niches

Clean vehicles and alternative fuels

Trends and visions

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SIXTH FRAMEWORK PROGRAMME

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Introduction

NICHES (New and Innovative Concepts for Helping European transport Sustainability) is a project supported by the Directorate General for Research of the European Commission. Its overall aim is to facilitate the coordination of research activities of academic institutions, industry, transport operators and authorities regarding key urban transport innovations that lack broad deployment. More specifically, NICHES promotes the most promising new urban transport concepts, initiatives and projects to move them from their current "niche" position to a "mainstream" urban transport policy application. The project thus wants to contribute to a more efficient and competitive transport system, a healthier environment and improved quality of life in urban areas. In order to explore these Innovative Concepts 4 thematic working groups were created within the project, namely:

- New Seamless Mobility Services
- Innovative Approaches in City Logistics
- New Non-polluting and Energy-efficient Vehicles
- Innovative Demand Management Strategies

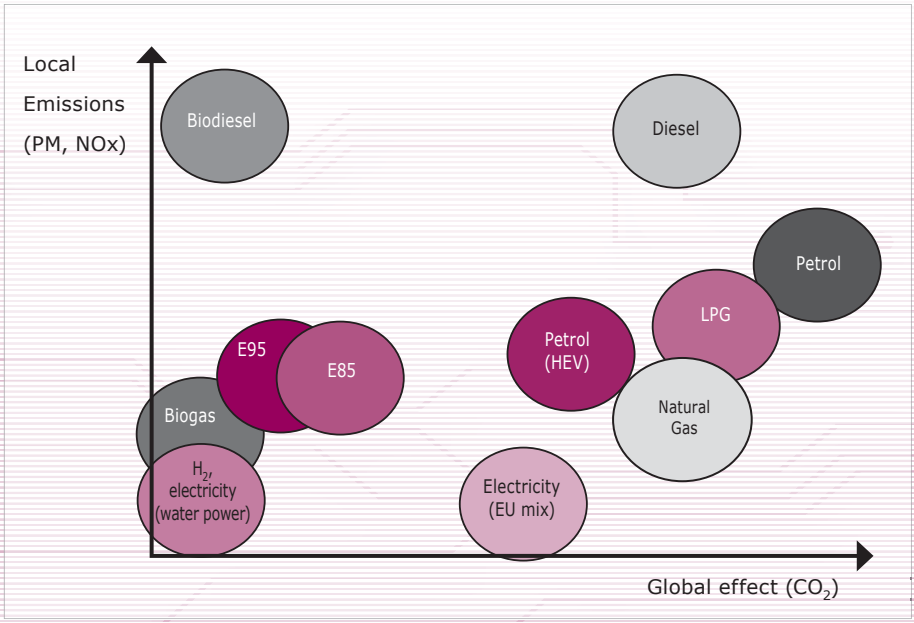
This publication is part of the research carried on within the working group "New Non-polluting and Energy-efficient Vehicles", lead by the City of Stockholm. It aims to provide an overview of the existing clean vehicle technology and fuels, their use and production, as well as the trends for the future in Europe, and an outlook to the USA and three emerging countries (China, Brazil and India).

Alternative Fuel Vehicles in Europe Today

The interest for alternative fuels is driven by an increasing concern for the environment. Different environmental problems however motivate different solutions. If climate change is the main concern, reduction of greenhouse gases is the answer. A non fossil alternative fuel such as biodiesel causes small levels of greenhouse gases but on the other hand significant amounts of local emissions (particulate matter and nitrogen oxides). In urban areas with air quality problems the use of fossil alternative fuels such as Liquified Petrol Gas (LPG) and natural gas is often motivated.

The figure below shows schematically the relation between local emissions and global effects for the most commonly used fossil (diesel, petrol, LPG and natural gas) and non-fossil (biodiesel, ethanol - E85 and E95 and biogas) fuels.

Figure 1: Local emissions in relation to global effects, for different fuels



Although environmental concern is a strong driving force to the increasing use of alternative fuels, the economic motives are often at least as strong. Rising oil prices, securing the energy supply, rural development and employment, are some of the additional motives for the EU and its member states, as well as other countries, to encourage the production and use of alternative fuels.

Policies

In 2001 the EU Commission presented a Communication on alternative fuels for road transportation and on a set of measures to promote the use of biofuels. Three alternative fuel solutions were identified that together have the potential to reach 20 percent substitution until 2020: biofuels, natural gas and hydrogen. The Biofuels Directive was presented in order to reach the goals for biofuels (2 percent by 2005, 5.75 percent by 2010).

The Commission also proposed targets for the introduction of natural gas as transport fuel: 2 percent by 2010, 5 percent by 2015 and 10 percent by 2020.
The main challenge is the establishment of new distribution infrastructure.
For hydrogen the Commission estimates that no substantial market penetration will take place before 2015. A 2 percent target by 2015 and 5 percent by 2020 have been set in the Communication. The Biofuel Directive will be reviewed by the Commission by the end of 2006 and new levels of ambition after 2010 will be set.

The EU Biofuels Directive has set the goal of obtaining 5.75 percent (energy content) of transportation fuel needs from biofuels by 2010 in all member states. The Directive aims at contributing to reduce the CO_2 emissions from transport, to improve the security of energy supply of the transport sector, and to create new opportunities for sustainable rural development.

Table 1:
National indicative targets for biofuel consumption for EU25 (2005)

Country	2003 Biofuel use	2005 Biofuel target
Austria	0.06%	2.5%
Belgium	0	2%
Cyprus	0	1%
Czech Republic	1.12%	3.7% (2006)
Denmark	0	0
Estonia	0	N/A
Finland	0.1%	0.1%
France	0.68%	2%
Germany	1.18%	2%
Greece	0	0.7%
Hungary	0	0.4-0.6%
Ireland	0	0.06%
Italy	0.5%	1%
Latvia	0.21%	2%
Lithuania	0 (assumed)	2%
Luxembourg	0 (assumed)	N/A
Malta	0.02%	0.3%
Netherlands	0.04%	2% (2006)
Poland	0.49%	0.5%
Portugal	0	2%
Slovakia	0.14%	2%
Slovenia	0	N/A
Spain	0.76%	2%
Sweden	1.33%	3%
United Kingdom	0.03%	0.3%

Source: ECA (2006)

Each member state must set national indicative targets in line with the reference percentages of the Biofuel Directive. The member states are free to choose a strategy to achieve these targets, either use biofuels in pure form in fleets or in blends with fossil fuels, or a combination of the two. There is however no obligation for the member states to use biofuels. Individual states can deviate from the reference values when justified, for example due to limited availability of biomass feedstock. A few examples of countries with goals set to 0 percent or close to 0 percent for 2005, for which the reference goal was 2 percent, are Denmark, Finland and Ireland. Most countries have not yet adopted a target for 2010.

In February 2006, the EU adopted a Strategy for Biofuels with a series of potential legislative and research measures to increase the production and use of biofuels. Germany and France, in particular, have announced plans to rapidly expand both the ethanol and biodiesel production, to reach the EU targets before the deadline.

European countries that have successfully introduced biofuels into their markets are France, Germany, Spain and Sweden. These countries have all given fiscal support for biofuels guaranteed for a longer term. In Sweden and Germany the motivations for the government support for biofuels has mainly been environmental concern, whereas in France and Spain the support for the agricultural sector has been in focus.

Malta, the Netherlands and the UK have not found current biofuels cost-effective enough. Malta and the UK hence have chosen to start with relatively small amounts of biofuels, giving only modest tax exemptions. The Netherlands and the UK have actively been developing policy instruments to encourage the introduction of more cost-effective biofuels.

