BioEthanol for Sustainable Transport

Results and recommendations from the European BEST project

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BioEthanol for Sustainable Transport

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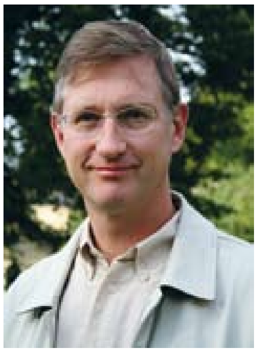
Coordinator's voice



Biofuels are renewable and can have a substantial effect on cutting greenhouse gas emissions from transport in Europe. They can also help Europe abate its dependency on fossil fuels, thus reducing the economic risks when oil production peaks and prices increase.

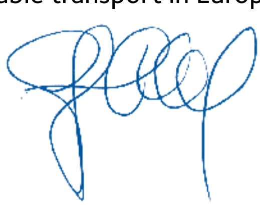
BioEthanol for Sustainable Transport, BEST, was a four-year demonstration project in several European regions and cities, with support from the European Commission. Different technologies were demonstrated, and different approaches to creating the market were tested and evaluated. The idea was to learn how the public and private sector together can create the right market conditions for a significant shift from fossil-fuelled vehicles to ones that run on a renewable fuel.

Despite the strong debate on the sustainability of biofuels, the project surpassed its own goals and introduced over 70,000 bioethanol-powered cars and buses, making it probably the largest demonstration project of vehicles ever carried out in Europe.

At most sites, work started without any legal framework for bioethanol as a fuel. Customs issues (such as regarding the fuel as drinking spirit), higher taxes on bioethanol than petrol in relation to their energy content, perceived risks at filling stations or in vehicles, etc., had to be dealt with before a comprehensive demonstration of vehicles could start. The results of these experiences are presented in this policy report. Advice to local governments, national governments and the EU are included for those who would like to speed up the shift from fossil fuels to renewables. Only by real-world demonstrations such as the BEST project could these results, both problems and solutions, be identified.

The results are clear: bioethanol can substitute a significant part of the fossil fuels used for transport in Europe today. The technology is available and works, and the fuel can be produced in a sustainable way, whether it is imported or produced in Europe. The project also clearly shows that the market will only develop rapidly if certain market barriers are dealt with on both European and national levels.

We are convinced that these results can contribute to the development of more sustainable transport in Europe.



Gustaf Landahl,
coordinator of the BEST project

Summary

This report is the conclusion of BEST – BioEthanol for Sustainable Transport, a four-year project to demonstrate the use of bioethanol in cars and buses. The project included ten sites – BioFuel Region (SE), Brandenburg (DE), Somerset (UK), Rotterdam (NL), the Basque Country and Madrid (ES), La Spezia (IT), Nanyang (China) and São Paolo (Brazil) – and was coordinated by the City of Stockholm (SE). Imperial College London was the evaluator and also led work on sustainability issues. BEST was part of the Alternative Motor Fuel programme within the Sixth Framework Programme, and co-funded by the European Union.

The transport sector is facing serious challenges, brought on by the oil and climate crises. Countries must urgently focus on developing more effective transport systems, where unnecessary transport is reduced, energy is used more efficiently, and a wide range of alternative fuels account for an increasing share of the market. In order to meet the European Commission's goal of a 20 % emission reduction in the EU by 2020, new fuels are needed.

BEST addressed the use of clean vehicles and fuels. BEST focused on bioethanol, because of its good properties for wider use. BEST studied the use of bioethanol from economic, technical, social, environmental and sustainability perspectives. One finding is that bioethanol is well suited as an important part of the future fuel mix.

Many ethanol fuels tested

High blends (E85, E100 and ED95) require dedicated vehicles and infrastructure, whereas low blends do not. High blends contain high proportions of bioethanol and effectively substitute fossil fuels. Low blends (E5, E10, HE15, E25, E-diesel and ED-diesel) represent a quick way to introduce large volumes of biofuel into road transport fuels without making alterations to fuel supply infrastructure or vehicles. The 2009 Fuel Quality Directive approved the use of blends including up to 10 % bioethanol in petrol in the EU. This means that blends such as E5 and E10 can be marketed and sold as petrol in the EU.

FFV sales confirm – the cars run well

The most noticeable activity in BEST is the introduction of flexifuel vehicles (FFVs) running on E85 – a mixture of 85 % bioethanol and 15 % petrol. FFV cars can run on E85, petrol, or a mixture of the two. During the project, nine BEST sites introduced over 77,000 FFVs, far exceeding the original aims. In 2008, there were around 170,000 FFVs in operation and 2,200 E85 pumps installed in the EU. 45 % of the vehicles operate at BEST sites and 80 % of the E85 pumps are found in the BEST countries. 70 % of all FFVs operating in the EU are found in Sweden.

BEST sites also evaluated both dedicated E85 pumps and flexifuel pumps and found very few problems. Guidance and regulations on safe handling and storage of E85 have been developed in Sweden and elsewhere and can be easily transferred to other EU Member States.

Satisfied FFV drivers

Evaluations carried out during the project show that drivers and fleet managers are satisfied and recommend the vehicles to others. They find FFVs reliable and easy to operate and maintain. The slightly higher purchase price can be offset by financial incentives to stimulate the sale of clean vehicles. However, the price of E85 and access to fuelling infrastructure are major concerns. Competitive pricing can be achieved by lower customs tariffs or by introducing a fuel tax system that takes into account energy content and emissions.

Better fuel economy than expected

A detailed assessment of the technical performance of 93 FFVs (11 different models used in a variety of situations at all sites) revealed 1–26% higher energy efficiency when running on E85, which resulted in better fuel economy than expected. In the best case only 1.14 times more E85 than petrol was necessary (instead of the theoretically assumed 1.41). This represents a significant finding and is an important area for future research. If engines could be adapted to the higher octane value in E85, increases in energy efficiency could be obtained and the fuel/energy consumption of bioethanol cars could be further reduced.

Parts of existing fleet can be converted to E85

Normal petrol cars can be successfully converted to FFVs if carried out by authorised specialists. Conversion of petrol cars to FFVs has been legalised in Sweden and could be applied in other EU Member States. A large percentage of the EU petrol vehicle fleet could be converted to FFV standard. It is estimated that up to 500,000 vehicles (one-eighth of the national fleet) could be converted in Sweden alone. BEST also included the conversion of a diesel vehicle to run on ED95. Tests showed that this is not viable using today's fuel and components. However, it should be possible to build bioethanol cars with diesel engines at the factory, resulting in better energy and emissions performance compared to diesel.

All links in the bioethanol chain must be addressed

Cooperation with key decision makers and stakeholders is crucial for stimulating the market and for development of effective incentives. BEST brought together manufacturers and consumers in constructive dialogue and identified actors that could be ambassadors for the use of FFVs and E85. For successful market development, all parts of the "bioethanol chain" – feedstock, production, vehicles, distribution, taxes and regulation, and end users – must be activated simultaneously. BEST recommends, for example, expanding alternative fuel supply infrastructure in parallel with other aspects of market development, such as fuel production and vehicle sales.

Fuel price highly important

Incentives must be relevant to the state of market development in a specific location. In a premarket phase incentives should promote vehicle supply and fuel distribution as well as remove legal barriers and tax disincentives. In a market development phase monetary incentives for end users and reliable information become effective tools.

A wide range of incentives were introduced during the project, including motor tax rebate, local purchase grants, free parking and access to restricted areas.

In Stockholm/Sweden, sufficient data was available to make a statistical analysis of the effect of various incentives. This showed that in a market development phase, the single most important incentive is to ensure that the price of bioethanol is equal to or lower than petrol. As long as bioethanol is subject to higher customs duties and energy taxes than fossil fuels, other incentives must be used to compensate for this. Exemption from congestion charging was the second most important instrument to stimulate the use of clean vehicles and bioethanol in Stockholm. The Swedish market was also boosted by a new "pump law", compelling petrol stations above a certain size to introduce pumps for alternative fuels.

Greenhouse gas reductions of 4–79 %

The greenhouse gas benefits of bioethanol used in BEST vary from marginal to substantial (4–79 %). Bioethanol produced from sugarcane in Brazil was the best-performing supply chain. However, European bioethanol produced using renewable energy and with efficient nitrogen use also achieved high greenhouse gas emission reductions. Effective implementation of the Renewable Energy Directive (RED) is likely to depend on the extent to which EU Member States synergise the use of bioethanol from the best-performing supply chains and make optimal use of high-quality imports.

Production can be multiplied

There is great potential for increased bioethanol production in the EU and volumes are predicted to rise dramatically. Estimations indicate that it is fully possible for global production to increase five- to sevenfold by 2030.

Sustainable production must be ensured

Bioethanol for fuel can be produced in a number of ways, using a variety of feedstocks. If produced under socially and environmentally sustainable conditions, bioethanol can be a viable transport fuel, considerably reducing emissions of greenhouse gases (GHG). Bioethanol is biodegradable and less toxic and explosive than petrol.

Regulated emissions within limits

More research is needed to determine the net effect on local emissions of switching from petrol or diesel fuels to ethanol, and the impact this would have on health and the environment. Knowledge about emissions from bioethanol fuels should improve as more and larger standardised tests are carried out.

Bioethanol buses now in several countries

When BEST was launched, the only bioethanol buses operating were in Sweden, and the Swedish partners have provided advice and guidance to other sites wanting to introduce the technology. Problems included the absence of regulations, procedures and guidance on how to import, handle and supply bus fuel. BEST demonstrated more than 190 bioethanol buses and 12 ED95 pumps at five sites, and helped increase knowledge about bioethanol buses in Europe, Brazil and China. An innovation within BEST was the demonstration of two dual-tank E100 buses developed by the Chinese vehicle producer Dongfeng. The new bus types were invented to overcome import duties and are a low-cost alternative for Chinese cities seeking to introduce bioethanol to their public transport systems.

All BEST sites will continue to drive their bioethanol buses in regular traffic and some are already planning to expand their fleets. The spin-off effects include the potential for wider use in heavy vehicles.

More suppliers would speed up market for buses

In Europe, there is a huge difference between the market for FFVs and E85 and the market for bioethanol buses and ED95. At present, there is only one supplier of bioethanol buses (Scania) and one supplier of ED95 (SEKAB). More suppliers would speed up the development of standards, which in turn would promote market development and the emergence of a stable second-hand market. Introducing bioethanol buses and ED95 is largely a question of political will, and public transport authorities can play a key role in supporting operators. Issues such as the price of ED95, number of filling stations, and ways to reduce fuel consumption in biofuel buses with the use of hybrid technology must be addressed.

Low blends can contribute to – but not fulfil – EU targets

Fuel suppliers appear to favour the low-blend option as a cost-efficient way of implementing EU targets for renewables. It is unlikely that use of low blends alone will enable the EU to meet its climate and energy targets, but a number of alternative low blends can make a contribution towards fulfilment of these goals. The urgent need to reduce diesel consumption in the EU means that development of an infrastructure grid to supply both diesel low blends and ED95 should be a priority. Market introduction of other low blends is more challenging, as HE15, E-diesel and ED-diesel fuels require different types of pumps, have high vapour pressure and different levels of complexity, and increase costs for distributors.

If low blends are not compulsory, they must be competitively priced for consumers. Taxation and excise on low blends varies in different EU Member States. It is questionable whether the use of tax exemptions for the bioethanol part of low blends is effective policy. Making low blends compulsory – or increasing taxation on the fossil content of fuels – may well be a better approach.

Lack of standards causes delay

In order to raise consumers' trust in bioethanol, as well as increase the quality of bioethanol production, fuel standards for the different high and low blends need to be harmonised in the EU. They must also be adopted and recognised in all relevant legislation. Standards for fuel storing and dispensing, and vapour-recapturing systems, are also necessary. Emission and type-approval standards must apply to vehicles running on different high blends of bioethanol. The standards should recognise the special properties of bioethanol and introduce the concept of non-bioethanol hydrocarbons.

Governments must create a level playing field

The use of bioethanol vehicles and fuels can help raise the profile of national and local governments and help improve public perceptions of the public transport system. Governments can remove barriers to the introduction of clean vehicles and fuels, develop climate change action plans, and adopt clean vehicle strategies, clean vehicle definitions and criteria for sustainable transport fuels. They should ensure procurement of clean vehicles and fuels in public fleets, and cooperate with wider EU and international schemes supporting clean vehicles and fuels. Counterproductive incentives that actually support the use of fossil fuels should be removed. Governments can demand development of energy-efficient vehicles that use alternative fuels.

EU framework must encourage use

Bioethanol can play a role in helping the EU achieve its 20-20-20 by 2020 strategy. But to enable a bioethanol market to develop further, the EU must work on a harmonised legislation for safety and environment, and directives and taxations that reflect energy content and well-to-wheel greenhouse gas emissions. A system for certification of sustainable biofuels must be launched and implemented. The EU and national bodies should encourage E10 and FFVs to be standard in petrol and petrol vehicles.

Glossary

Binding Tariff Information (BTI) Legally binding in all EU Member States and must be used in all countries. A Swedish BTI exists (CN code 3824 90 98 99) for bioethanol (see page 72).

Bioethanol Bioethanol for fuel is predominantly produced from sugar cane, wheat and sugar beet. If produced correctly, bioethanol is a sustainable resource and can reduce emissions of fossil carbon dioxide (CO_2). Bioethanol can be supplied in low and high blends (see page 17 for definitions) or in hydrous and anhydrous forms (page 18).

Biomethane Compressed methane from renewable Sources.

CEN The European Committee for Standardisation (CEN) has 30 National Members that work together to develop voluntary European technical specifications and standards.

Clean Vehicle Directive Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles obliges public entities to procure clean vehicles and conduct well-to-wheel analysis of all vehicles they purchase.

Climate change Anthropogenic climate change, primarily caused by the burning of fossil fuels and greenhouse gas emissions, as defined by the United Nations Framework Convention on Climate Change (UNFCCC).

