nd generation BTL biorefineries in Finland. Stora Enso/Neste Oil, UPM and Metsäliitto/Vapo are basing their designs on the gasification of biomass and Fischer Tropsch synthesis. The planned facilities would each have the capacity to produce 100,000-200,000 tonnes of biodiesel annually. All three consortia have applied for EU´s NER300 funding. The EIB decisions are expected to be available at the end of 2012. Additional Finnish government funding would be available up to €100 million in the event the BTL plant did not get the NER300 funding. The expected investment cost of the BTL plant is in the order of €400-900 million.

New biofuel production P&D plants are under way. Stora Enso & Neste Oil are planning a joint Fischer Tropsch diesel demonstration plant (12 MW) at Stora Enso's pulp mill in Varkaus. The gasification and gas cleaning technology

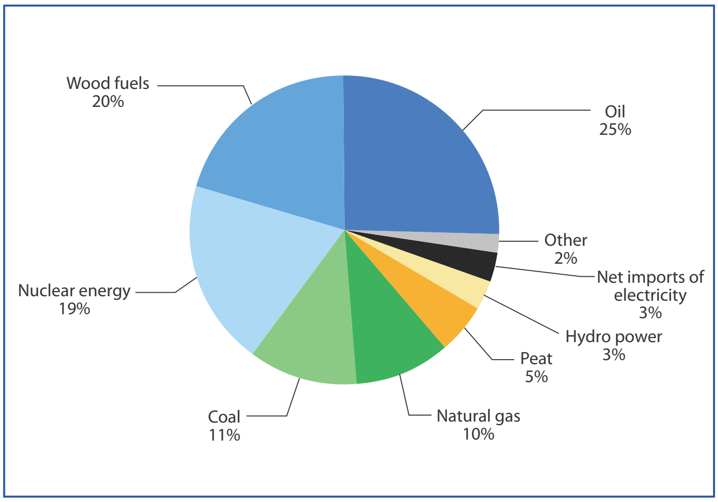

Figure 24. Total Finnish energy consumption 2009. Source: Energy Statistics - Yearbook 2010, Energy.

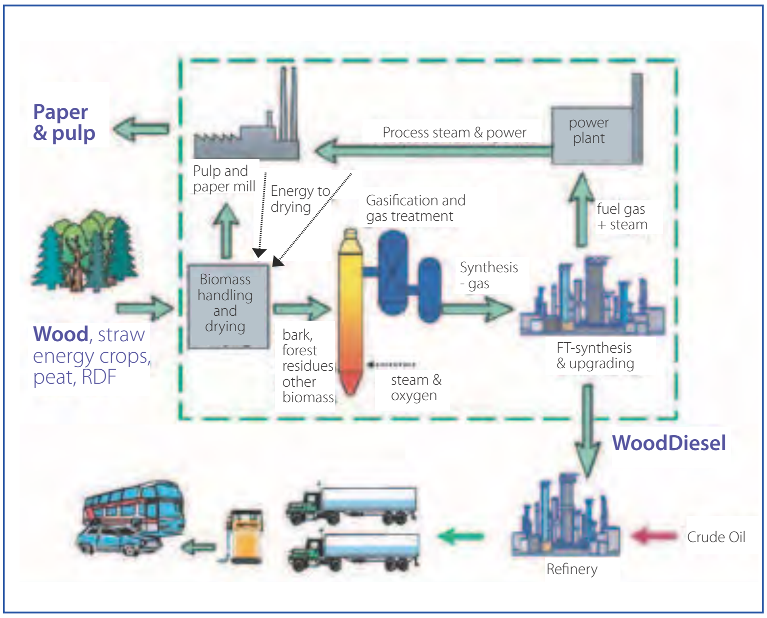

Figure 25. Integration of Fischer Tropsch technology into an existing pulp and paper mill.

has been piloted at VTT on a 0.5 MW scale. UPM & Andritz Carbona are planning FT diesel pilot tests at GTI's facilities in the USA. St1 has five EtOH plants is operation and is looking for new raw material options for REFuel E85 production. Biogas production and upgrading to grid quality is in the starting phase. Up to five years of development and pilot-scale industry testing is anticipated but after 2015, large plants should be built to reach the 20% goal in transport.

The 'BioRefine – New Biomass Products' programme (2007-2012) of Tekes, the Finnish Funding Agency for Technology and Innovation, supports industry to develop innovative new products, technologies and services based on biomass refining and biorefineries. In October 2010, the volume of the industrial projects was about €175 million, 45% funded by TEKES. About 80% was allocated to company projects (23 projects/37 participants) and 20% of the budget went into research projects (27 projects/16 participants). Part of the Tekes funding to company projects was channelled to research institutes through sub-contracting. It is estimated that the total volume of the projects will reach about €200 million by 2012. Eleven projects also involve international cooperation with USA and Canada.