Fossil alternative fuels

Natural gas

Fuel

Table 2: Emissions from Natural gas compared to petrol, as mass per energy content

NOx	-29%
SOx	-89%
CO	-81%
PM	-53%

Source: calculations based on IVL (2001)

Natural gas consists primarily of methane and other hydrocarbon gases. Natural gas vehicles cause lower emissions of carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx) and particulate matter (PM) compared to petrol vehicles. Natural gas is however a fossil fuel, therefore natural gas is not always considered a clean fuel alternative.

The emissions of green house gases from natural gas vehicles (in a life cycle perspective) is approximately 130 g CO_2 equivalents per kilometre, which is 23 percent less than from a conventional petrol vehicle.[1]

Vehicles

More than 40 different manufacturers, including Citroën, Fiat, Opel, Volkswagen, DaimlerChrysler, Ford, General Motors, Toyota and Volvo, currently produce NGVs (Natural Gas Vehicles). The number of NGVs worldwide is about 5 million. Most NGVs operate using compressed natural gas (CNG). The other alternative is liquid natural gas (LNG).

Market trends

Due to infrastructural limitations natural gas is often restricted to use in dedicated fleets: buses, taxis etc. Urban air quality and high oil prices have accelerated the use of natural gas for buses all around the globe. There were in 2005 more than 45 000 buses running on natural gas in Europe.

Of about 470,000 cars running on natural gas in Europe today, 400,000 are to be found in Italy. Possessing natural gas resources, Italy began building up its fleet long ago. In Germany close to 40,000 vehicles run on natural gas today. Most of these are personal cars but there is also a fair share of trucks. German incentives for NGV use is for instance a tax freeze.

In France the use of natural gas is promoted through tax incentives, subsidies for the purchase of NGVs, regulatory constraints that work in its favour as well as different supportive policies. NGV still represents only a very small proportion of the French market, but the French Natural Gas Vehicle Association (AFGNV) and the French ministry of economy, finance and industry, recently signed a memorandum of agreement targeting a fleet of 100,000 private cars by 2010. This would mean a large leap from the 6,000 cars of today.

CNG car

Photo: SUGRE EU projet, www.sugre.info

1 – Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, Overview of Results, EUCAR/JRC/CONCAWE slide 18 .

Table 3:
NGVs in Europe (2005)

Country	Total	Cars/LDVs	Buses	Trucks
Austria	584	580	2	2
Belarus	5,500			
Belgium	300			
Bosnia & Herzegovina	1	1		
Bulgaria	12,500	12,300	150	15
Croatia	100	100		
Czech Republic	390	300	90	
Finland	86	7	74	5
France	8,400	6,000	2,000	400
Germany	38,933	30,557	1,227	6,688
Iceland	50	46	2	2
Ireland	81			
Italy	402,300	400,000	1,800	500
Latvia	310	30	10	270
Liechtenstein	26	7	19	
Luxembourg	51	24	27	
Macedonia	32		32	
Moldavia	4,500			
Netherlands	540	165		385
Norway	147	70	77	
Poland	771	360	41	370
Portugal	242	8	234	
Russia	46,000	3,000	8,000	35,000
Serbia & Montenegro	95	93	2	
Slovakia	286	90	189	7
Spain	944	47	356	509
Sweden	7,880	7,039	565	276
Switzerland	2,081	1,985	70	26
Turkey	520	396	124	
Ukraine	67,000	7,000	30,500	29,500
United Kingdom	503	72	5	426
Total	**601,153**	**470,277**	**45,596**	**74,381**

Source: ENGVA

LPG

According to the World Liquefied Petroleum Gas Association (WLPGA) 10 million vehicles currently operate on Liquefied Petroleum Gas (LPG) in the world. When used in cars LPG is also known as "Autogas".

Fuel

LPG consists predominantly of propane, and is a by-product from crude oil refining (ca 40 percent) and natural gas processing (ca 60 percent). LPG is liquid at low pressure and ambient temperature, which simplifies storage and vehicle refuelling.

The environmental benefits of LPG compared to petrol include reduced emissions of nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO) and particulate matter (PM). The fuel does not contain lead or sulphur.

Table 4:
Emissions from LPG compared to petrol, as mass per energy content

NOx	-19%
SOx	-47%
CO	-79%
PM	-38%

Source: calculations based on IVL (2001)

The emissions of green house gases from LPG vehicles (in a life cycle perspective) is approximately 148 g CO_2 equivalents per kilometre, 12 percent less than for conventional petrol vehicles.[2]

Vehicles

LPG vehicles can be designed as such by original equipment manufacturers (OEMs), or converted from other fuel systems. A typical aftermarket conversion includes installing a new fuel tank, fuel pressure regulator, electric or vacuum-operated switches, and electronics.

Vehicles running on LPG can either be dedicated to LPG or be dual fuel vehicles, storing petrol and LPG in two separate tanks. Examples of manufacturers offering factory assembled bi-fuel LPGs are Volvo and Vauxhall Motors.

Market trends

LPG was first introduced as a motor fuel in the USA in 1912. It was introduced in Italy and the Netherlands in the 1950s and in France in the 1970s. But it was first in the 1990s that it gained wider spread popularity in these countries. Today the LPG market grows predominantly in developing countries.

According to the WLPGA, successful automotive LPG market depends on achieving critical mass. The number of vehicles must be large enough to show fuel providers that LPG is a viable business. The fuel must be widely available and convenient to consumers. The market must be large enough to ensure an adequate supply of equipment and mechanics trained to convert and maintain LPG vehicles. The market must be sustainable so that OEMs are willing to develop LPG vehicles.

Table 5:
LPG sales, vehicles and filling stations (2003)

Country	Sales of automotive LPG (tonnes)	Number of LPG vehicles	Number of LPG filling stations
Belgium & Luxembourg	100,000	93,000	600
Denmark	9,000	2,750	8
France	166,000	180,000	1,851
Germany	15,000	12,000	460
Hungary	39,300	75,000	483
Ireland	1,100	1,000	105
Italy	1,188,000	1,220,000	2,100
Netherland	440,000	290,000	2,100
Norway	3,000	2,000	39
Poland	1,770,000	1,100,000	4,500
Spain	18,000	4,000	36
Sweden	1,000	300	9
Turkey	1,141,000	1,000,000	4,000
United Kingdom	100,000	105,000	1,272
TOTAL	**4,991,400**	**4,085,050**	**17,613**

Source: AEGPL

2 – Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, Overview of Results, EUCAR/JRC/CONCAWE, slide 13

The largest European Autogas markets are Poland, Turkey and Italy. Autogas consumption in Poland increased by 20 percent between 2004 and 2005, and now represents 13 percent of the fuel market. In Turkey there are currently 1.5 million vehicles running on autogas, 20 percent of all cars. A rapid growth followed when the Turkish government subsidised LPG heavily in 2000, making autogas 70 percent cheaper than petrol. The growth of 300 percent in only a couple years was uncontrollable and many problems followed with incorrect and unsafe practices. Since then new safety regulations have been set into practice and tax incentives have been lowered. LPG is now 30 percent cheaper than petrol and the market is growing, but not at the same rapid pace.

Italy is home to more than 1.2 million LPG vehicles. The country is also a leading producer and marketer of LPG-related equipment. In Italy LPG has an excise tax advantage over petrol and diesel, and the government subsidises LPG conversion of buses, taxis, and some private vehicles. Furthermore, LPG vehicles are allowed to operate during smog alerts that limit operation of conventional vehicles.