CNG Compressed Natural Gas (mainly methane) from fossil sources.

CO_2 Carbon dioxide – one of the most dominant greenhouse gases, produced when burning fossil fuels as well as biofuels.

CO Carbon monoxide – toxic compound in vehicle exhaust.

Controlled emissions Emissions from vehicles which are regulated and thus also controlled and declared in type approval procedures. Acceptable levels are defined in the european emission standards for vehicles (see page 26).

E85 High blend bioethanol consisting of 85% anhydrous bioethanol and 15% petrol, used in flexifuel vehicles (FFVs).

ED95 High blend bioethanol consisting of 96.5% hydrous bioethanol and 3.5% additives, used in bioethanol buses and other heavy diesel vehicles.

ETBE Ethyl tertiary butyl ether, commonly used as an oxygenate gasoline additive in the production of petrol. ETBE can be produced from bioethanol and used in petrol low blends.

EU The European Union, also denoted by EU15, EU25 and EU27 to reflect number of members during different periods.

FAME Fatty Acid Methyl Esters – diesel type of fuel based on oils made from rapeseed, palm oil or soy bean.

FFVs Flexifuel vehicles – cars with a spark ignition engine designed to run on a mixture of petrol and bioethanol, including high blends such as E85.
Fossil fuels – were formed over millions of years and are fuels containing high percentages of carbon and hydrocarbons. Combustion of fossil fuels such as petrol or diesel produces large volumes of greenhouse gas emissions and local air pollutants.

Fuel Quality Directive Directive 2009/30/EC aims at tightening environmental quality standards for fuels, enabling more widespread use of bioethanol in petrol and introducing a mechanism for reporting and reducing lifecycle emissions of greenhouse gases from fuel.

GHG Greenhouse Gases – gases that contribute to global warming. The main greenhouse gases are carbon dioxide, methane, and nitrous oxide.

HC Hydrocarbons – a collective parameter for various hydrocarbons in vehicle exhaust.

IEA International Energy Agency - intergovernmental organisation acting as energy policy advisor to 28 member countries. Author of the annual World Energy Outlook.

ILO International Labour Organisation – UN agency promoting social justice, human and labour rights.

Kyoto Protocol An international and legally binding agreement to reduce greenhouse gas emissions worldwide.

LUC Land use change – changes impacting upon ecosystems and the environment, as well as human society and the economy. Both direct LUC and indirect LUC are further defined on page 35.

NO_x Nitrogen oxides – local emission created when nitrogen and oxygen from the air are mixed in combustion engines.

OPEC - Organisation of the Petroleum Exporting Countries - an intergovernmental organization made up of oil producing nations.

Peak Oil The moment at which expansion of global oil production is impossible and supply of oil begins to decline.

PM Particulate matters – also created during combustion

PTA Public Transport Authorities – organisation administrating public transport in a municipality. A PTA may operate or purchase transport services.

RED Directive Directive 2009/28/EC on the Promotion of the Use of Energy from Renewable Sources, setting out renewable energy targets for EU Member States and including specific targets for alternative fuels and sustainable biofuels.

S-curve Describes the development of markets for many new technologies.

Tailpipe emissions Fuel combustion in the vehicle engine produces emissions which are released via the exhaust (tailpipe). Vehicle emission standards are usually based on measurement of tailpipe emissions (see page 31)
UNEP United Nations Environment Programme – UN agency specialising on environmental issues and sustainable development.

Well-to-wheel (WTW) emissions – assesses the environmental impact of fuels from throughout the supply chain. Also known as lifecycle analysis.

WTO World Trade Organization – intergovernmental organisation dealing with the rules of trade between nations.

Introduction

Human society faces two complex, immediate and interdependent crises. For over a century, consumption of low-price fossil fuels have fuelled economic growth and helped many countries achieve rapid development. This era is now coming to an end as global oil stocks are passing their peaks and prices are rising. This first is a resources crisis that includes the risk of an energy crisis.

Crisis 1: Oil is becoming more scarce

Peak Oil is the moment at which further expansion of global oil production is impossible and the supply of oil declines. Recent estimates suggest that Peak Oil is imminent.

In 2007, the IEA predicted that output from the world's existing oil fields would decline at 3.7% per year. Temporary supply problems could still be met by increased investment or production. However, in 2008 – following a new assessment based on a study of the decline rates at the world's 800 largest oilfields – the IEA stated that the projected rate of decline was now 6.7%. Moreover, the IEA predicted that production of conventional oil would peak by 2030 and that non-OPEC production would peak within three – four years.

The IEA's reference scenario for world oil production to 2030 (Fig. 1) suggests that conventional crude oil products from currently producing fields may already have passed their production peaks. The development of new oil fields and new discoveries are needed to meet the decline in production. An increase can only be achieved by producing non-conventional oil (such as oil sands-based products) or natural gas liquids. However, the IEA reference scenario may be overly optimistic. The UK Energy Research Centre has analysed over 500 studies on Peak Oil and concluded that there is "a significant risk of a peak before 2020"[1].

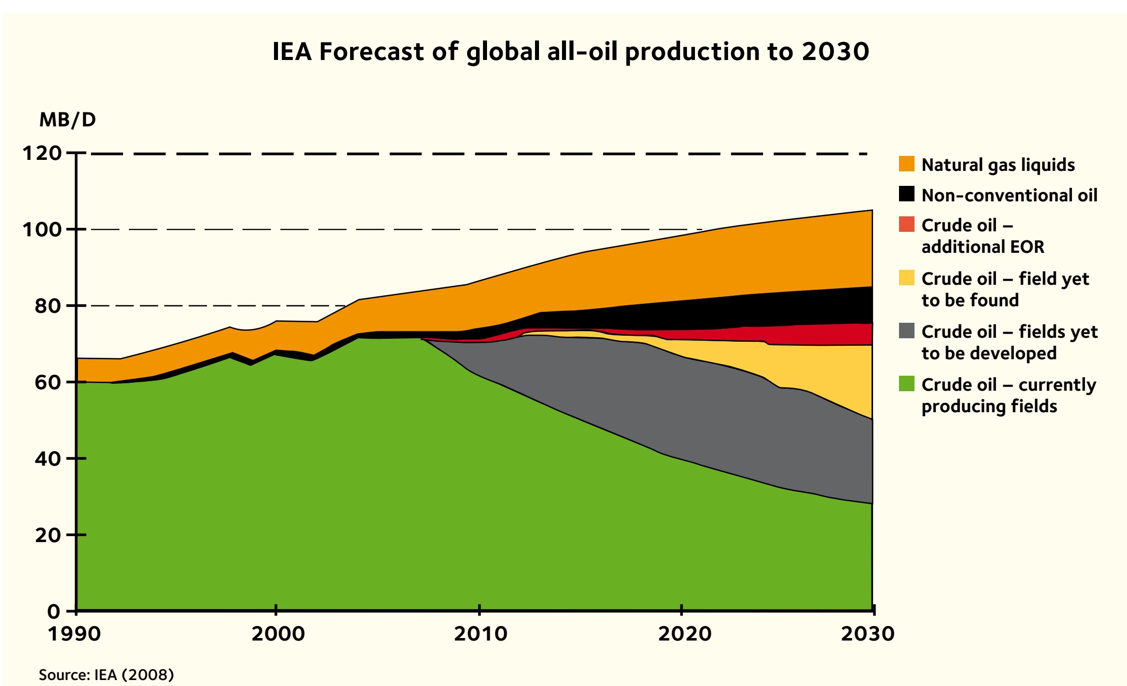


Fig. 1 Production at today's oil fields has already started to decline. Source: UK Energy Research Centre (2009).

[1] UK Energy Research Centre, *Global Oil Depletion – An assessment of the evidence for a near-term peak in global oil production* (2009).

Oil products more expensive

Peak Oil raises the prospects of three immediate challenges for the global transport sector:

1) Oil will become more scarce.
2) Oil products will increase in cost.
3) Increasing demand and limited supply, especially for diesel, will accelerate both 1) and 2).

Production of non-conventional oil or natural gas liquids is theoretically possible, but higher production costs would be reflected in the price. Increased demand for a depleted resource and vastly increased production costs mean the further past the moment of Peak Oil we travel, the higher the price of oil products will be. Prices will accelerate most in sectors dependent on fossil fuel-based products, such as transport.

The same is true for greenhouse gas emissions – production of non-conventional oil occurs with significant and increasing emissions relative to conventional products. Thus, countries must focus on developing more effective transport systems, in which the overall volume of unnecessary transport is reduced, energy is used more efficiently and a wide range of alternative fuels are offered and account for an increasing market share. This is particularly important for countries that import oil for use in transport and for regions, such as the EU, whose oil reserves are disappearing fast.

Crisis 2: The climate is changing

The second crisis concerns the global climate. Anthropogenic climate change is primarily caused by the combustion of fossil fuels and poses a critical challenge to the global environment. The world must take urgent action to drastically reduce greenhouse gas emissions in order to reduce the risk of dramatic transformations to the planet's climate and ecosystems.

As the Stern Report made clear, the costs and difficulty of reducing greenhouse gas emissions will increase exponentially with time. The cost-effective way to tackle climate change is to act immediately and aggressively across all sectors to replace fossil fuel infrastructure and reduce greenhouse gas emissions.[2]

The EU has consistently demonstrated its commitment to address climate change. According to the European Environment Agency, the EU15 is on track to meet its Kyoto Protocol commitment of an 8% reduction in emissions by 2012. However, additional measures are needed to meet the European Commission's goal of a 20% reduction in emissions in the EU27 by 2020.[3]

Emissions have been reduced in all main sectors except transport, which is responsible for one fifth of EU15 greenhouse gas emissions – an increase of 26% from 1990 to 2006. Road transport causes over 90% of total EU domestic transport emissions, making this

a critical and urgent environmental problem to target. Indeed, the 2007 Environment Policy Review stated that transport is "one of the most difficult issues in the fight against climate change and other pollution".[4]

Public transport accounts for a relatively small and fairly consistent volume of emissions in the EU and is highly efficient in terms of emissions per passenger. However, public transport accounts for a high proportion of emissions in urban areas. The use of clean vehicles and fuels in public transport has strong symbolic value and demonstrates potential for transformation of the heavy vehicle sector, which has a much larger and more widespread impact on the environment and climate.

2 HM Treasury, *Stern Review on the Economics of Climate Change* (2006).
3 European Environment Agency, *EEA Report No 5/2008* (16 October 2008).
4 European Commission, *2007 Environment Policy Review* (COM (2008) 409 final of 2 July 2008.

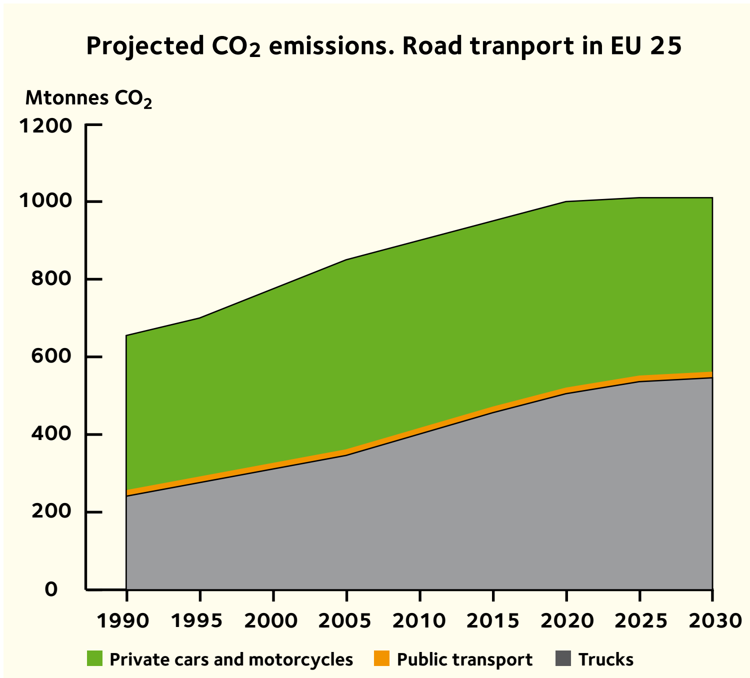


Fig. 2 The vast majority of emissions resulting from the road transport sector are caused by private cars, motorcycles and trucks. Source: EC DG-TREN, European Energy and Transport Trends to 2030, (2008).

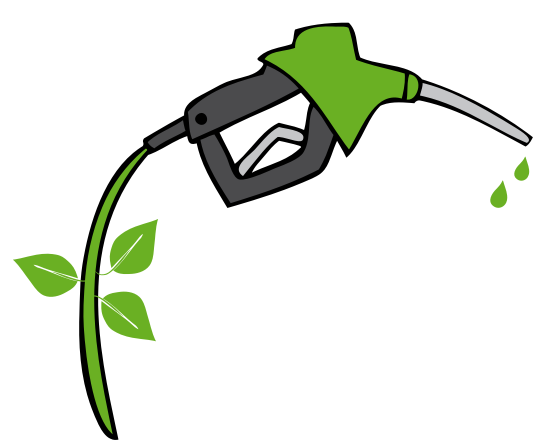
A wide range of assessments have been made about the means and potential of reducing greenhouse gas emissions resulting from the road transport sector. For example, the IEA suggests that the supply of biofuels will increase fivefold by 2030, to meet 5% of the energy demand of the road transport sector. IEA scenarios up to 2030 consider a slow but consistent growth in the share of biofuels although restrictions relating to land and other resources (such as water) need to be considered.[5]

Green growth is needed

Both the resource and climate crises have socio-economic causes and consequences.

Energy systems can be managed to minimise the impact of Peak Oil, and communities can increase their resilience to climate change through mitigation and adaptation. The financial cost of making these changes will increase the longer actions are postponed. Citizens will also have to change their behaviour, assumptions and aspirations to achieve a sustainable global society.