Both the EU and the USA have set targets for increasing the use of biofuels in transport. The EU has set a 10% binding minimum target for renewable energy in transport to be achieved by each Member State by 2020. In the USA, the mandated production target of biofuels in transport is set for 136 billion litres (36 billion gallons) per year by 2022 (see contribution of Jim McMillan, page 11) in the Energy Independence and Security Act (EISA). The total target of 2022 includes 21 billion gallons of advanced biofuels.

In 2010 a special focus of the BioRefine programme has been to involve small and medium-sized enterprises.

SESSION 5 – SUMMARY AND CONCLUSIONS

The four facilitators summarised the contributions and discussions at the end of the day. They concluded that there is a pressing need to accelerate the development of advanced fuels and associated technologies in order to promote sustainable development, combat climate change and mitigate transportation GHG emissions. The overall aim is to move rapidly with key technologies to reach a 50% CO_2 equivalent emission reduction over 2005 levels by 2050.

Using their Biofuel Roadmap, IEA has shown in its Blue Map scenario that it is possible to achieve the targets set. However, there are a number of challenges to be met. Efficiency improvements will be the biggest contributor to emissions reductions and, in particular, biofuels will be needed to decarbonise heavy transport modes (aeroplanes, marine vessels and long-haul trucks) that rely on liquid fuels. Over the next 40 years, new biofuel technologies must come to the market, using less land and showing better overall efficiencies, to contribute to meeting the roadmap targets. Up to 27% biofuels will be needed by 2050 corresponding to 65 EJ primary biomass – equivalent to 100 million ha. Starting with conventional biofuels, cost competitiveness with fossil fuels can be achieved by 2015/2020 and for advanced biofuels by 2030.

There is no question that a stable, coherent long term framework with continuous funding and support measures is needed. Sustainability criteria are crucial for the development but compromises will be needed to reach consensus. One way to increase trust and demonstrate low environmental impact is by using waste as the basis for fuel production, either via HVO processes or more importantly through biogas production. However, waste materials alone as feedstocks for fuel production will not solve the transport problem. The most we can expect is the equivalent of about 2-3% of today's transport fuel, because waste separation, re-use and recycling is expected to increase.

The oil and ethanol industry has decided to go down the route of strongly expanding sugarcane production in Brazil and in other dedicated areas around the equator in a sustainable way. But there are a few hurdles to overcome. The most important is probably the need for stable political conditions allowing payback of the huge investments to be made. This is also true for ethanol from grain and cellulosics in the USA. A large number of distilleries have been built in the USA under the RFS1 and RFS2. However, due to a number of unforeseen market factors and political uncertainties, the RFS2 targets for cellulosic and other advanced biofuels are not yet being met. Currently more than 50 billion litres of EtOH are produced in about 200 grain plants in the USA, but cellulosic ethanol production levels have only reached about 10 million litres. European biodiesel production is suffering even more, despite the promotion of 7% blending, for two reasons. The sometimes ill-informed discussion around 'food versus fuel' has completely dominated the attention of customers. In addition, the reaction against biodiesel has been influenced by the introduction of a full mineral oil tax by the German government.

The car industry is equally determined to develop highly efficient vehicles with alternative engines. However, yet again, political continuity is of crucial importance before large investments in new developments will be initiated. Volkswagen has designed a roadmap for the development of new vehicles, starting with gas fuel and moving into liquid biofuels and subsequently into partially and fully electricity driven cars. As a first step, conventional combustion engines will be improved. The question is, which biofuels should the engines be developed for first. Standards need to be established soon.

The jet aviation industry has advanced quite far in the standardisation of biofuels as drop-in fuels to match the performance of kerosene. Biofuels have not achieved too many flying hours yet, however they have proved their feasibility for a range of aeroplanes from a number of manufacturers.

The car industry is faced with an additional challenge – that of consumer behaviour and preferences. Often the consumers' expectations for cars are changing faster than new car models and types can advance. The biogas-driven car is a classic example. It is undisputedly one of the best and most sustainable powertrains available, but unfortunately consumers have turned their focus towards other solutions.

Providers of gas fuelling stations are touched by the same problem. Even though they have developed standardised compression and filling stations – thus reducing the investment cost – they cannot sell enough plants (at least not in Europe) to achieve the payback on their initial investment. Hence with the global recession there are not yet enough filling stations available. In Europe, the 1.4 million NGV are served by 3,700 filling stations, corresponding to 380 NGVS per station whereas usually 150 vehicles per station are standard for petrol.

Finland has somewhat different challenges for fuelling vehicles with biofuels due to its low population density and requirement for long driving distances under cold conditions. Electric cars are therefore not really an option, nor are gas fuelled cars, because gas grids are available only in the very south of the country. On the other hand, Finland has huge forests and a highly innovative forest industry. This, in combination with substantial support from the government, has made them one of the leaders in producing advanced liquid fuels from lignocellulosic sources. Even though only on a demonstration scale (except for hydro-treated biofuels), long term full-scale experiments with public buses have shown that Finland is on the right track.

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