In Europe, the only countries other than Poland and Turkey where autogas accounts for more than 10 percent of the automotive-fuel market are Bulgaria and Lithuania.

LPG also enjoys some popularity in for example the Netherlands, France and the UK. The LPG markets in these countries had a boost around year 2000, following rather generous government incentives.

About 5 percent of cars in the Netherlands run on LPG. The share has been slowly decreasing over the past years.

In France LPG sales have been stagnating over the past five years. The market has suffered from a poor public image following some highly publicised accidents. Other explanations are the limited range of factory-built cars available on the market and low efforts from car manufacturers and dealers to promote them. Furthermore, diesel vehicles represent close to 60 percent of France’s vehicle market, which limits the conversion potential.

The UK currently has 117,000 vehicles running on autogas. In 2005 the UK government withdrew a subsidy for converting petrol cars to LPG. This crippled the industry, dropping demand for LPG cars significantly.

LPG is not a big success in Germany, despite tax advantages in comparison to petrol. Part of the explanation is the competition from natural gas and the market dominance of diesel vehicles.

In Spain the fuel is used almost exclusively in taxis and buses and the market has been slightly declining.

Biofuels

In 2005 a total of 3.9 million tonnes of liquid biofuel was produced in the EU, 1/5 comprised of ethanol and 4/5 of biodiesel.

Bioethanol

Fuel

Bioethanol fuel is mainly produced by a sugar fermentation process. Sugar cane is the most important crop for producing bioethanol today followed by corn. There is also ongoing research and development into the use of cellulose to produce ethanol fuel.

Table 6: Emissions from ethanol, e85, (sulphite) compared to petrol, as mass per energy content

NOx	-33%
SOx	-90%
CO	-72%
PM	-56%

Source: calculations based on IVL (2001)

Ethanol burns to produce carbon dioxide and water. It is a high octane fuel and has replaced lead as an octane enhancer in petrol. By blending ethanol with petrol the fuel mixture is oxygenated. It burns more completely and reduces polluting emissions. Low fuel blends of ethanol (as ethanol or ETBE) are widely sold. In Sweden ordinary petrol is blended up to 5 percent with ethanol. The most common blend in the USA is 10 percent ethanol (E10). Only flexi-fuel vehicles (FFVs) can run on up to 85 percent ethanol and 15 percent petrol blends (E85).

Greenhouse gas emissions caused by bioethanol is very dependant on the circumstances under which the fuel is produced. Using the best available technology and best suited feedstock, E85 emissions (in a life cycle perspective) can be as low as 40 g CO_2 equivalents per kilometre, about 75 percent less than for conventional petrol vehicles.[3]

The sugar based ethanol production is known as "first generation" ethanol. There are also advanced techniques for producing ethanol from cellulose biomass. The future ability of producing ethanol from cellulose biomass such as wood, grasses and crop residues, implies considerably larger fuel production potential as well as local production opportunities for a wider range of countries. It also would mean less interference with the food economy.

The second generation of biofuel technologies, lignocellulose processing, is already in a pilot phase in Sweden, Denmark and Spain. Biofuel industries in the North of Sweden will start building two large-scale production units (CHP) for cellulose based ethanol that will start delivering fuel during 2009. It is however generally believed that second generation bioethanol will not get a broad breakthrough on the market in the coming decade.

Choice at the pump
Photo: Kristina Birath

3 – Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, Overview of Results, EUCAR/JRC/CONCAWE, slide 45.

Vehicles

Ford, Saab, Volvo and Renault have introduced ethanol vehicles on the European market. New models come out on the market every year. Citroën, Peugeot and Audi will also launch ethanol driven vehicles in 2007 and 2008. Volkswagen and Mercedes have flexi-fuel vehicles in Brazil and can be expected to present models in Europe as well.

The next step will be to increase the energy efficiency of the cars. One way is to apply the hybrid electric technology (see also section Electric Drive). Toyota introduces the Toyota Prius FFV in Brazil during 2007. Saab has a concept plug-in hybrid E100 car that will be in production in 2010.

A Ford Focus FFV
Photo: Kristina Birath

Market trends

The production of bioethanol doubled during the period of 2000-2005. In 2005, Brazil produced 16.5 billion litres of fuel ethanol, 45.2 percent of the world's total. The second largest ethanol producer is the United States at 16.2 billion litres, or 44.5 percent of the total.

Table 7:
Ethanol production in the European Union in 2004 and 2005, in tonnes

Country	2004	2005	Change
Czech Republic	-	1,120	-
Finland	3,768	36,800	877%
France	80,887	99,780	23%
Germany	20,000	120,000	500%
Hungary	-	11,840	-
Latvia	9,800	960	-90%
Lithuania	-	6,296	
Netherlands	11,146	5,971	-46%
Poland	38,270	68,000	78%
Spain	202,354	240,000	19%
Sweden	56,529	130,160	130%
EU	422,754	721,927	71%

Source: Biofuels Barometer 2006, EurObserver

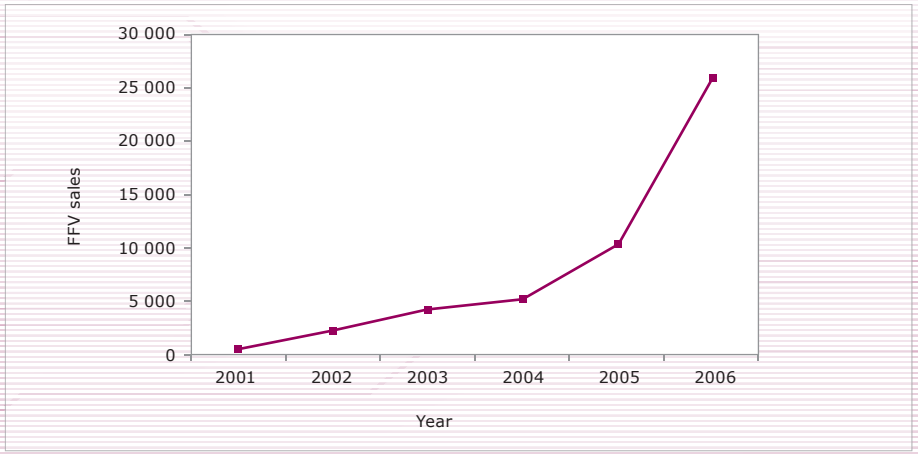
Total production of bioethanol in Europe amounted to 0.7 million tonnes in 2005. The largest European bioethanol producer is Spain, followed by Sweden and Germany. France used to be Europe's second largest ethanol producer, and is now in fourth place, having been surpassed by Sweden and Germany. In France bioethanol is mainly converted to ETBE, an oxygenate for petrol. Also in Spain ethanol is mainly used as ETBE.

Today ethanol is used as low-blends in many countries. In 2004 a Swedish national committee[4] concluded that in order to reach the goals in the Biofuel Directive it will be necessary to introduce high blends of ethanol.

The availability of high blend ethanol is expected to increase. There are today 600 fuel stations for E85 in Sweden. The increasing availability of E85 is making way for increasing FFV sales. In Sweden the FFV market is growing quickly. In 2006 the number of FFVs sold almost three times larger than in 2005.

Other countries selling E85 are Ireland, the UK, Italy and the Netherlands. During 2006 50-70 E85 fuel stations will have opened in Germany. Also France will introduce E85 and expects to have 500 fuel stations by 2009.