Communities across the world must dare to think differently and employ innovative and creative solutions to ensure green growth. A combination of measures to raise awareness amongst citizens – to encourage individuals to act smart and choose sustainable actions – and instruments compelling citizens to act differently will be required. Only by harnessing the collective potential of every little action can we expect to overcome the oil and climate crises whilst continuing to achieve improved living standards for the majority of the Earth's inhabitants.



5 IEA, *World Energy Outlook*, (2008).

Rethinking transport the BEST way

A broad, deep reorientation of transport policies will achieve a reduction of transport, an end to unnecessary transport, more efficient transport (better techniques, increased numbers of users, etc.) and a switch to clean vehicles and fuels.

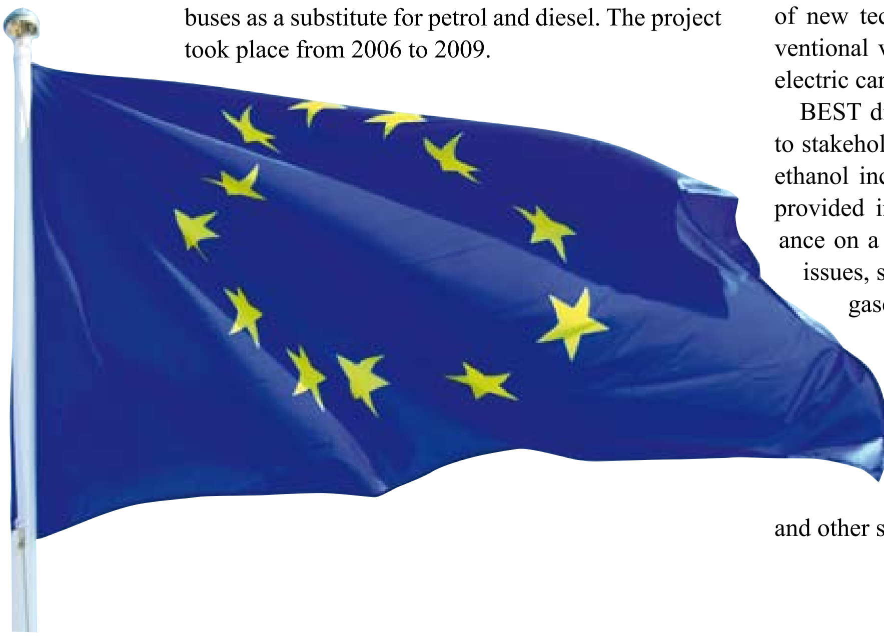
Such a shift would promote "eco-mobility" (e.g. walking and cycling), multi-passenger journeys (e.g. public transport and car-sharing), and clean vehicles and fuels. In such a matrix, the use of fossil fuels – in both private cars and public fleets – would always be the last resort.

The project BioEthanol for Sustainable Transport (BEST) was developed to address the final part of the eco-mobility chain – the use of clean vehicles and fuels. There are a number of alternative fuels, but BEST chose to focus exclusively on bioethanol, which was considered to have properties making it suitable for wider use. BEST aimed to assess if this was the case and studied the use of bioethanol at ten sites from economic, technical, social, environmental and sustainability perspectives.

This is BEST

The BEST project

BEST – BioEthanol for Sustainable Transport – was a demonstration project supporting the European Union's strategy to reduce consumption of fossil fuels and greenhouse gas emissions. BEST investigated the use of bioethanol in vehicles such as cars and buses as a substitute for petrol and diesel. The project took place from 2006 to 2009.



BEST initiated a large-scale introduction of vehicles and infrastructure for low and high blends of bioethanol. The project studied market developments with reference to issues such as incentives, regulations and standards, pricing and awareness, and tested a range of new technologies, including conversion of conventional vehicles to run on bioethanol, and hybrid electric cars.

BEST disseminated information about bioethanol to stakeholders across the EU and awareness of bioethanol increased rapidly during the project. BEST provided insights, shared results and offered guidance on a wide range of issues, including technical issues, sustainability and emissions of greenhouse gases and local air pollutants.

BEST demonstrated that bioethanol can be reliably used as a vehicle fuel and, when compared with fossil fuels and produced sustainably, offers benefits in terms of energy efficiency, reduced impact on the climate and the environment, and other socio-economic benefits.

Scope of the BEST project

BEST facilitated the introduction of vehicles running on bioethanol by establishing multi-stakeholder collaborations at ten sites:

- BioFuel Region and Stockholm, Sweden.
- Brandenburg, Germany (2007–2008).
- Somerset, UK.
- Rotterdam, the Netherlands.
- The Basque Country and Madrid, Spain.
- La Spezia, Italy.
- Nanyang, China.
- São Paulo, Brazil.

The project was coordinated by the City of Stockholm and evaluated by Imperial College London, which also led the work on sustainability issues.

BEST was supported financially by the European Union. This means that several of the investments and some of the work were co-financed by the EU. The partners financed the majority of the project.

BEST was a demonstration project within the Alternative Motor Fuel Work programme. This was part of the Sixth Framework Programme.

Demonstration of clean vehicles and fuels enabled BEST to:

- create capacity (such as fuel infrastructure) for a lasting and accelerated transition to clean vehicles and fuels in the EU.
- validate the functionality and performance of the technologies from technical and environmental perspectives.
- raise levels of knowledge, awareness and experience of bioethanol amongst key stakeholders.
- assess and analyse the market development of bioethanol and document the BEST experience, enabling a transfer of experience regarding incentives, safety, regulations etc., to other locations in the EU.

Collectively, these actions aimed to provide the EU with sufficient knowledge and experience about the market for bioethanol vehicles and fuels, as bioethanol will comprise an important part of the future fuel mix.

Important work conducted within the BEST project included:

- Demonstration of over 77,000 flexifuel cars and 310 E85 pumps at nine sites.
- Demonstration of over 190 bioethanol buses and 12 ED95 pumps at five sites.
- Conversion of four conventional petrol and diesel vehicles to run on bioethanol.
- Testing of three hybrid electric vehicles running on an E25 blend.
- Testing and demonstration of low blends, including two standard diesel buses to run on ED-diesel, 1 ED-diesel pump and 14 E10 pumps.
- Guiding followers on issues linked to the distribution of vehicles and fuels, such as fuel standards, fuel handling regulations, tariff information, and clean vehicle definitions.
- Research to identify incentives and disincentives for market development.
- A sustainability assessment for a scaling-up of bioethanol production and consumption, taking into account environmental, socio-economic and policy factors linked to biofuels.
- Lifecycle analyses of various bioethanol supply chains and contributions to developing biofuels certification frameworks.

What is bioethanol?

Bioethanol used for fuel is predominantly produced from sugar or starchy crops such as sugar cane, wheat and sugar beets. In the USA, corn is also an important feedstock. Bioethanol can be produced in a number of ways. If produced under socially and environmentally sustainable conditions, bioethanol can be a viable transport fuel and will reduce emissions of fossil carbon dioxide (CO_2). Bioethanol is biodegradable and less toxic and explosive than petrol.

Different blends of bioethanol

A range of fuel blends can be produced from bioethanol, and BEST demonstrated, tested and assessed several different blends, represented in the "bioethanol tree" below.

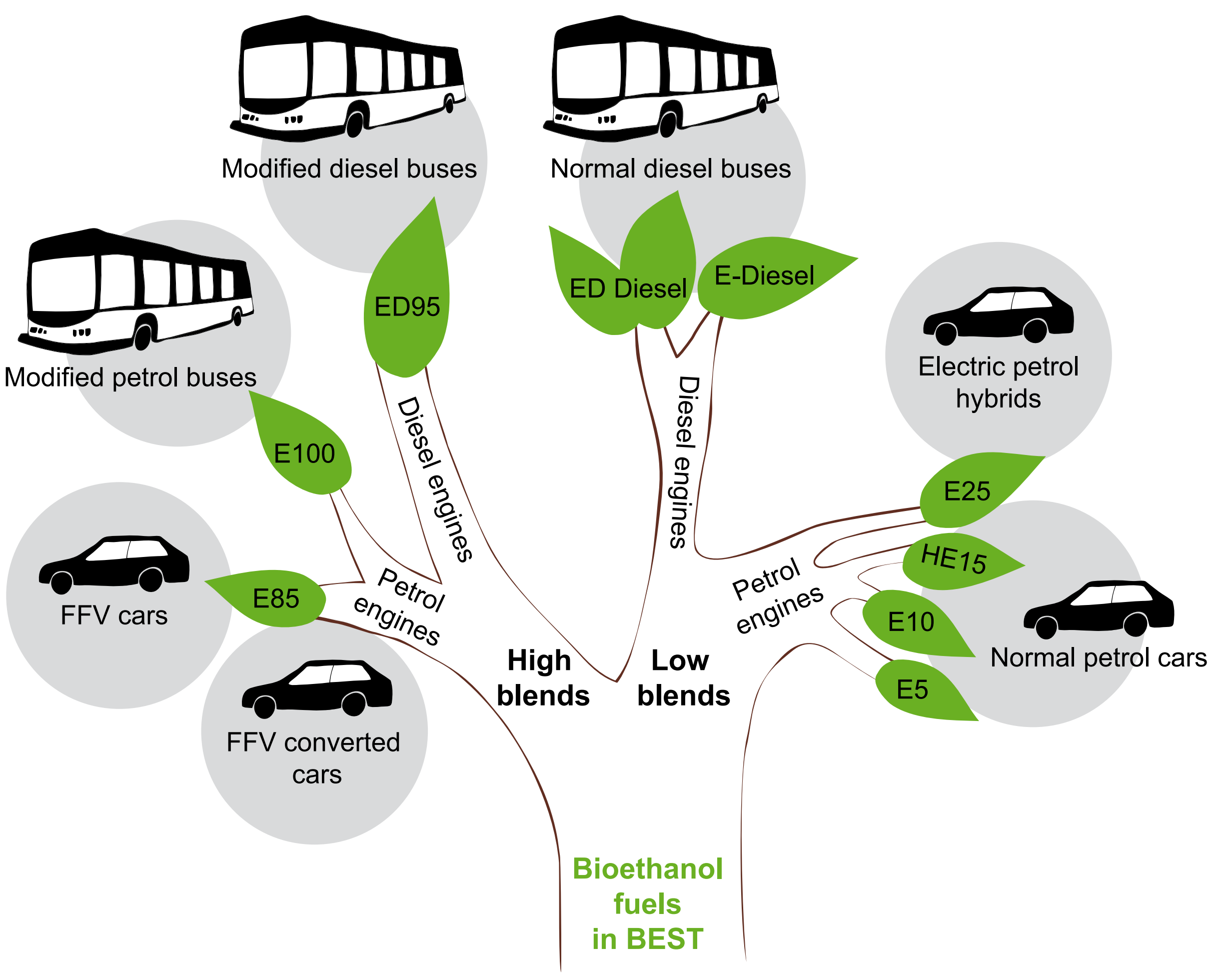


Fig. 3 There are a variety of bioethanol fuel blends. This "bioethanol tree" illustrates the fuels that were tested in the BEST project.

High blends

High bioethanol blends require dedicated vehicles, whereas low bioethanol blends do not. High blends contain a high proportion of bioethanol and effectively substitute fossil fuels. High blends can substantially reduce greenhouse gas emissions, depending on how they are produced. Due to the difference in properties between fossil fuels and bioethanol, high blends require some modifications to the vehicle engine and a dedicated fuelling infrastructure.
In BEST, three high blends were reviewed:

- E85 – 85 % anhydrous bioethanol, 15 % petrol – used in cars known as flexifuel vehicles (FFVs, purpose-built or converted petrol vehicles).
- E100 – 100 % hydrous bioethanol – used in modified petrol buses in Nanyang and (outside BEST) in petrol cars in Brazil.
- ED95 – 96.5 % hydrous bioethanol, 3.5 % additives – used in bioethanol buses, converted diesel vehicles and dedicated heavy diesel vehicles, such as waste collection trucks.

For more information about the demonstrations of high blends, please see page 42 ff and 66 ff in this report.

Low blends

Low blends represent a quick way of introducing large volumes of biofuel into road transport fuels without making any alterations to fuel supply infrastructure or vehicles. Low blends are seen as a relatively cost-effective way of reducing fossil fuel consumption.

Low blends using biofuels such as bioethanol and biodiesel have been used in Europe since the early 1900s. The 2009 Fuel Quality Directive approved the use of blends including up to 10 % bioethanol in petrol in the EU.[6] This means that blends such as E5 and E10 can be marketed and sold as petrol in the EU.
In BEST, several low blends were demonstrated:

- E5 – 5 % anhydrous bioethanol, 95 % petrol – used in existing petrol cars and pumps.
- E10 – 10 % anhydrous bioethanol, 90 % petrol – used in existing petrol cars and pumps.
- HE15 – 15 % hydrous bioethanol, 85 % petrol – used in conventional petrol cars. Not recognised as petrol by the Fuel Quality Directive, but can be sold under the specific name HE15.
- E25 – 25 % anhydrous bioethanol, 75 % petrol – normal minimum blend used in Brazil.
- E-diesel – 7.7 % anhydrous bioethanol, 0.62 % additives and diesel – tested in a bench cell. More flammable than diesel and must be handled as petrol.
- ED-diesel – 10 % bioethanol derivative (not pure bioethanol) blended in diesel – used in two city buses and handled as diesel.

BEST experiences with low blends are described on page 78 ff in this report.

Explanation

Hydrous and anhydrous bioethanol

Chemically, all alcohols are identical, irrespective of how they are produced, although foreign materials are sometimes added to make the fuel undrinkable – such "denaturised" bioethanol can be used as vehicle fuel.

There are two types of fuel bioethanol – hydrous and anhydrous.

Hydrous bioethanol means water-containing ethanol (usually 2 %–7 % water). This ethanol is used in neat ethanol engines (engines adapted to use 100 % ethanol) like buses, and in some special fuels like HE15 tested in the Netherlands.
Anhydrous bioethanol is the product remaining when hydrous bioethanol is dehydrated, enabling it to be mixed in low blends with petrol and diesel. This fuel contains very small volumes of water – in Brazil a maximum water content of 0.7 % is permitted. This is the ethanol used in E85.