Figure 2: Flexi-fuel vehicle sales in Sweden 2001-2006



4 – SOU 2004:4

Biodiesel

Fuel

Biodiesel is made from plant oils, animal tallow or recycled cooking oils through a chemical process to remove glycerine and yield methyl or ethyl esters (Fatty Acid Methyl Ester, FAME) optimised for combustion.
Biodiesel itself is non toxic, non-flammable and non-volatile, making it safe to handle and store. When blended with diesel or burned as a pure fuel, biodiesel can significantly reduce diesel engine exhaust particulate matter (PM), sulphur oxides (SOx) and toxics. Biodiesel does however imply increased emissions of nitrogen oxides (NOx) and carbon monoxide (CO).

The emissions of greenhouse gases (in a life cycle perspective) is very dependant on the technology and feedstock used in the production. With the best available technology and suitable feedstock, GHG-emissions can be as low as 30 g CO_2 equivalents per kilometre, 81 percent less than for conventional petrol vehicles.[5]

All diesel engines operate at extremely high pressures and require good lubrication in the fuel to prevent wear. One important benefit of biodiesel is that it adds needed lubrication to diesel fuel.

Table 8: Emissions from biodiesel compared to conventional diesel, as mass per energy content

NOx	-32%
SOx	-5%
CO	13%
PM	-12%

Source: calculations based on IVL (2001)

Vehicles

Biodiesel can be used in its pure form, "neat biodiesel", (B100). But this requires modifications of the diesel engine. It is usually blended with standard diesel fuel.
A common blend that is mostly used for transport vehicles is 20 percent biodiesel (B20).

A share of five per cent biodiesel (B5) can be admixed to diesel without changing engine technology. As more and more governments (Germany and Sweden for instance) allow B5 to be sold as regular diesel, many large oil companies have begun admixing. In the start-up phase many companies have however experienced problems with viscosity at winter temperatures, causing cold start problems. This problem can however be solved by using an extra additive. The fact hat these problems have occurred highlights the issue of a lack of standardisation.

Market trends

Nearly 90 percent of all biodiesel worldwide is produced in Europe. The main feedstock of European biodiesel is rape seed. Biodiesel has been produced on an industrial scale in the EU since 1992. Today, there are approximately 120 plants. In 2005 the total European biodiesel production was 3 million tonnes, 65 percent more than in 2004.

Germany stands for more than half of this production. The three largest producers, Germany, France and Italy, together make up 80 percent of the total European biodiesel production. The German Biofuels Industry Association (VDB) is now concerned that Germany is moving towards biodiesel overcapacity. In 2006, biodiesel sales are expected to reach 2.5 million tonnes while production capacity is expected to reach 4.2 million tonnes.

5 – Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, Overview of Results, EUCAR/JRC/CONCAWE, slide 46

The second largest European biodiesel producer is France, producing close to 0.5 million tonnes in 2005. The French government plans to expand the tax-favoured production capacities for biofuels, and between 2008 and 2010 France wants to increase the capacities for biodiesel by 700,000 tonnes.

Table 9:
European biodiesel production (2005)

Country	Production 2005 (tonnes)	Change 2004-2005
Austria	85,000	49 %
Belgium	1,000	0
Cyprus	1,000	0
Czech Rep.	133,000	122%
Denmark	71,000	1.4 %
Estonia	7,000	0
France	492,000	41%
Germany	1,669,000	61%
Greece	3,000	0
Italy	396,000	24%
Latvia	5,000	0
Lithuania	7,000	40%
Malta	2,000	0
Poland	100,000	0
Portugal	1,000	0
Slovakia	78,000	420%
Slovenia	8,000	0
Spain	73,000	462%
Sweden	1,000	-29%
UK	51,000	467%
EU	3,184,000	65 %

Source: European Biodiesel Board

According to VDB there is enough land in Germany to grow the quantities of rapeseed needed to meet the 5.75 percent target, in a sustainable manner. Countries with large areas and relatively large populations such as France, Spain, Italy or the United Kingdom would probably also be able to reach the EU goals with their own raw materials according to VDB. If the biofuels share is to exceed 5.75 percent, other fuels, such as cellulose ethanol, biomass-to-liquid (BtL) or biogas would have to come on to the market.

Biodiesel represents 2 percent of the total European transportation consumption. According to the European Biodiesel Board the fact that only 5 percent biodiesel is allowed blended in conventional diesel constitutes a major obstacle in order to guarantee a further development of biodiesel, especially in Member States (e.g. Germany and France) that have taken a lead in the production and the use of biofuels and biodiesel and are ready to go further.

The European biodiesel production per country in 2005 is shown table 9. The table also shows the change compared to 2004. Altogether the European biodiesel production increased by 65 percent between these two years. The output increased or remained constant in all biodiesel producing countries except Sweden.

A new kind of biodiesel will be produced by the Finnish company NESTE, NExBTL. The first plant will be ready in mid 2007. The biodiesel is made from vegetable oils and animal fat.

Biogas

Methane for vehicle use does not have to be from fossil sources. It can also be obtained by fermenting organic matter. This methane is known as biogas.

Fuel

Biogas is produced by the anaerobic digestion or fermentation of organic matter including manure, sewage sludge, municipal solid waste, biodegradable waste or any other biodegradable feedstock, under anaerobic conditions. To be used as motor fuel the biogas has to be upgraded to natural gas quality.

Emissions of greenhouse gases caused by biogas (in a life cycle perspective) is highly dependant on the crude material used. Biogas from municipal waste causes approximately 30 g CO_2 equivalents per kilometre, 81 percent less than for conventional petrol vehicles. Manure is even more GHG-efficient. Using liquid manure stops methane emissions to the atmosphere, leading to "negative" emissions of green house gases, -150 g CO_2 equivalents per kilometre.

Other environmental benefits of biogas compared to petrol include reduced emissions of nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO) and particulate matter (PM).

Table 10: Biogas emissions compared to conventional petrol, as mass per energy content

NOx	-32%
SOx	-86%
CO	-80%
PM	-22%

Source: calculations based on IVL (2001)

Vehicles

Biogas for transport is chemically equal to natural gas and can thus be used in ordinary natural gas vehicles. So far however, only Sweden and Switzerland have considerable amounts of NGVs actually driving on biogas.

Market trends

Recently, developed countries have been making increasing use of biogas generated from both wastewater and landfill sites or produced by mechanical biological treatment systems for municipal waste.

The biogas market for vehicle applications has thus far been limited. For economic reasons more direct applications of biogas such as for heating or electric power are more widely spread. In countries with a strong natural gas and NGV sector the interest for biogas production has now however started to grow.

Both Austria and Germany have in 2006 set up voluntary agreements between the gas industry, the government and the biogas producers to increase the ratio of renewable fuel in the natural gas supplied as vehicle fuel.

Germany is the European country with the strongest growth in the biogas production sector. There are currently more than 3 000 biogas plants in Germany. The strong development of the biogas production sector together with a rapid development of the NGV-sector has now created the possibility to use biogas also in the transport sector.

Austria is another large producer of biogas for energy use, but here there are so far only around 700 NGVs. To promote the use of biogas in the transport sector the Austrian government has signed an agreement with the oil and gas company OMV.

The agreement includes favourable frame conditions for acquisitions of NGVs, enhanced national program for NGV refuelling infrastructure and biogas production, reduced taxation for gaseous fuels, and improved technical and legislative framework for biogas injection into the natural gas grid.

Sweden is ground-breaking when it comes to biogas in transport. Sweden started to produce biogas as vehicle fuel in a larger scale in 1996. Methane accounts for 0.5% of the Swedish road fuels. More than 50 percent of this methane comes from renewable sources.

The development has been driven by the gas industry in cooperation with regional authorities. An important driver to the success is the Governmental programs to introduce clean urban bus fleets. The urban market development was followed by biogas supply to cars. Biogas vehicles however now see more and more competition from other clean vehicles. FFVs have sold ten times better than bi-fuel gas vehicles in 2006. One consequence is that Volvo has announced that they will stop producing bi-fuel cars due to the limited demand.

E20 Highway between Stockholm and Gothenburg will be fully equipped with biogas infrastructure by 2009.

Electric Drive

There are several ways of letting electricity run a vehicle.

Fuel

The advantage of electric vehicles is the low emissions, at least locally. Electricity is not a fuel per se, but an energy carrier. The emissions caused are hence associated with the electricity production (nuclear, wind, water, coal etc).

In recent years the use of "internal power plants" in conventional petrol vehicles has become more and more common, utilising energy that would otherwise go to waste as heat. This principle is more commonly known as electric hybrid. The hybrid technology can reduce the consumption of petrol and hence the emissions caused, by 15 percent.[6]

Table 11: Emissions from hybrid electric vehicles compared to conventional petrol vehicles, as mass per energy content

NOx	-15%
SOx	-15%
CO	-15%
PM	-15%

Source: calculations based on IVL (2001)

The fuel cell technology is also a way of letting electricity run the vehicle. A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity, with water and heat as its by-product. As long as fuel is supplied, the fuel cell will continue to generate power. Since the conversion of the fuel to energy takes place via an electrochemical process, not combustion, the process is clean, quiet and highly efficient.

Fuel cells are often seen as the optimal fuel solution. Tailpipe emissions are almost none. The method of production of the hydrogen needed however is crucial. With electricity production from renewable sources Green House Gas (GHG) emissions are almost zero. Hydrogen produced through electrolysis, with electricity produced with coal (EU-mix) however implies GHG emissions of 400 g CO_2 equivalents per kilometre, more than double the GHGemissions caused by conventional petrol vehicles.

Table 12: Emissions from fuel cell vehicles compared to conventional petrol, as mass per energy content

NOx	-97%
SOx	-99%
CO	-99%
PM	-95%

Source: calculations based on IVL (2001)

Vehicles

Hybrid electric vehicles (HEVs) have been on the European market since 2000. The two main manufacturers so far are Toyota (Prius) and Honda (Civic and Insight). Today's HEVs are powered by an internal combustion engine as well as electric motors. The result is a better mileage and reduced emissions.

6 – Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, Overview of Results, EUCAR/JRC/CONCAWE, slide 21

Market trends

The success of the hybrid technology has encouraged more and more manufacturers to produce or announce plans to produce HEVs, including models running on alternative fuels instead of petrol.

A disadvantage of traditional electric vehicles has been their limited range. Existing electric vehicles are not suitable for long distance driving. The solution may be the PHEV (plug-in hybrid electric vehicle), that is said to be on its way. The PHEV combines the successful electric hybrid idea with traditional electric vehicle technology. Some hybrid electric vehicles have already been converted to plug-ins, although this solution is not yet commercially available.

Today, fuel cells are very expensive, but improved technology and mass production will reduce costs in the future. Moreover the infrastructure of hydrogen fuelling stations required to make fuel cell vehicles an option for more than demonstration projects are not in place.

Most manufacturers have fuel cell development projects. The objective of General Motors for example is to: "Design and evaluate automotive competitive fuel cell propulsion system by 2010", where "automotive competitive" refers to a system that has the performance, durability and cost (at scale volumes) of today's internal combustion engine systems.

In September 2006 Shell Hydrogen and Total France, along with the vehicle manufacturers BMW, DaimlerChrysler, Ford, General Motors, MAN and Volkswagen announced their joint approach to advance hydrogen as a fuel for road transport in Europe. While each company is pursuing its own specific timelines, the group has commonly identified key phases over the next decade, comprising continuous technology development and cost reduction, pre-commercial technology refinement and market preparation, with commercialisation of hydrogen powered vehicles potentially starting around 2015.

Biomass to Liquid

FT-diesel, DME, hydrogen, methanol and ethanol can also be produced from synthetic gas derived from gasification of biomass. The same fuels can also be produced from coal and gas (CTL, coal-to-liquid and GTL, gas-to-liquid). Several companies and research institutes are at present developing processes for production of BTL-fuels on a pilot scale.

Visions for Europe

It is hard to tell what the future has in store for alternative fuels in Europe. Depending on the paths chosen we can expect different outcomes.

The EU so far focuses on biofuel production and use. Biofuels are naturally also the focus of the Biofuels Research and Advisory Council. Their vision for the year 2030 is that the European Union covers one fourth of its road transport fuel needs by clean and CO_2-efficient biofuels, and that a substantial part is provided by a competitive European industry. This significantly decreases the EU fossil fuel import dependence. Biofuels are produced using sustainable and innovative technologies; these create opportunities for biomass providers, biofuel producers and the automotive industry.

The Biofuels Research and Advisory Council have identified the required steps for development to ensure a large scale deployment of biofuels by 2020-2030:

- In the short term (until 2010): existing technologies should be improved and R&D into second generation biofuels and a bio-refinery concept should be carried out. The first second generation demonstration plants should also be set into practice.
- In the medium term (2010-2020): the deployment of second generation biofuel should be implemented. There should be demonstrations of the bio-refinery concept, and continued R&D to improve lingo cellulose biofuels and integrated bio-refinery processes. There should also be development of options for energy crops and sustainable agriculture.
- In the long term (beyond 2030): there should be large scale production of second generation biofuels and deployment of integrated bio-refining complexes.

The Biofuels Research and Advisory Council do not find a penetration of the transport market for fuel cells probable even as far off as 2030. According to the Biofuels Research and Advisory Council the current engine technologies will still prevail until 2030, and biofuels will mostly be used in petrol and diesel internal combustion engines. They do however find it possible that specialised power trains (as for instance fuel cells) will be used in certain applications or in dedicated fleets. They also believe that biogas is likely to replace an increasing share of fossil natural gas. Biomethane could, if serious developments now start in a number of countries, provide for an additional 4 percent or more by this year. In a 2030 or 2040 perspective biogas could account for at least 20-30 percent according to ENGVA, providing such development is supported by legislative action.

The costs of biofuel production will be reduced through an economy of scale effect and a better integration into the fuel supply chain. The Biofuels Research and Advisory Council also address the question of sustainability. Production of feedstock supplies need to be assessed globally, taking account of different growing conditions and labour costs.

An important next step will be more efficient use of the biofuels, when hybrid systems are introduced in combination with biofuels. Toyota will soon introduce a Flexi-fuel Prius in Brazil and other combinations of biofuels and hybrid systems will follow suit.

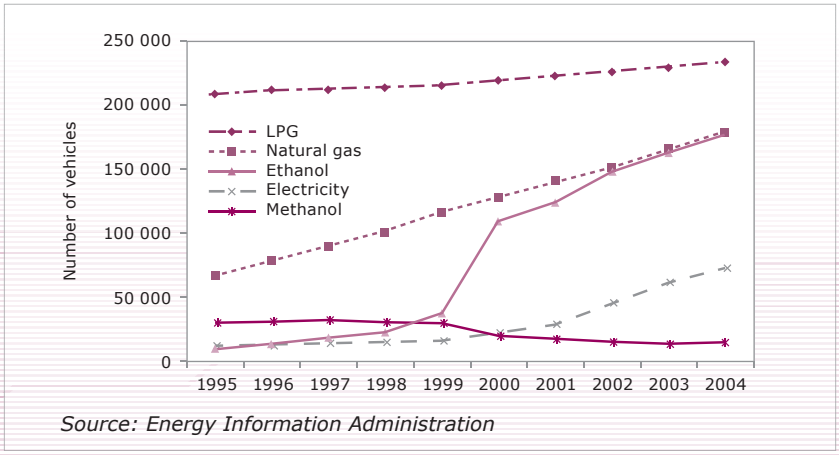
An outlook

This chapter provides an outlook to four interesting alternative fuel markets outside of Europe: USA, China, Brazil and India.