[6] Directive 2009/30/EC of the European Parliament and the Council of 23 April 2009.

Multi-stakeholder action essential

The introduction of clean vehicles and fuels is a highly complex process involving many players. BEST was a multi-stakeholder project that included municipalities and regional authorities, research institutions and industry players, including the vehicle manufacturers Ford and Saab.

Multi-stakeholder action is essential to stimulate biofuel market development. BEST sites shared the experience of a "chicken and egg" moment when implementing tasks. E85 filling stations are unlikely to be constructed if few cars operate on bioethanol; consumers will not purchase bioethanol cars if they cannot access fuel supplies; and few manufacturers will deliver a product to a market without consumers.

By bringing together manufacturers and consumers, the BEST project aimed to overcome this "first-mover" problem. Imagining a "bioethanol chain" in which all stages of the market development process are interdependent is one way of identifying the steps and stakeholder involvement required. The BEST bioethanol chain has six key stages leading up to market development – feedstock, production, vehicles, distribution, taxes and regulation, and end users.

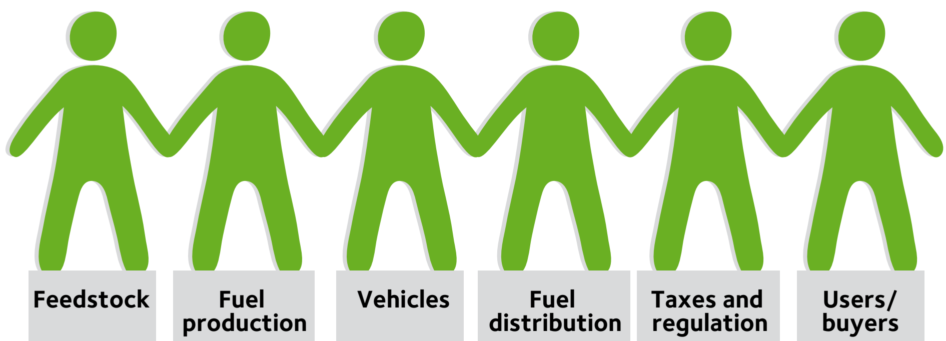


Fig. 4 All parts of the "bioethanol chain" must be activated simultaneously in order to achieve market development.

Cooperation between players at each stage of the chain is essential for market development. If one or more links are missing, the chain will break down. Several BEST sites experienced difficulties in the implementation of tasks due to problems with the "taxes and regulation" link, which slowed down market development.

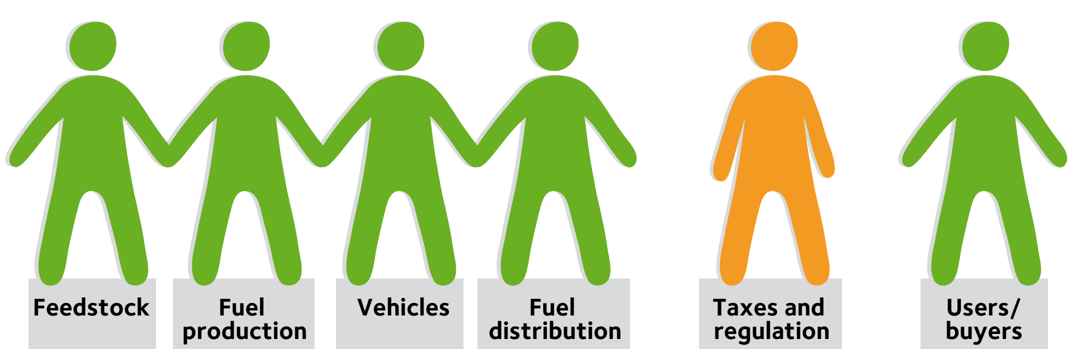


Fig. 5 In BEST appropriate incentives, taxation and regulations for bioethanol were missing at several sites. This delayed introduction and market penetration.

BEST stakeholders – key to success

BEST aimed to identify all stakeholders essential to the success of the project and incorporate them at all relevant points in the project. Stakeholder analysis enabled the project to prioritise stakeholders and identify mutually beneficial forms of cooperation. It was also used to monitor and assess whether such cooperation was successful, and if attitudes changed over time. Continual reassessment of stakeholders enabled BEST to add new stakeholders as they emerged.

Key stakeholder groups identified by BEST include:

- Politicians and policy-makers. This group is critical to market development, as they can launch initiatives to formulate policies, incentives, regulations and standards. Moreover, national politicians maintain control over taxation, which has been shown to be essential for competitive pricing of bioethanol and other alternative fuels. Local politicians can initiate local actions, such as "greening" of public transport and municipal fleets, and introduce local incentives. Many actions from other stakeholders depend on approval from politicians.
- Authorities working with issues such as environmental protection and fire safety.
- Ministries dealing with finance, trade and industry, transport and the environment.
- Oil companies are important actors in the fuel market.
- Fuel producers manufacturing bioethanol, and their suppliers.
- Fuel retailers, especially independent retailers who do not own stakes in fossil fuel supplies, are essential to be able to establish a supply infrastructure.
- Automobile manufacturers and car dealers ensure a supply of bioethanol vehicles.
- Mechanics, especially those working on large fleets, are important to ensure high-quality maintenance.
- Buyers and users including fleet managers are vital stakeholders and information disseminators.
- Opinion-formers and information providers including scientists, NGOs and the media play a key role in informing all of the above groups and consumers about bioethanol.

Detailed stakeholder analysis was conducted at each site. BEST partners defined each stakeholder according to their place in the bioethanol chain and their influence, potential contribution and attitude towards the BEST goals. This helped find positive stakeholders for collaboration across the bioethanol chain. The most positive players included independent fuel retailers, car importers, biofuel suppliers, universities, environment ministries, local/regional authorities and working groups made up of a combination of these stakeholders.

The stakeholder analysis also helped identify and better tackle critics.

S-curve for assessing market development

In order to assess market development during the implementation of the BEST project, various models for introducing new technology were considered. The S-curve was found to be a useful tool when studying the BEST results.

The S-curve describes the market development of many new technologies, including computers and mobile phones. When new technologies are first introduced in the market, most consumers are reluctant to purchase them. The product may be considered unusual or untested and the market is dominated by "early adopters", who are buyers with a special interest in new technology or in the particular qualities of a specific technology.

Over time, as the volume of products in the market increases, new suppliers enter the market and the technology develops. Market barriers such as a high purchase price, lack of information, or perceived quality shortcomings diminish. Instead, demand increases, prompting producers to add new models to the market.

When a new product becomes more available, and the market has reached a so-called "acceptance level" or critical mass, mainstream consumers show a greater interest. Then, the market share increases rapidly until it reaches maximum penetration and is considered a mature product.

The BEST project aimed to assess whether the development of an "S-curve" was observed at BEST sites, or whether other changes took place. For more information on market development, page 58 ff.

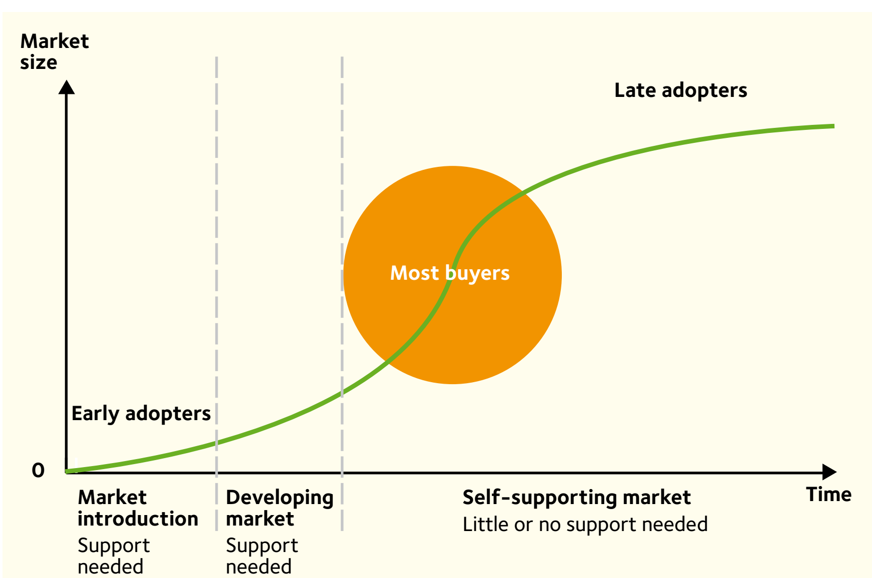


Fig. 6 S-curve showing the relationship between time and market penetration of new technology. "Support needed" indicates the need for some degree of incentives (such as reduced tax) to assist market development during the early phases. This support can be phased out once the market has matured. "Early adopters" are buyers with specific knowledge or motivations that make them purchase early and with less reference to criteria such as cost or fuel availability than buyers who purchase in the later market phases. Source: BEST D5.12, *Promoting Clean Cars – Case Study of Stockholm and Sweden* (2009).

Influencing attitudes

In addition to financial incentives, it is essential to work with attitudes and norms to stimulate the introduction and increased use of clean vehicles. Changes in social attitudes and values can also be understood by using the S-curve – once a certain number of people have changed their attitude, the rest will follow. Any market development program is likely to be more effective when using the early adopters as ambassadors to influence late adopters.

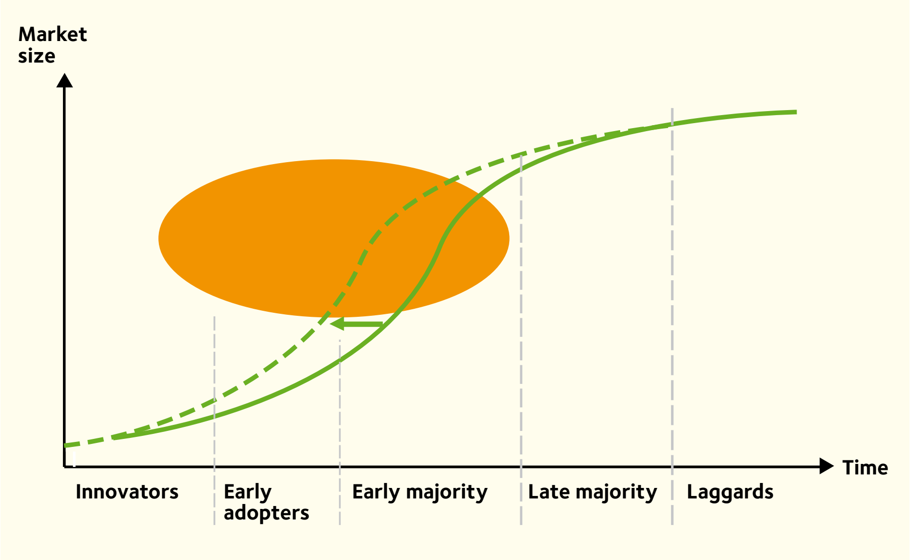


Fig. 7 Changes in attitudes and behaviour can also be understood as an S-curve, with early adopters as well as laggards.

Identifying motivation – a tool for convincing

It is essential to understand that individuals are motivated by various factors. The players that can be influenced in each respective development phase must be identified.

BEST studies showed that first adopters have a certain set of values motivating them to choose clean vehicles. For example, they may be very environmentally-aware or highly interested in new technology.

The groups that follow the early adopters may have slightly different motives, which may in turn differ greatly from those of the last group (the laggards or sceptics). Some individuals may only be interested in personal benefits, such as the possibility of reduced tax through the use of clean vehicles, whereas others may be ideologically opposed to the concept of clean vehicles and fuels.

Finding ambassadors who can influence consumers

During BEST, project partners communicated extensively about FFVs and E85, focusing mainly on cars and fuels, performance and experiences. All BEST sites have a unique situation, governed by national differences, different media habits, differences in values, and different communication methods. Partner organisations also have different traditions, possibilities and individual skills for communicating these types of issues.

Some general conclusions on communication in BEST are:

- Efficient communication to influence the use of FFVs and E85 should be aimed at:
  - those able to exercise influence
  - those that influence others
  - large groups, or those deciding over large fleets.
- Start with positive players and save the sceptics until last, as they will ultimately be influenced by their surroundings.
- Locally tailored communication is the most important way of influencing individuals and creating change.
- Defining leading local players that will influence consumers is a key activity. Existing "green" players, such as companies, organisations, and influential individuals, can be used as promotion vehicles to the wider public and can be highly effective in influencing social and personal norms.

Once the initial steps are taken and momentum is building:

- One way to strengthen the development is by continuously reporting on increasing sales of clean vehicles and fuels in the country or region. This shows a positive trend. In this way, individuals are likely to view clean vehicles as the new "norm", and conventional fossil-fuelled cars as unattractive, outdated and obsolete machines.
- Working with national opinion-formers, such as popular politicians, celebrities (from different groups and sub-groups), and technological front-runners will have a positive influence on the public.

Read more about BEST communication activities in BEST D7.01, *Communication programmes in BEST: 2006–2009* and BEST D7.2, *Local communication reports.*

More about attitudes towards clean cars in BEST D9.24, *A comparative report about consumers' attitudes, world views and purchase intentions for clean vehicles* and in D9.25, *Report on survey of fleet operators' attitudes towards ethanol vehicles and fuel.*



Outlook

China third largest bioethanol consumer and producer

China faces rising energy consumption and increased imports of fossil fuels. Rapid growth of private vehicle ownership has contributed to environmental problems in many Chinese cities. China is attempting to reduce the dependence on fossil fuels – and their negative impacts – through introduction of alternative fuels including bioethanol.

China has rapidly become the world's third largest producer and consumer of bioethanol, behind the USA and Brazil. In 2000, bioethanol low blends were introduced and ten provinces now use E10 as the standard petrol blend. Since 2001, blends of up to 5 % bioethanol in petrol have been exempt from excise and value-added tax is repaid to bioethanol suppliers after sales.

An allowance per ton of denatured fuel bioethanol is also paid to the producer. To ensure effective implementation of these incentives, only five bioethanol production facilities are licensed and only two companies supply bioethanol.

One production facility is located in Nanyang and provided the bioethanol used in BEST for demonstrations of FFVs using E85 and bioethanol buses using E100.

Nanyang was the first city in China to demonstrate high blend bioethanol in motor fuels and used several incentives to support the introduction. For example, the ten FFVs and two bioethanol buses used in BEST were exempted from road maintenance taxes, which all other vehicles in China pay. Free parking for FFVs was also provided. However, the administration was not able to secure exemption from custom duties for imports of FFVs, buses or additives from EU countries.

Likewise, Nanyang attempted to introduce FFVs to taxi fleets but was unable to finalise an agreement with the relevant parties within BEST. Other subsidies aimed at manufacturers and bus fuel costs may also accelerate use of high blends of bioethanol as a vehicle fuel in China.

China has not introduced a fuel tax but if the country should do so – and if bioethanol were exempted – it would have a profound impact on the cost-effectiveness of using bioethanol. National policy remains relatively neutral with regard to high blends and most incentives are oriented towards ensuring use of E10.

The "food and fuel" debate did little to help arguments for high blends and resulted in a change in national policy, with the government decreeing an end to use of foods in biofuel productions. This in turn has had an impact on the attitudes of vehicle manufacturers, who are uncertain about how the market will develop in the future.

For more information, see BEST D5.13. *Status, experiences and strategy incentives beyond BEST – Nanyang* (2009).

Sustainability

Short summary

Use of bioethanol fuels may lead to reductions or increases in emissions of CO, HC and NO_x relative to petrol or diesel. If such emission levels increase, they usually do not exceed the limits permitted by regulations. Particulate emissions are usually reduced, but emissions of acetaldehyde and formaldehyde increase.

Bioethanol usually reduces GHG emissions, but the reduction will vary widely depending on how the bioethanol was produced and from which feedstock. Bioethanol chains using renewable energy to supply the production process and with efficient use of nitrogen fertilizers are most effective in reducing greenhouse gas emissions.

To ensure sustainable bioethanol production, labour conditions and land use change are two of several factors that must be monitored. A variety of verification and certification schemes are being developed to facilitate sustainable bioethanol production and trade. International certification systems are necessary, but may take time to be fully operational. However, it is clear that international cooperation can stimulate sustainable agriculture, and that sustainable bioethanol production can create jobs and increase wealth, both in developing countries and in rural economies in Europe.

Increased focus on sustainability

During the project, a major and often hostile debate on the sustainability of biofuels emerged, in which biofuels were accused of worsening the climate crisis and having negative socio-economic impacts. BEST was sometimes blamed for promoting a product that was perceived as unsustainable.

Partly as a result, the scope of BEST changed to include more work on sustainability issues and more dissemination activities. Communication on issues linked to transport, oil and climate can be complex and may be met with resistance, apathy or bewilderment. In this context, the demonstration and validation activities in BEST represent a key step towards a sustainable future.

Local emissions

Combustion of petrol and diesel, as well as biofuels, generates undesirable products in engine exhausts. Some of these emissions are regulated, as they can be harmful to human health and the environment. In addition, there are many unregulated emissions that may have important negative effects. Modern vehicle systems and fuels are designed to prevent such emissions rising above prescribed limits. Emissions tests are performed on new vehicles during the type approval procedure, which is required before any new vehicle model is permitted to be sold in the EU. The regulated components of vehicle emissions are:

- Particulate matter (PM) – complex, heterogeneous mixtures of solid or liquid particles suspended in the air, and are linked to adverse impacts on human health.
- Carbon monoxide (CO) – a toxic compound caused by incomplete combustion of fuels. CO reduces the blood's ability to transport oxygen and in high concentrations may lead to suffocation.
- Hydrocarbons (HC) – a collective parameter for various hydrocarbons – unburned and partially burnt fuel products mixed with engine exhaust gases. Various hydrocarbons contribute, to a varying extent, to the formation of ground-level ozone, and some hydrocarbons are known to have a direct adverse effects on human health.
- Oxides of nitrogen (NO_X) – created when oxygen and nitrogen mix during combustion. NO_X is linked to respiratory illnesses and production of ground-level ozone.

Of all the regulated emissions, PM is considered to have the most severe effect on human health, estimated to cause many premature deaths per year in EU[7].

Bioethanol has a number of properties that offer potential emission reductions for several local air pollutants when burning it either as a pure fuel or in blends with diesel or petrol. For example, bioethanol does not contain olefins, aromatics or sulphur, which have negative impacts on air quality.

Literature surveys and new emission tests were carried out in the BEST project to investigate the impacts of bioethanol fuels on emissions of regulated and non-regulated pollutants from motor vehicles. There were significant variations between the results.[8]

When studying emissions it is important to differentiate between emissions during (cold) start (i.e. when the catalytic converter is not in full operation) and emissions during normal operation. Emissions are always higher during start, and the difference increases in low temperatures. Once the catalytic converter is warm, emissions from ethanol are generally lower than emissions from corresponding petrol and diesel cars.[9]

HC, CO and NO_X within limits – but no clear trends

Some studies showed that emissions of the regulated pollutants carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NO_X) are higher when bioethanol fuels are used compared to petrol or diesel, while other studies showed lower emissions with bioethanol. It is unclear whether these studies concern cold starts or normal operation. In the few studies that differentiate between cold start and normal operation, emissions/km was usually lower from ethanol cars. In addition, the use of bioethanol fuels normally resulted in levels within the permitted limits.

"Total hydrocarbons" is used as an indicator for harmful hydrocarbons in the exhaust fumes. FFVs emit high levels of unburned bioethanol when cold-starting. But non-combusted bioethanol is usually considered less hazardous to human health than e.g. unburned petrol. Thus, comparing total HC from petrol and bioethanol cars could be misleading. BEST tests showed that around 60 % of the hydrocarbons emitted are non-combusted bioethanol[10]. This result is in line with earlier analyses on ethanol bus exhausts.[11, 12]

Lower emissions of particles

Almost all studies that considered particulate matter (PM) report lower PM emissions with bioethanol fuels than with petrol or diesel.

7 Methodology for the Cost-Benefit analysis for CAFE: Volume 2: *Health Impact Assessment; Clean Air for Europe (CAFE) Programme*.
8 BEST D9.26, *BEST Final Evaluation Report* (to be published end 2009).
9 R Westerholm, et.al, *An Exhaust characterization study based on regulated and unregulated tailpipe and evaporative emissions from bi-fuel and flexi-fuel light-duty passenger cars fuelled by petrol (E5), bioethanol (E70, E85) and biogas tested at ambient temperatures of + 22° C and -7° C*; Swedish National Road Administration, Dnr AL90B 2005:16320
10 BEST D1.20, *Emissions and experiences with E85 converted cars in the BEST project* (2009).
11 Haupt. D, et.al, *Vad är det vi mäter med en hfid när vi kör en 11-liters etanoldriven bussmotor?*, not published
12 Boström C-E, Camner P, et.al, *Health risk assessment of ethanol as a bus fuel*, Report 1996:19, KFB, Stockholm (1996).

Higher emissions of acetaldehyde and formaldehyde

Compared with petrol and diesel combustion, the use of bioethanol fuels normally results in increased emissions of aldehydes (mainly acetaldehyde, but also formaldehyde). Studies indicate that these emissions occur mainly under cold start conditions. Once the catalytic converter has warmed up – normally after a few minutes – levels of aldehydes emitted from vehicle exhausts are considerably reduced. Nevertheless, with current technology, increased use of bioethanol can be expected to lead to increased emissions of aldehydes. However, use of bioethanol also normally results in reduced emissions of benzene and 1.3 butadiene. The positive impacts of these reductions on overall emissions toxicity may outweigh the negative impacts of increased aldehyde emissions. The current academic literature does not provide a definitive statement on the net effect of switching from petrol or diesel fuels to ethanol on overall emissions toxicity. It should be noted that the exposure to aldehydes in vehicle exhausts is much lower than the exposure indoors.[13]

The change in the typical composition of VOC emissions that results from switching to ethanol can also be expected to affect the ozone-forming potential of emissions. Recent studies do not provide a definitive assessment of the ozone-forming potential of ethanol fuels.

Suggestions for reducing uncertainties

As bioethanol use grows worldwide, improved emission control measures may be necessary to ensure that emissions are kept within acceptable limits. BEST therefore recommends:

1. Measuring "non-bioethanol HC" should be a complement for bioethanol vehicles. This makes it possible to better judge how dangerous these emissions are to human health and the environment. It would give bioethanol cars the same fair treatment as biomethane/CNG cars, for which both "non-methane HC" and total HC are measured.
2. Comparative evaluation on the harmfulness of regulated and unregulated emissions from petrol, diesel and bioethanol vehicles.
3. If deemed necessary, research and development to improve vehicle design, exhaust after-treatment and other measures.

A major limitation in generalising emissions impacts of bioethanol fuels is the small number of test results (mainly because of the high costs of testing), which means that the results are neither comparable nor representative. Knowledge about emissions from bioethanol fuels should improve as more and larger standardised tests are carried out.

In-depth

Tests and studies on emission from various bioethanol fuels

- **E85** Several studies on emissions from E85 are reported in the academic literature. Most studies show decreased emissions during normal operation and higher emissions during cold start. However, even the increased levels reported are within the limits of the Euro IV standard.
- **ED95** There are relatively few studies on emissions from ED95. The studies analysed show substantial reductions in PM emissions from ED95-fuelled buses, when compared to diesel-fuelled buses without PM traps. The studies also show ED95 producing significant reductions in NO_X, increases in HC, and inconsistent results for CO.
- **Low Blends** Studies of low blends of bioethanol in petrol (E5 and E10) also report both increased and decreased emissions of regulated pollutants compared with petrol. Most of these studies show CO emissions decreasing with use of low bioethanol blends. Evaporative emissions of volatile organic compounds increased with bioethanol low blends compared with petrol.
- The relatively few emissions tests carried out on intermediate blends of bioethanol in petrol (E20-E50) also gave inconsistent results, although regulated emissions levels were generally within the limits of the Euro IV standard. Emissions testing of E38 in the BEST project did record CO emissions in excess of the Euro IV limit.
- **E-diesel** Studies showed reductions in PM and inconsistent results for CO, NO_X and HC. A small number of tests on ED-diesel reported improvements for all regulated pollutants.

[13] Bruinen de Bruin, et.al, *Characterization of urban inhalation exposures to benzene, formaldehyde, acetaldehyde in the European Union, Environmental Science and Pollution Research*, 15(5): 417-430 (2008).

Preventing leakage

Bioethanol is the least toxic of all alcohols. Bioethanol released into the environment dissolves readily in water and is degraded by micro-organisms without major negative impacts. Bioethanol consumes oxygen when degraded. A large leak could therefore deoxygenate water, affecting aquatic organisms. Bioethanol does not accumulate in the environment and the toxic effect is limited.

Nevertheless, when storing and handling bioethanol, fuel must be prevented from leaking into the environment. Leaks and run-off on fuel station forecourts are collected and filtered through oil separators before being transferred to water treatment facilities. Being water-soluble, bioethanol runs straight through the separator, but experiments show that this has little or no effect on the separation of petrol and diesel hydrocarbons.

Greenhouse gases in the carbon cycle

The road transport sector is responsible for an increasing share of global greenhouse gas emissions and is therefore intimately linked to global climate change (see page 15). Transport accounts for more than 20 % of EU greenhouse gas emissions. It is essential that greenhouse gas emissions – primarily fossil carbon dioxide – from road transport are reduced in both the short and long-term at all levels of society.

Biofuels have the potential to reduce greenhouse gas emissions if produced in a sustainable way. The reduction potential depends on a number of factors, including the form of growth, amount of inputs (e.g. fertilizers), direct and indirect land use change caused by feedstock production, transport, conversion process, and energy used throughout the entire supply chain, as well as the actual combustion process in the vehicle.[14]

These factors are recognised in the RED Directive, which states that biofuels used in the EU must demonstrate a greenhouse gas reduction of at least 35 % compared to fossil fuels. This requirement will rise to 50 % from 2017. From 2018, reductions must exceed 60 % for installations in which production started on or after 1 January 2017. The greenhouse gas savings from biofuels must be calculated to include the impact of land use change.[15]

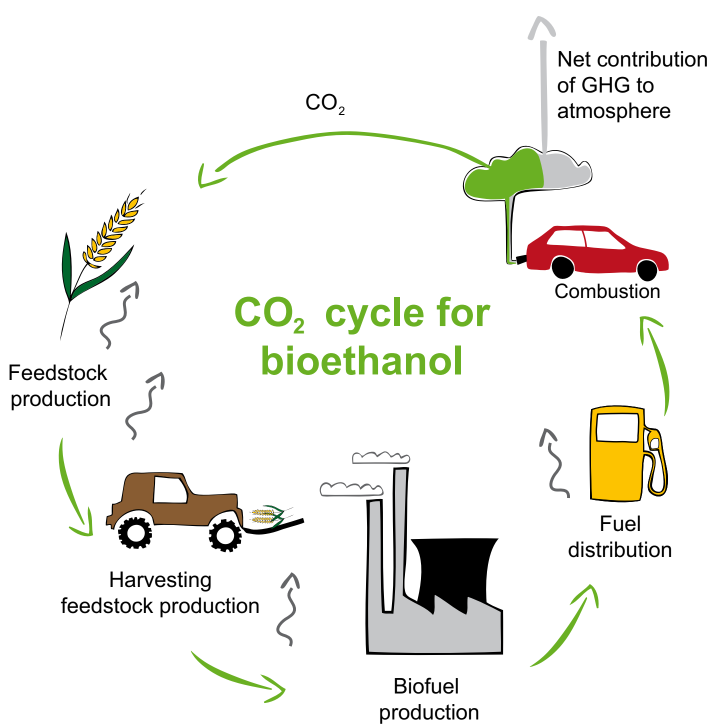


Fig.8 "Well-to-wheel" analyses calculate emissions from all steps in a fuel chain. For bioethanol, all aspects from feedstock production to burning fuel in vehicles are included. Plants absorb CO_2 from the atmosphere when they grow. But all steps in the bioethanol chain also add GHG emissions, due to fossil energy use, leakage, release from soils, transports, etc. WTW emissions express the **net contribution** of GHG to the atmosphere.