USA

The US market for alternative fuels and alternatively fuelled vehicles is still limited. Less than 2 percent of current US car sales are alternatively fuelled vehicles. Alternatively fuelled vehicle sales are however increasing rapidly, especially electric hybrids and flexi-fuel ethanol vehicles.

Figure 3: Alternatively fuelled vehicles in the USA 1995-2004. ("Electricity" does not include hybrid electric vehicles)



Source: Energy Information Administration

Legislation such as the Clean Air Act Amendments (CAAA) and first Energy Policy Act 1992 and now Energy Policy Act 2005 has helped to open the market for alternative fuels in the USA. Also the JOBS Act of 2004 has given a boost to the domestic production of alternative fuels such as ethanol and biodiesel.

The US Energy Policy Act of 2005 ("EPAct 2005"), implies several commitments of the US government towards the alternative fuel sector. The Environmental Protection Agency responsible to ensure that petrol sold in the United States contains a minimum volume of renewable fuel. A national Renewable Fuel Program (also known as the

Table 13:
Estimated distribution of Alternatively Fuelled Vehicles in Use in the United States per Census Region (2003).
("Electricity" does not include hybrid electric vehicles)

Fuel	Northeast	South	Midwest	West	Total
LPG	5%	47%	19%	29%	100%
Natural gas	18%	31%	11%	39%	100%
Ethanol	12%	38%	28%	22%	100%
Electricity	31%	22%	6%	41%	100%
Methanol	4%	5%	4%	87%	100%
Total	**13%**	**38%**	**18%**	**31%**	**100%**

Source: Energy Information Administration

Renewable Fuel Standard Program or RFS Program) will increase the volume of renewable fuel required to be blended into petrol. RFS will require the use of 7.5 billion gallons (28 million m^3) of biofuels for transportation by 2012.
The EPAct 2005 also includes funding for several types of development and pilot projects, a few examples are: a research program to advance commercialisation of hybrid flexi-fuel vehicles or plug-in hybrid flexi-fuel vehicles, a fuel cell school bus demonstration program and a biodiesel engine testing program.

The EPAct also provides tax credits for purchases of new alternative fuel vehicles: light-, medium- and heavy-duty fuel cell, hybrid and dedicated natural gas, propane (LPG) and hydrogen vehicles. Light-duty lean burn diesel vehicles are also eligible. There are also tax credits for alternative fuel infrastructure and biofuel production.

Fossil alternative fuels

Natural gas and LPG used to be the main alternative fuels in the USA. Like for other alternative fuel vehicles also the market for LPGs and NGVs are growing, but they are nonetheless losing market shares to ethanol vehicles and hybrids.

Today there are more than 200,000 LPG vehicles in the United States. About 50 percent of these are found in the southern states.

In 2005 there was a total of 130,000 light duty NGVs in the US. These are primarily fleet vehicles, for instance taxis, government and police. NGVs are mostly found in the north eastern and western states.

Biofuels

Current biofuel use in the US represents around 1.5 percent of transport fuels on energy basis. Taking into account the anticipated biofuel increase by 2012, biofuels would represent around 2.5 percent of fuel consumption on energy basis in the US in 2012.

Concerning biofuels the focus in the United States has mainly been on ethanol. The US government has since 1978 maintained national tax incentives to encourage ethanol fuel production and use.

Ethanol

Ethanol is the fastest growing alternative fuel in the USA. Rising oil prices and concern about the oil supply has raised the interest. Being produced primarily from corn it also sees strong support from the farming lobby. The federal ethanol fuel incentives, primarily the reduced tax on ethanol/petrol blends, are however generally acknowledged as the driving force for ethanol production and use. A tax credit to small producers contributes to a trend toward more producers and smaller plants.

In 2005 the production of ethanol in the USA 2005 was 16 million m^3, and it is expected to almost double by 2012. Almost all ethanol is used in the blended market at levels of up to 10 percent by volume. Today approximately 30 percent of all US petrol is blended with ethanol.

Ethanol vehicles are especially popular in the Midwest, where also the production of ethanol is predominately concentrated, due to the abundant supplies of corn.

Flexi-fuel vehicles are a success in the US. Until 2005 a total of 4 million FFVs had been introduced to the US market. However many never run on ethanol, having been sold as standard models. The US auto industry has thus been accused of equipping vehicles with flexi-fuel technology just to gain fuel economy credits. EPAct 2005 now requires automobile manufacturers to label all dual-fuel vehicles to inform the owners that the vehicle can be operated with an alternative fuel, in this case E85.

Biodiesel

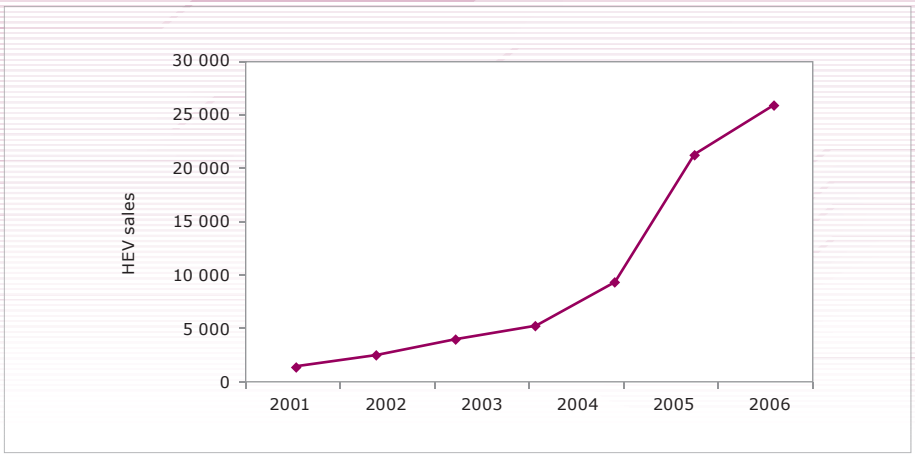
US biodiesel production is also growing at a rapid rate. The production of biodiesel was threefold in 2005 compared to 2004, 78 million gallons (295,000 m^3) compared to 25 million gallons (95,000 m^3). The total of biodiesel sold is still less than 0.5 percent of all diesel. The limited use of biodiesel so far can partly be explained by the relatively low fraction of diesel use. The most common biodiesel blend today is B20.

The primary source for US biodiesel production is soybean. This is not the most efficient crop for biodiesel production. The dominance has more to do with its common use in US food products.

Electric drive

Hybrids are the alternative vehicles causing the most "buzz" in the USA. Since the first hybrid electric model, Honda Insight, was introduced to the American market in 1999, sales have grown every year. In 2005 more than 200,000 hybrids were sold in the US, 1.3 percent of total car sales. One fourth of all hybrids were sold in California. In 2006 the HEV sales passed 250,000.

Figure 4: Number of hybrid electric vehicle sales in the USA, 2000-2006



Source: EDTA & Green Car Congress

There are currently about 10 hybrid models on the US market. Toyota's models dominate, answering for 75 percent of all HEV sales in 2006.