14 Börjesson, *Good or bad bioethanol from a greenhouse gas perspective – What determines this?* Applied Energy No 50/86 p589-594 (2009).
15 Directive 2009/28/EC on the *Promotion of the Use of Energy from Renewable Sources*.

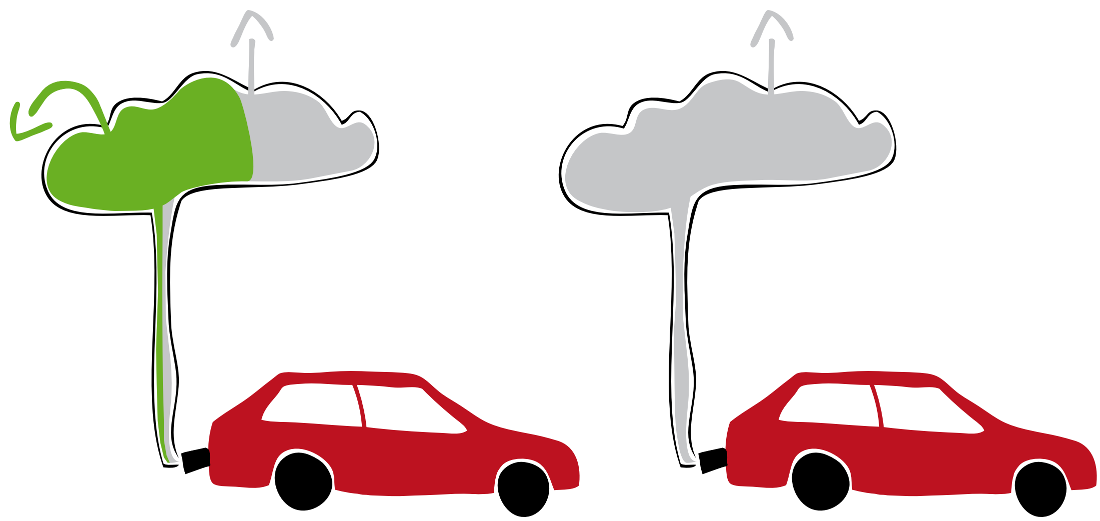


Fig.9 Comparing **tailpipe** emissions from cars running on petrol and biofuels is not comparing like with like, and does not reveal the true GHG savings from renewable fuel. Tailpipe emissions reflect the amount of CO_2 emitted when burning fuel in the vehicle, but give no "credits" to biofuels – even though a substantial part of the emitted CO_2 is part of a carbon cycle that does not increase CO_2 amounts in the atmosphere.

A literature study[16] was conducted, showing that conventional ("first generation") biofuels have different emission reduction potentials depending on how they are produced and which feedstocks are used (excluding land use change). For example:

- Maize: the type and intensity of cultivation is a key factor affecting emissions, and results varied widely. Under some conditions, maize may result in more greenhouse gas emissions than conventional fossil fuels.
- Wheat: despite significant variation in results, all studies of wheat bioethanol showed net reductions of greenhouse gases compared to conventional petrol. The best production methods were on par with sugarcane ethanol.
- Sugarcane: all studies agreed that producing bioethanol from sugarcane can reduce emissions by more than 70 % compared to conventional petrol. Some studies offering extremely high results include credits for co-products of bioethanol production (non-energy products and sale of surplus electricity).
- Sugar beet: results showed reductions of greenhouse gas emissions of less than 50 % compared to conventional petrol if used purely for ethanol. When combined with biogas production, sugar beet may reach the same reductions as sugarcane ethanol.[17]

The literature study also presents results for advanced biofuel technologies (so-called "second generation" biofuels). All "second generation" alternatives offered considerable net benefits in both energy and greenhouse gas emission savings compared to fossil fuels and conventional biofuels, with the exception of some biomass-to-liquid fuels (BtL) from agricultural biomass (particularly short-rotation wood). However, BtL processes using wood from forestry or biomass residues demonstrated excellent potential for reducing greenhouse gas emissions.

BEST bioethanol saved 4–79 % of greenhouse gas emissions

A supply chain analysis of the lifecycles of bioethanol feedstocks and fuels used in BEST was carried out.[18] This was used to calculate the impacts of BEST activities at the different sites and demonstrate impact variations between bioethanol fuels produced in different locations.

Twenty-five bioethanol supply chains were identified across the eight European BEST sites and Nanyang, China. Of these, sufficiently detailed and reliable data was obtained to carry out life cycle GHG emissions calculations for thirteen supply chains, revealing a wide range of results.

16 BEST D9.28, *Sustainability analysis of biofuels production and use*, (to be published end 2009).
17 Börjesson.P., 2008, *Good or bad ethanol – What determines this?* Report no 65B, Lunds University
18 BEST D9.21, *Report on life cycle greenhouse gas impacts of ethanol supply chains at BEST sites* (2009)

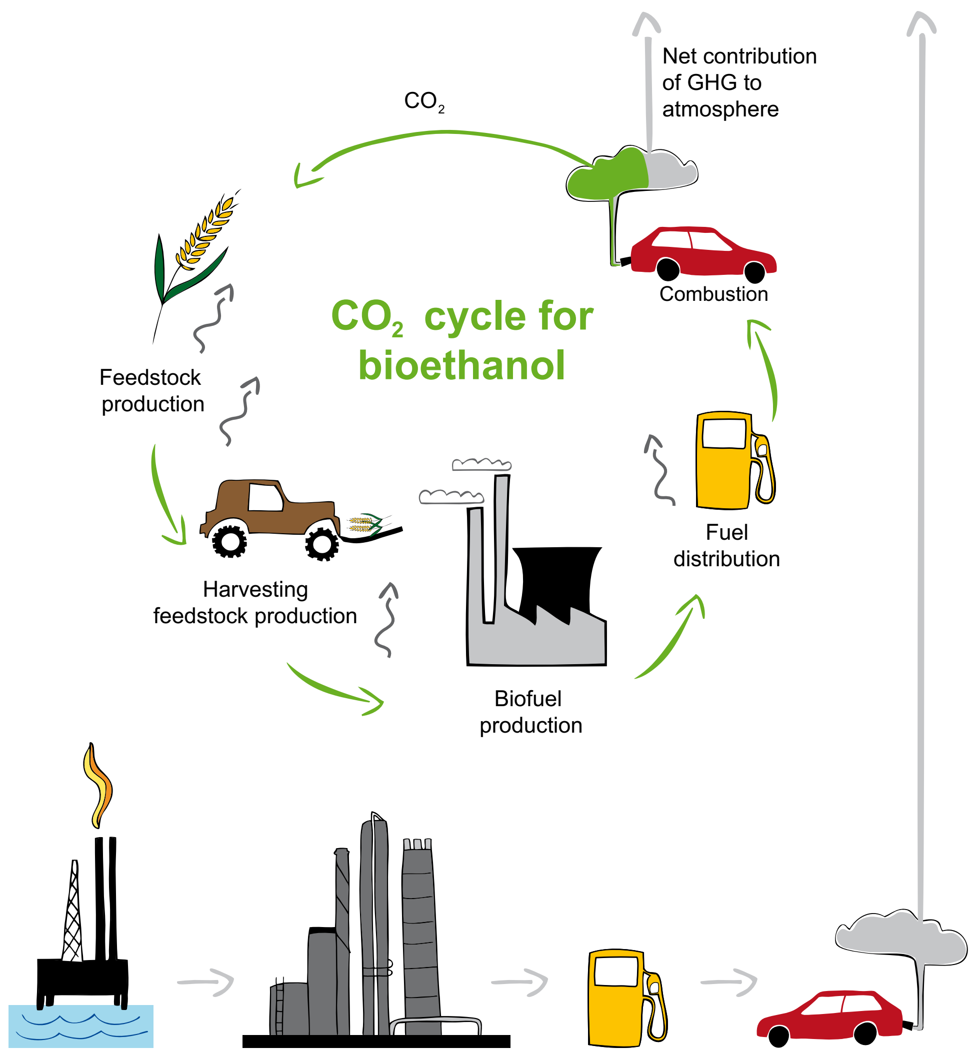


Fig. 10 The net contribution of greenhouse gases to the atmosphere is usually much lower from biofuels than from fossil fuels. When burning biofuels, CO_2 that was taken up during growth is released into the atmosphere. A substantial part of this CO_2 is then reabsorbed by other plants. Burning fossil fuels, on the other hand, releases CO_2 that was stored deep underground and increases the amount of CO_2 in the atmosphere.

The greenhouse gas benefits of driving on bioethanol (E100) instead of petrol are dependent on the source of the bioethanol. The calculated GHG savings compared with petrol covered a range from 4–79 %. This serves to highlight the importance of selecting and promoting appropriate bioethanol production and distribution pathways to achieve GHG reduction objectives. The bioethanol supply chains that are most effective for reducing greenhouse gas emissions are those that use renewable energy to supply the production process, and use nitrogen fertilizer efficiently.

The GHG benefits of bioethanol currently on sale in Europe vary from marginal to substantial. Bioethanol produced from sugarcane in Brazil was the best performing supply chain, but European bioethanol produced using renewable energy and with efficient nitrogen use also achieved high GHG emissions reductions. Fig. 11 shows the results of the supply chains studied in the BEST project.

As all the supply chains analysed show positive GHG savings in comparison with petrol, the implications of the analysis are favourable for the BEST strategy of mitigating growth of GHG emissions through the use of bioethanol. However, the calculations also show that some of the existing bioethanol supply chains are considerably more effective than others in saving greenhouse gas emissions.

Bioethanol used at several BEST sites meets the 35 % greenhouse gas reduction target set by the EU Directive on the Promotion of the Use of Energy from Renewable Sources. Moreover, several supply chains are set to meet the upper requirement for a 60 % reduction from installations established from 2017.

It is worth noting that the best performing bioethanol used in BEST was produced from sugarcane in Brazil. Effective implementation of the RED Directive is likely to depend on the extent to which EU Member States synergise the use of bioethanol from the best-performing supply chains and make optimal use of high-quality imports.

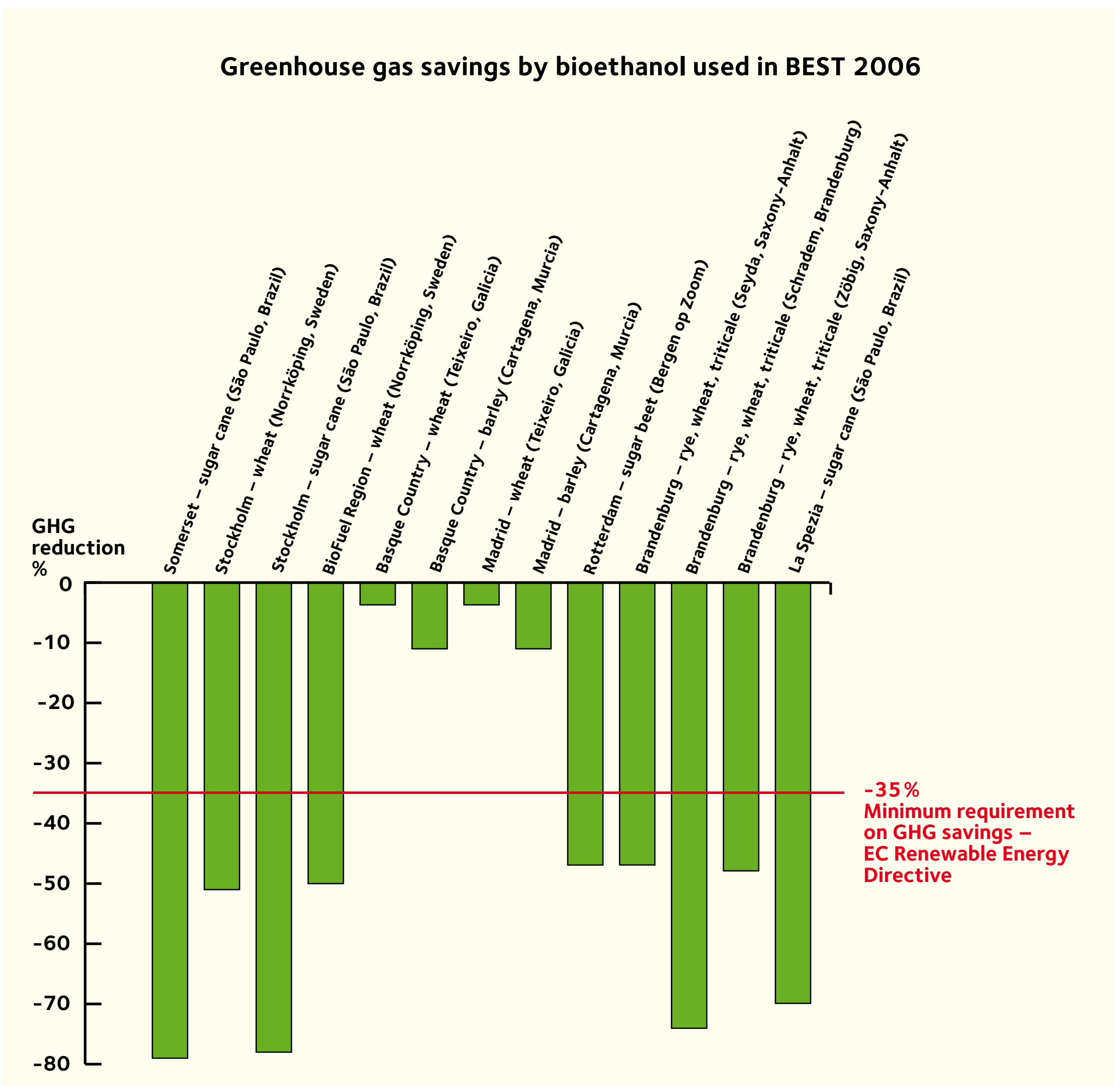


Fig. 11 Greenhouse gas emissions reductions per GJ of bioethanol E100 compared with petrol per GJ for the thirteen supply chains analysed. Source: BEST D9.21. Report on life cycle greenhouse gas impacts of bioethanol supply chains at BEST sites, (2009). This analysis is based on ethanol supply chain data for 2006. Stockholm, BioFuel Region and Rotterdam have since then gone over to use practically only Brazilian sugar cane ethanol making their ethanol supply chains significantly more GHG efficient (an approximate GHG reduction of 78 %).

FFVs' impact on greenhouse gas emissions in BEST

Based on the results of the technical assessment of closely monitored vehicles (se page 44) and BEST's analysis of bioethanol supply chains (see page 34), preliminary calculations for the CO_2 impact per vehicle were made. The impact depends on variables such as vehicle fuel economy and life cycle emissions from supply chains, as well as the reported contributions of the different supply chains to total bioethanol sales at sites. The highest performing bioethanol used in BEST was produced from sugarcane in Brazil. The lowest performance came from Spanish wheat-based bioethanol produced in natural gas fuelled plants.[19]

The preliminary calculations suggest potential life cycle reductions of collective greenhouse gases of between 7 and 152 tonnes of CO_2 equivalent, with the cars running purely on E85. The potential saving of 7 tonnes was based on bioethanol from the Spanish wheat, whereas a potential saving of 152 tonnes can be made if the bioethanol is supplied from Brazilian sugarcane.

By mid 2008, more than 67,500 flexifuel vehicles had been purchased at BEST sites. This corresponds to approximately 0.04 % of the total European petrol car fleet and a potential reduction of between 6,500 – 142,200 tonnes of GHG emissions, assuming that all the vehicles run on E85 containing bioethanol from Spanish and Brazilian supply chains, respectively. This corresponds to approximately 0.01 % of the total GHG emissions from transport in 2008. Since the vast majority of FFVs are used in countries using Brazilian sugarcane bioethanol in E85, the upper limit is more realistic. (See table 4 on page 61 for distribution of FFV cars in EU.)

Based on the above supply chains, and assuming that the closely monitored FFVs are representative of the EU fleet structure and driving habits, BEST found that:

- If 10 % of the EU petrol passenger car fleet is substituted by FFVs driving on E85 only by 2020, GHG emissions from the transport sector will potentially be reduced by 0.1 – 3.4 % in 2020.
- If 50 % of the EU petrol passenger car fleet is substituted by FFVs driving on the best E85 only by 2030, GHG emissions from the transport sector will potentially be reduced by up to 16 % in 2030.

For details and underlying calculation assumptions please refer to BEST D9.26, *BEST Final Evaluation Report* (to be published end 2009).

Please note that all projections for the future and for the 67,500 FFVs in BEST sites, assume that the FFVs use E85 only. Experience from Sweden shows that in 2008, the average Swedish FFV user fuelled E85 to 90 %.[20] The figures thus represent the maximum possible GHG savings, rather than the actual.

[19] BEST D9.21, *Report on life cycle greenhouse gas impacts of ethanol supply chains at BEST sites* (2009).
[20] Swedish Environmental Protection Agency, *2008 Index of the climate impact of new vehicles* (2009).

Methods needed to monitor land use change

In many countries, the production of biofuels is a relatively new and fast-growing activity. A number of players have expressed concern that increased production of biofuels will become unsustainable. Sustainable biofuel production does not displace the production of food or activities that are more ecologically sustainable than biofuel production.

Existing regulations and proposed certification systems need to be refined to ensure sustainable production and use of biofuels. They must also assess the impact of direct and indirect land use change.

Direct land use change

For example, when farmers use previously uncultivated land or open new land areas from forests to grow crops. The change impacts on ecosystems and the environment, as well as on human society and the economy.

Indirect land use change

For example, when the use of a crop or part of its production (previously used for other purposes) is turned to produce biofuels. This may increase demand for the crop in question, and there will therefore be an indirect land use change to meet the increased crop production in other places.[21]

BEST addressed the issue by submitting input to several official inquiries, such as the UK Gallagher Review. This review suggested that estimates of greenhouse gas emissions resulting from land use change could be made using a set of emission factors. Sustainable land use change would increase or avoid losing carbon sequestration capacity, and minimise or avoid emission of greenhouse gases throughout the lifecycle of crops and products, resulting in a net overall benefit for the climate.

Highly complex calculations and scientific analysis are needed to evaluate the impacts of indirect land use change and lifecycles. On a practical level, the issue is complicated in the real world, where farmers responding to the effects of land use change (e.g. a rise in demand for cereals) may be thousands of kilometres away from the cause. Local production has the advantage of being much easier to monitor. The topic is currently under continuous debate.

[21] Modified from Lywood, W.J.s. *Methodology for evaluation of Indirect Land Use Change from Biofuel crops and estimate of GHG emissions*, (2008) ENSUS. Not published report.

Production expected to multiply

Biofuels currently account for 1 % of global land use, a proportion that is not insignificant, but also not likely to profoundly impact on other sectors. The global forestry and meat production industries have a much greater socio-economic impact than biofuels. According to UNEP, world production of biofuels reached 54 billion litres in 2007, accounting for 1.5 % of all liquid fuels. Fuel bioethanol accounted for 46 billion litres of this, and 95 % of production took place in the USA and Brazil.[22]

Bioethanol production has increased in France, Germany and Spain and there is significant potential for further production of bioethanol in the EU, where 16 Member States have constructed bioethanol plants, and where installed capacity is greater than actual production.

A number of estimates have been made about the production potential for biofuels:

Analysing the availability of various feedstocks, a seven-fold increase in bioethanol volumes by 2030 is suggested by Fulton. See Table 1.

The IEA suggests that the supply of biofuels will increase five-fold by 2030 to meet 5 % of the road transport energy demand.[24] Scenarios up to 2030 consider a slow but consistent growth in the share of biofuels, although restrictions relating to land and other resources (such as water) need to be considered.

Walter et al. predict an eight-fold increase in the consumption of fuel bioethanol between 2005 and 2030; based on current trends in the transport sector, see table 2.

Table 1 **Bioethanol potential production from different stocks (billion litres)**

Country/region and feedstock	2010	2020
World bioethanol sugar cane (excluding Brazil)	21.0	61.3
Brazil – sugar cane	40.7	154.3
North America – grain	28.9	68.2
Rest of the world – grain	4.6	10.6
Lignocellulosic bioethanol	0.0	21.2
Total from feedstock	**86.3**	**281.7**
Share of bioethanol in estimated petrol demand	**5 %**	**13 %**

A seven-fold increase of bioethanol production may be possible. Source: Adapted from Fulton (2004) in Rosillo-Calle and Walter (2006)[23]

22 UNEP, *Green Jobs: towards decent work in a sustainable, low-carbon world* (2008).
23 Rosillo-Calle, F. & Walter, A. *Global market for bioethanol: histotrical trends and future prospects*, in Energy for Sustainable Development, Vol 10 (1), March 2006, pp. 20–32.
24 IEA, *World Energy Outlook* (2008).

Table 2 **Bioethanol potential production from different stocks**

Country/region	Consumption in 2005 (billion l)	Consumption in 2030 (billion l)	Annual growth rates 2005–2010	Annual growth rates 2005–2030
USA	15.3	55.3	8.4 %	5.3 %
EU-25	1.6	36.0	26.0 %	13.2 %
Japan	0.5	9.3	34.3 %	12.5 %
China	1.0	21.6	20.4 %	13.1 %
Brazil	13.3	50.0	8.6 %	5.4 %
Rest of World	1.3	100.2	60.8 %	19.0 %
World	33.0	272.4	15.1 %	8.8 %

Table 2 Fuel bioethanol consumption in the world (estimates for 2005 and for 2030) Source: Walter et al. (2008). [25]

Cooperation stimulates sustainable agriculture

Nearly 70 % of the world's poorest people live in rural areas and could directly benefit from increases to revenues achieved through increased exports of agricultural products. In recent years, structural issues in the world economy – such as dumping of subsidised surplus products or reductions in overseas development aid for agriculture – combined with low commodity prices and speculative trading, have profoundly impacted on agricultural communities in the Southern Hemisphere.

If biofuels are produced sustainably – as part of an integrated strategy to achieve production of both food and fuel without negative environmental or social impacts – they may provide an important alternative source of income to communities in developing countries, particularly in regions where food production is challenging due to difficult soils or climatic conditions.

The development linked to the biofuel industry is expected to not only benefit developing countries. For example, the EU can potentially benefit from inward investment and increased cohesion in the rural economies of member countries.

International cooperation for research and joint development programmes can help stimulate sustainable agricultural practices that both respond to the immediate challenges faced by communities in developing countries (such as shortages of food, water and income) and lay the foundations for future growth and development (by increasing community resilience and creating an export market). However, reform of the global trade system to remove barriers inhibiting fair trade and exports is needed if developing countries are to benefit from a potential sustainable bioethanol market.[26, 27]

25 Walter, A, et.al., *Analysis of Environmental and Social Impacts of Bio-ethanol Production in Brazil* (2008).
26 For example: www.bioenergytrade.org
27 Walter, A, et.al., *Analysis of Environmental and Social Impacts of Bio-ethanol Production in Brazil* (2008).

Job creation in rural economies – and in Europe

Growth in the global bioethanol market may lead to job creation in both the EU and other producer countries. This is likely to have a positive effect on rural economies, which may in turn bolster national cohesion and reduce the likelihood of migration from rural to urban areas in many countries.

For example, during the 1990s, Brazil generated 2,200 direct jobs for every one million tonnes of sugar cane produced (1,600 for production, 600 for processing). Over 380,000 people in the São Paulo region were directly or indirectly employed in the biofuels industry in 2007. On average, workers receive two to three times the minimum wage – income that can be spread to other sectors of society.[28]

UNEP states that around 1.2 million workers currently work with biomass (mostly biofuels) in Brazil, the USA, Germany and China. In the wake of the international financial crisis, many countries are investing large sums in "green job" agendas, and the number of jobs is likely to increase rapidly. UNEP suggests that around 12 million jobs will be created in biofuels related agriculture and industry by 2030. The biofuels market – which generated USD 20.5 billion in 2006 – will expand four-fold to generate more than USD 80 billion by 2016. Other estimates suggest the potential for jobs and revenues will be much higher.[29]

The jobs generated will vary depending on the type of feedstock involved. Normally, a basic technology implies more temporary labour and low salaries, while technological advances – such as sugar cane mechanisation – reduce the number of jobs in the agricultural sector but promote skilled jobs. It is expected that more skilled jobs will be created for second generation biofuels. For instance, the BEST partner SEKAB's lignocellulosic pilot plant has 25 full-time staff. Service and maintenance around the pilot plant together with feedstock handling generates around 50 full-time jobs. A larger facility (around 100–150,000 m^3) will generate an additional 50 full-time jobs and around 120–150 jobs in feedstock handling, service and maintenance. Additionally, the construction of new plants for first and second generation of biofuels around the world provides jobs at the different stages of design, construction and operation, as well as the jobs created along the supply chain.

The BEST partner city Nanyang has also seen an increase in bioethanol production, and the total number of workers in the bioethanol plant has grown as a consequence. (BEST D9.28, Sustainability analysis of biofuels production and use (to be published end of 2009).)

Labour conditions must be assessed

Sustainable biofuels are likely to be assessed against sustainability criteria including strict criteria on working conditions. In 2006, the UK Low Carbon Vehicle Partnership identified nine criteria – correlating to International Labour Organisation norms – that must be considered: child labour, freedom of association, health and safety conditions, discrimination, forced labour, wages, working hours, contracts and subcontractors, and land rights.

Many of these issues have strong relevance for developing countries, but may also be relevant for EU Member States. They need to be assessed country-by-country.

28 UNICA, *Sugar cane's energy: twelve studies on Brazilian sugar cane agribusiness and its sustainability* (2005).
29 UNEP, *Green Jobs: towards decent work in a sustainable, low-carbon world* (2008).

Certification – a tool to guarantee sustainability

A wide range of criteria are important for sustainable biofuels, and environmental, economic and social criteria must be balanced. However, certification systems must not become a new type of trade barrier. A level playing field for all transport fuel types would create opportunities to develop appropriate pricing structures and would generate consumer awareness about sustainability issues related to the range of fuels available in their local market.

Noticeably, most of the systems currently used for certification do not fully include other areas of production such as fossil fuels or food.

Several national verification schemes were launched during 2008.

Examples of existing third-party biofuel certification schemes include:

- United Kingdom: Renewable Transport Fuel Obligation (RTFO) [30]
  The RTFO obliges fuel suppliers to ensure 5 % biofuel blends in transport fuels by 2010, and requires companies to report on the sustainability of the biofuels they sell. In October 2008, the first RTFO report was published. It showed that biofuels accounted for 2.61% of transport fuels, slightly more than the fuel companies' obligation (2.5%).
- Nordic Ecolabel [31]
  Following consultations with over 300 organisations, Nordic Ecolabel has certified biofuels since August 2008. This allows distributors to use the "Swan" eco-label when marketing bioethanol, biodiesel and biogas if they meet criteria including reduced greenhouse gas emissions and lower energy consumption in production.
- Greenergy in the UK has been verifying bioethanol imported from Brazil since 2008.