As in many other areas concerning alternative fuels, California is taking a lead in hydrogen infrastructure and fuel cell vehicles. The "Vision 2010" for California's Hydrogen Highways is to ensure that by the end of the decade every Californian has access to hydrogen fuel along the State's major highways, with a significant and increasing percentage of that hydrogen produced from clean, renewable sources. One major hurdle for a fuel cell technology break through in the commercial transport sector is the lack of hydrogen infrastructure. Under the Energy Policy Act federal fleets are required to begin purchasing or leasing fuel cell vehicles and hydrogen energy systems no later than 2010. The US Department of Energy has set targets to address major problems of cost, durability, hydrogen production and storage of hydrogen.

Visions for USA

According to the Biomass Technical Advisory Committee, established by the Biomass R&D Act of 2000, in the US biofuels will stand for 4 percent of transport fuels in 2010, 10 percent in 2020 and 20 percent in 2030. This was formulated in their "Vision for Bioenergy & Biobased Products in the United States" in 2002.

China

This section is based on an interview with Professor Dehua Liu of Tsinghua University, Beijing.

Today

In recent years, China has made great progress in the use of renewable energy resources with the average growth rate per year exceeding 25 percent.

Table 14: Renewable energy capacity in China (2004)

Renewable energy	Annual capacity
hydropower	110 million kW
wind-power	760 000 kW
solar-energy photovoltaic cells	60 000 kW
biogas	5.5 billion m^3

Since 2001, bioethanol (E10) is used in transport. By the end of 2005, the total E10 consumption has reached more than 10 million tonnes, which equals about 20 percent of total petrol consumption in China in 2005. Biodiesel has attracted more and more attentions and some biodiesel factories have been (or are being) built in China. The standard of biodiesel has been compiled and is waiting for approval and issued.

Since 1999, the Chinese government has encouraged research and development of clean vehicles, including cars using alternative fuels, electric cars, hybrid cars and fuel cell cars. The state invested more than 1 billion yuan (120 million US dollars) into research and development, producing 22 technical standards for electric cars manufacturing and 40 standards for alternative fuel cars.

The costs of clean fuels are usually much higher than petrol/diesel. China has no incentive policy for clean vehicles. China adopts the same tax for all the fuels. The prices of clean vehicles are also usually much higher than the conventional vehicles.

By the end of 2001, there were 109,650 clean vehicles in total in China, 77 percent of these were LPG vehicles and 22 percent were CNG vehicles.

During 2005-2009 a total of 100 flexi-fuel vehicles and 4 E95 buses are going to be demonstrated in China, as a part of the EU supported BEST project. During the project 30 E85 fuelling stations will be built.

Trends

There is an increasing need and interest for clean fuels in China. It is proposed by China National Development & Reform Commission (NDRC) that, the substitute biofuel will reach 2 million tonnes in 2010. Furthermore an official of China's Ministry of Science and Technology has claimed that 90 percent of public buses and 70 percent of taxis will be clean vehicles in Beijing in 2008, when Beijing hosts the Olympics. By this year, Shanghai, China's most populated city and a financial hub, will have at least 1,000 clean electric vehicles, including 20 to 30 fuel cell cars.

Clean vehicles are now also attracting the attention of domestic auto manufactories, and NDRC is considering encouraging Chinese auto manufacturers to develop FFVs. There is however a shortage in biofuel sources that need to be addressed. Part of the solution could be the development and demonstration of technology on ethanol from cellulose that is gaining more and more interest.

Visions for China

NDRC have proposed that the substitute biofuel will reach 10 million ton in 2020. Professor Liu predicts that the share of clean vehicles in China will continue to grow, reaching approximately 10 percent in 2020. The alternative fuels in use will be bioethanol including second generation ethanol from lignocellulose biomass, biodiesel and probably DME from biomass.

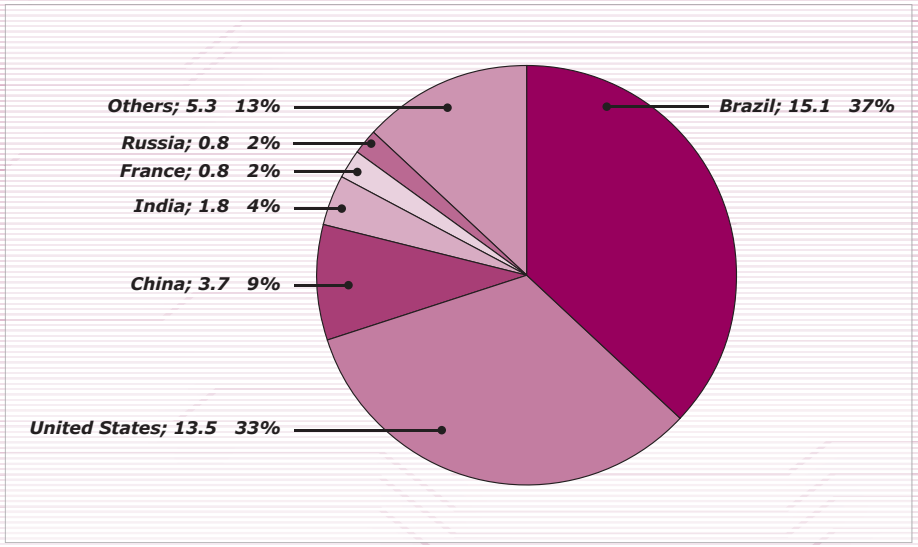
Brazil

Brazil has a unique alternative fuel market. The country is the world's leading producer of ethanol, and has a vehicle stock consisting of more than 20 percent of ethanol vehicles. This unique position of ethanol in the transport market is a result of a purposeful venture of the Brazilian government.

The Brazilian government launched its National Fuel Alcohol Program, Proalcool, in 1975, following the oil crisis. The vision was to make Brazil self-supporting when it comes to energy for transportation. The first phase of the programme 1975-1979 aimed at facilitating distillery expansions and higher conversion rates in the mixture gasoline-alcohol. In phase two, from 1980, the government kept authorising and subsidising the expansion of sugarcane production capacity and industrial investments in mills and distilleries, and vehicle manufacturers started producing dedicated ethanol cars with the technology developed in universities and research centres. In the mid 1980s the majority of new cars sold were ethanol cars.

As the decade progressed the military government was replaced by democracy, oil prices dropped and the subsidies to ethanol producers were gradually pulled away as a part of economic reforms caused by serious inflation problems. Sugar processing plants turned from ethanol to edible sugar, creating a shortage of ethanol supplies at fuelling stations. By the mid 1990s car manufacturers had stopped producing ethanol cars almost entirely.

Figure 5:
World ethanol production in 2004, million m³ and percent



After the backlash of the late 1980s and early 1990s ethanol has now regained its former status on the Brazilian fuel market, much thanks to rising oil prices, increased efficiency in the ethanol production, new government credits to the ethanol fuel industry, and the introduction of the flexi-fuel technology to the Brazilian vehicle market.

Fuels

The ethanol sold as fuel domestically in Brazil is either "neat" (94 percent ethanol and 4 percent water) or a gasoline blend of 78 percent gasoline and 22 percent ethanol.

The main feedstock for Brazilian ethanol production is sugarcane. This means that the fuel production is sensitive to not only the price of oil, but also the price and demand of sugar. Brazil has proved to have a rather unique and volatile ethanol market. It is a large exporter, but has in periods also been a large importer of ethanol. Some reasons for this instability in the ethanol production are fluctuations in crop yields (caused by climate) as well as fluctuations in the sugar market.

A natural gas distribution network is in construction in a large portion of the country. For a long time the known natural gas reserves in Brazil were located in the Amazon region, very far from the consumption market. Just recently, with the help of new developed technologies applied to deep ocean exploration, it has become possible to identify large gas reserves, closer to the consumption points.

NGV fuelling stations have been a powerful feasibility instrument to justify the construction of pipelines in areas that otherwise may not have been viable. Brazil today has more than a thousand stations selling natural gas as fuel spread throughout 140 cities. Most of these facilities are multiple fuel filling stations.

Vehicles

Dedicated ethanol vehicles came into the market in 1980, as a part of the Proalcool program. Ethanol vehicle sales peaked in the mid 1980s, dominating all vehicle sales. The 1990s saw a drop in ethanol vehicle sales, caused partly by an uncertainty of fuel supply. Still in the late 1990s more than 20 percent (4.6 million) of all cars in Brazil were ethanol vehicles.

When flexi-fuel vehicles were introduced to the Brazilian market, providing the possibility to use gasoline in times of shortage of ethanol, they were a success. Flexi-fuel cars represented 22 percent of the car sales in 2004, and 53 percent in 2005. Manufacturers selling FFVs on the Brazilian market include Chevrolet, Fiat, Ford, Peugeot, Renault and Volkswagen.

Natural gas was introduced as a fuel for light vehicles in 1996. There are now close to 1 million vehicles on Brazil's roads. This makes Brazil the second largest NGV market after Argentina. Most of these vehicles are aftermarket converted taxicabs or commercial medium duty vehicles.

Visions for Brazil

With a unique presence of ethanol in the fuel market, Brazil is believed to continue on its path towards oil independence. Flexi-fuel vehicles are predicted to reach close to 100 percent of all car sales in the immediate future. The next step for Brazil is getting into the production of second generation ethanol.

India

India has one of the fastest growing economies in the world, and fuel consumption is rising with an average of around 5 percent per year. This will seriously increase India's dependence on imported oil. Measures are now taken to rid this dependence.

Another important driving force for introduction of alternative fuels is air pollution. India's urban pollution levels are among the worst in the world. Since the early 1990s, several Indian cities have taken steps to improve their increasingly compromised air quality, including introduction of buses and taxis powered by compressed natural gas (CNG) or LPG.

Fuels

Despite an existing ethanol production in India (for non fuel purposes) the process of introducing low blends of ethanol to the petrol market has been held back by such factors as lack of appropriate policy framework, price agreements, reluctance of domestic oil companies and insufficient supply of feedstock.

India produces 1.2-1.8 million m^3 of ethanol per year, most of it for potable or industrial use. The feedstock used is surplus of sugar and molasses.

A government program was introduced in 2003, with the aim to gradually introduce ethanol as a blend in petrol. In the first phase 5 percent ethanol would be admixed to petrol in the entire country and subsequently the share would be increased to 10 percent. In 2003-2004 there was a crop shortfall, leading to the need to import molasses (from Pakistan) and ethanol (from Brazil) to cover domestic needs. In late 2004 the Indian government suspended a mandatory blending of ethanol in petrol, because of the shortage of feedstock.

The program is now back on track and starting in October 2006 the Indian government requires refiners to blend 5 percent ethanol in petrol nation wide, with an expected raise to 10 percent in 2007.

The strategy for the introduction of biodiesel as blend in diesel is different from the strategy for ethanol. It has been decided from the beginning that edible feedstock will not be used in the production of bioethanol. Some of the proposed crop to be used instead, especially Jathropa, can be cultivated in areas with difficult climate conditions on wasteland. At a national level 10 million hectares of wasteland could give about 5 million tones of biodiesel output per year.

The Planning commission has proposed a National mission on biodiesel, with a target of achieving 20 percent blending of bio-diesel with diesel. The first phase of the program consists of demonstration projects in various states across the country. The second phase is proposed to be people driven, with the state as facilitator. The first aim of phase two is to achieve 5 percent blend in nine states, then in the entire country.

LPG and natural gas (CNG) are already relatively well established alternative fuels in India. Their use is promoted predominantly due to air quality benefits. For the consumers these fuels are also generally economically beneficial. LPG costs more than CNG in India. It is not subsidised but still is 40 percent less expensive than petrol. The consumption of autogas LPG tripled in 2005, to 70,000 tonnes.

A Supreme Court order mandating Dehli bus fleets to convert to CNG came into effect in 2002. There is currently CNG infrastructure in only two Indian cities: Dehli and Mumbai, but there are plans to set up infrastructure in an additional 28.

Vehicles

India has the fifth largest fleet of natural gas vehicles in the world, after Argentina, Brazil, Pakistan and Italy. There are today 300,000 NGVs on the road in India (Dehli and Mumbai).

Major LPG and CNG car manufacturers offering OEMs on the Indian market include Maruti Udyog (a Suzuki subsidiary), Tata, Ford India, and Hyundai. Aftermarket conversions to LPG costs less than one third to the cost of aftermarket conversion to CNG.

Visions for India

In June 2006, Indian President A. P. J. Abdul Kalam held a speech to the Biodiesel Conference Towards Energy Independence, where he called for a national goal of producing 60 million tonnes of biodiesel per year by 2030, with a short-term goal of 6 million tonnes of production by 2010, and a mid-term goal of 30 million tonnes by 2020.

Conclusions

During the past few years a minor break through for clean vehicles and alternative fuels has been seen. Car manufacturers now compete in introducing "environmentally friendly" alternatives to the consumers. FFVs and electric hybrid vehicle sales are growing fast in the USA and in parts of Europe. Climate change, rising oil prices, and concern for oil and natural gas dependence, are catalysts in this process. However, clean vehicles still stand for a rather small fraction of the total vehicle stock of the world. Consequently, so does the consumption of alternative fuels.

The market potential of alternative fuels is dependant on the existing vehicle fleets and fuelling infrastructure. Biodiesel for instance has a larger potential to grow in a diesel dominated market like France's, than in for instance Sweden where diesel vehicles stand for only 5 percent of the total passenger car fleet.

Some alternative fuels such as methane (natural or biogas), LPG or hydrogen need special distribution systems in the vehicles whereas ethanol, ETBE and biodiesel can be used as blends in conventional fuels. In many markets converting to the latter type of fuel has a larger potential, at least in the short term.

Europe, the US, China, Brazil and India have all set targets for alternative fuels in transport with focus on biofuels. Ethanol is growing globally, whereas biodiesel is so far mainly of European concern.

First generation biofuels (ethanol, biodiesel/FAME) have limitations as low production cost effectiveness and energy balances. Furthermore a production based on sugar (ethanol) and oily feedstock (biodiesel) implicates a competition situation with food supplies. The fact that they are typically used as blends at 5-10 percent in the present fleet, in it self limits the conversion potential. High blends as E85 or E100 are currently only an option in a few European countries, the USA and Brazil.

Second generation biofuels are in focus of research and development. With second generation biofuels, biofuel production will become a global business. More countries will be able to produce biofuels locally.

Commercial production of second generation biofuels is in its infancy. An example is the two large-scale production units (Combined Heat and Power, CHP) for cellulose based ethanol that are being built in the north of Sweden, and are expected to start delivering fuel during 2012.
Biogas and natural gas so far are mainly utilised in dedicated fleets. To be introduced to the transport market at a broader scale serious measures have to be taken by governments and producers. Steps in this direction have been taken in countries like Sweden, Germany and Austria.

LPG that does not need the same investments in infrastructure as methane, and is mainly gaining market shares in developing counties, particularly sensitive to oil dependency.

The development of energy efficient vehicles has to continue and the combination of electric hybrid drive and renewable fuels is the next step. Both technologies have proven to be reliable and accepted, and efficient use of biofuels is needed.

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