A wide range of other ongoing initiatives include: the Roundtable on Sustainable Palm Oil, the Roundtable on Responsible Soya, and the Roundtable on Sustainable Biofuels (RSB). The RSB is an international multi-stakeholder initiative aiming to develop a global standard for sustainable biofuels. Draft principles and criteria for a global verification system were released in August 2008.[32]

The Better Sugarcane Initiative (BSI) is a global non-profit initiative aimed at reducing the environmental and social impacts of sugarcane production. BSI includes a wide range of stakeholders, including representatives for bioethanol producers and NGOs, and is working to achieve standards and certification systems to measure and monitor the impacts of production.[33]

Sweden supports companies and public bodies seeking to procure biofuels via the Swedish Environmental Management Council's Guidance for Sustainable Procurement. The Netherlands has the "Cramer Criteria" and Germany has an ordinance on sustainability regulation. Both the United Nations and the EU are working on their own systems. The UN system will be voluntary, whereas the EU is developing mandatory requirements linked to the Renewable Energy Directive, RED. RED also considers the use of the Common Agriculture Policy's "Good Agricultural and Environmental Conditions". The Global Bioenergy Partnership (GBEP) is also leading the development of a system with indicators aimed at national bodies.

The technical standards for biofuels are being drawn up by CEN in the EU, and the International Standard Organisation (ISO) is leading development of another initiative. Although the EU is already working on a verification system (that will be introduced in 2010), a global verification system may take longer to implement.

There is a risk that the costs of verification (both in terms of time and personnel) may become too great for smaller producers to bear, but this issue can only be managed if there is a system in place.
Nevertheless, a global approach for all fuels will be needed if the biofuels market is to develop into a global sustainable transport fuels market.

30 www.renewablefuelsagency.org
31 www.svanen.nu
32 http://cgse.epfl.ch/Jahia/site/cgse/op/edit/pid/65660
33 www.bettersugarcane.org/

Example

Verified sustainable ethanol

One example of a voluntary initiative to achieve sustainable ethanol was developed by the BEST partner SEKAB in close cooperation with Brazilian ethanol producers. SEKAB and its partners now supply “verified sustainable ethanol” that is produced according to criteria including:

- Minimum 85 % reduction in fossil carbon dioxide compared with petrol, from a well-to-wheel perspective.
- At least 30 % mechanisation of the harvest, plus a planned increase in the degree of mechanisation to 100 % by 2014.
- Zero tolerance for deforestation or child labour.
- Rights and safety measures for all employees in accordance with UN guidelines.
- Ecological considerations in accordance with UNICA’s (Brazilian ethanol producer) environmental initiative.
- Continuous monitoring that the criteria are being met.

SEKAB began selling the world’s first verified sustainable ethanol (E85 and ED95) in August 2008. SGS, an independent auditing firm, audit each production plant in order to verify that manufacturers meet the requirements put in place by the system.

SEKAB refers to their system as a first step aimed at raising standards in the industry, and will synchronise the criteria with international regulations when these are in place.

Flexifuel vehicles and E85

Short summary

The most noticeable activity in BEST is the introduction of flexifuel vehicles (FFVs) running on E85 – a mixture of 85 % ethanol and 15 % petrol. FFVs can run on E85, petrol, or any mixture of the two.
The BEST evaluation shows that:

- FFV drivers and fleet managers are satisfied and recommend the vehicles to others.
- FFVs are reliable and run well.
- Service and maintenance are the same as for petrol cars, with the exception that FFVs require a change of oil and oil filters 1.5–2 times as often.
- The purchase price of FFVs is about the same as that of petrol cars, whereas operating costs depend on fuel prices.
- Using and handling E85 is as safe as using petrol, but the risks are slightly different.
- Driving FFVs can result in significant greenhouse gas emissions savings providing the ethanol fuel is produced in an efficient and sustainable way.

Cars optimised for both petrol and ethanol

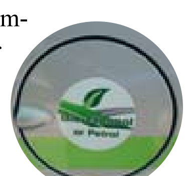
Flexifuel vehicles have a spark ignition engine designed to run on a mixture of petrol and bioethanol. Since bioethanol is more corrosive than petrol, non-corrosive materials are used in some engine components. Fuel injection and spark timing is adjusted automatically by electronic sensors, so the cars' engine can combust any blend of bioethanol and petrol – the cars are in other words "flexible".

Normal petrol cars can be converted to FFVs. The conversion of petrol cars to FFVs has been legalised in Sweden and could be applied in other EU Member States to enable rapid conversion of fleets to run on E85. Converted cars can – just like new FFVs – run on any blend of petrol and E85. A large percentage of the EU's petrol vehicle fleet could be converted to FFV standard. It is estimated that up to 500,000 vehicles (one eighth of the national fleet) could be converted in Sweden alone.

Ethanol with 15 % petrol

E85 is a commercial fuel blend used by flexifuel cars. It is a fuel blend comprising 85% bioethanol and 15% petrol. The petrol is added mainly to improve ignition and cold starts.

Special winter blends may be used in colder-climate countries. These contain an increased volume of petrol, to maintain the fuel's cold-start performance at extreme temperatures. This has no significant effect on vehicle performance as the vehicle is "flexible", but gives a slight increase in controlled emissions and fossil carbon dioxide emissions compared with blends used for summer driving (due to the higher petrol content).



New pumps are needed to supply E85. There are two alternatives:

- A dedicated E85 pump selling only pre-mixed E85, which means that service stations need two sets of pumps to be able to offer both petrol and E85. This option involves lower investment costs, but requires more space on the forecourt. Pre-mixed E85 can also be sold in a pump connected to two underground fuel tanks offering petrol and E85, but no blends.
- A "flexifuel" pump dispensing various blends, from unblended petrol and mixtures such as E5 and E10 up to E85. Blends are mixed at the point of delivery. Customers select the blend using a button on the fuel dispenser. Petrol and E85 are stored in two underground fuel tanks, but only one pump is required. Flexifuel pumps cost slightly more than dedicated E85 pumps, but much less than pumps for gaseous alternative fuels such as biomethane.

In-depth

Conversion of normal petrol cars to FFVs

The conversion requires significant changes to the vehicle software. The engine management system is recalibrated to achieve FFV functionality. Some engine parts such as fuel injectors may need to be replaced, as the lower energy content calls for more fuel to be injected. Bioethanol is more corrosive than petrol and resistant materials are therefore required for all parts that come in contact with the fuel.

In order to guarantee emissions performance, conversion must be elaborated individually for each vehicle model. BEST is aware of the existence of "do-it-yourself" home conversion kits, but these are known to have caused damage and reduced performance in "converted" vehicles, resulting in negative effects such as increased emissions.

Within BEST three conventional petrol cars were converted to FFVs by BEST partner BSR Svenska AB, which made BSR a licensed provider of conversion kits, costing between EUR 860 and EUR 1,350 per vehicle. Conversion is complex and requires a high level of experience and knowledge in order to meet the regulated standards for functionality, drivability, durability and emissions.

The vehicles converted in BEST were tested according to the NEDC (New European Driving Cycle) regulations, and the effects on fuel economy, controlled emissions, greenhouse gas emissions, maintenance requirements and safety were evaluated. Results indicate that converted vehicles running on E85 will contribute towards the reduction of greenhouse gas and other emissions from the road transport sector. There are no technical impediments to conversion and no change in vehicle performance as a result of authorised conversions.

A detailed analysis of authorised conversion and translations of the Swedish conversion regulations are included in the report BEST D 1.20, Emissions and experiences with E85 converted cars in the BEST project (2009).

Converting a diesel car to run on ethanol

In-depth

BEST also trialled the conversion of a diesel vehicle to run on ED95. The technique requires increased compression for ignition and an altered fuel injection system. The diesel conversion tests demonstrated that bioethanol can be used in diesel cars with at least the same good fuel economy as fossil diesel and fulfilling emission standards when driving. There were however recurring problems involving rapid corrosion of engine components after conversion. The tests demonstrated that conversion of diesel cars to run on ED95 using today's fuel and components is not viable, as either a range of components or the properties of ED95 must be adapted to prevent corrosion.

Again, from a technical point of view, using ethanol in an engine with diesel engine characteristics (as opposed to with petrol engine characteristics as those commonly available today) should not present any major problems.

As diesel engines are more efficient than spark-plug engines this could reduce fuel consumption and greenhouse gas emissions even further.

By choosing the right materials in the construction phase, it should be possible to build ethanol cars with diesel engines at the factory, rather than attempting conversion later. This would result in improved energy and emissions performance compared to the use of diesel.

Better-than-expected fuel economy

The majority of new vehicles introduced in BEST are FFV passenger cars capable of running on petrol and ethanol blends up to E85. BEST carried out a detailed assessment of the technical performance of 93 FFVs across 11 different models – predominantly from Ford and Saab but also from Volvo. These vehicles were operated at all sites, sometimes by individuals and sometimes in car pools (with multiple users). A wide range of users included home-service providers for the elderly and disabled and fire inspectors in Stockholm, the Mayor of La Spezia, the Mayor, Alderman and Councillors of Rotterdam, the municipal waste service in Madrid, Somerset County Council and Avon and Somerset Constabulary. In total over 2,164,000 kilometres' worth of vehicle performance was assessed in the BEST FFV study.

Bioethanol has a lower energy content than petrol, and manufacturers of FFVs usually inform customers that these cars consume up to 30 to 40 per cent more fuel than conventional petrol cars. Based on the different energy content and a hypothesis that FFVs utilise the energy contained in petrol and E85 with equal efficiency, it can be assumed that FFVs consume 1.41 times more E85 than unblended petrol on a volume basis. See explanation, page 45.

Preliminary results from tests of on-road use of FFVs enabled a breakdown of occasions when the various FFVs were running on pure E85 or pure petrol. In the periods that the vehicles were running on E85, the FFVs consumed an average of between 8.57 and 14.7 litres per 100 kilometres, while when they were running on petrol they consumed an average of between 8.57 and 13.4 litres per 100 kilometres[35].

These averages are based on a range of results from a number of different sites, with wide variations in data for fuel consumption and the number of vehicles in each sample. The variations can in part be explained by contextual factors – different car models, different driving styles, the distance travelled and the type of journey (city traffic or motorway), fuel supply (E85 was not always available at all sites), refuelling choice, etc.

The evaluations carried out within BEST suggest that the energy efficiency when running on E85 may be between 1 % to 26 % higher than when running on petrol. This results in a significantly lower E85 consumption than anticipated – in the best case only 1.14 times more E85 than petrol was necessary (instead of the theoretically assumed 1.41). This is considered to be an important area for future research.

The above represents a significant finding, further described in the report BEST D 1.19, *The BEST experiences with bioethanol cars* (2009).

It is worth noting that E85 has a higher octane value (approx. 104) than petrol (95). If engines could be adapted to this higher octane value in the future, further increases in energy efficiency could be obtained and the fuel/energy consumption of bioethanol cars could be further reduced.

35 BEST D9.26, *BEST Evaluation Report* (to be published end 2009).

Explanation

Energy efficiency of cars

The fuel consumption of cars is often confused with energy efficiency.
Bioethanol has a lower energy content per litre than petrol:
Petrol: .... 32 MJ per litre
Petrol with 5 % low-blended ethanol: ...... 31.5 MJ per litre
Ethanol: .... 21 MJ per litre
E85 (85 % ethanol): .... 22.7 MJ per litre [36]

Thus, E85 contains 71 % of the energy of petrol (22.7/32 = 0.709). As a result, the fuel consumption measured as litres per kilometre is higher when the car is running on E85, and more frequent refuelling is therefore required. If the energy contained in E85 and petrol is utilised equally as efficiently in the car, 1.41 times more E85 would be required (32/22.7=1.41).

BEST experiences show that FFVs are more energy efficient and do not consume as much E85 as theoretically anticipated (see page 44).

In order to reduce the negative environmental impact of vehicles it is necessary to:

- Improve energy efficiency (engine development).
- Reduce energy consumption (smaller cars etc.).
- Refuel with renewable fuels.

Reliable cars, but more frequent maintenance

Regular reporting on maintenance shows that no additional unscheduled maintenance was required on FFVs compared with conventional cars. FFVs were as reliable as conventional vehicles and suffered no technical problems that may have impeded their functionality. However, more frequent regular maintenance is required for FFVs compared to petrol or diesel vehicles, and energy consumption and performance are directly linked to keeping regular maintenance schedules. Oil and oil filters must be changed 1.5–2 times as often in FFVs as in petrol or diesel vehicles, as bioethanol droplets absorb water from the combustion and get in to the oil, causing impaired lubrication performance. Thus, engine oils offering better compatibility with bioethanol must be developed.

36 Directive 2009/28/EC on the *Promotion of the Use of Energy from Renewable Sources*

Few incidents with E85 pumps

E85 pumps have similar functions and safety requirements as petrol pumps and require no additional maintenance. Nine BEST sites assessed the performance of 24 pumps – 12 dedicated E85 pumps in Rotterdam, Somerset, BioFuel Region, Madrid, Nanyang, La Spezia and Brandenburg, and 12 flexifuel pumps in the Basque Country and BioFuel Region.

In Somerset and Brandenburg existing pumps were rebuilt, while at all other sites new pumps were installed. Only four pumps (one each in Madrid, the Basque Country, BioFuel Region and La Spezia) made use of new fuel tanks. Fuel was provided by nine different suppliers. Installation costs varied considerably, from as little as EUR 4,000 for reconstructing an existing pump and tank, to between approximately EUR 18,000 and EUR 70,000 for new pumps. These are total costs, and thus in some cases also include costs for a new tank, piping, software, etc.

There were a total of 21 reported incidents at the sites, causing a low number of repairs and stops. Incidents were more common at rebuilt pumps, but out of all incidents, only one concerned the fuel, when the wrong rubber O-rings were used in nozzles in Somerset, causing minor seepage from the swivel at the junction of the hose/nozzle. Further information can be found in the report BEST D 4.20, *BEST experiences with distribution of bioethanol for vehicles* (2009).

In-depth

E85 – safe handling and storage

Guidance and regulations on safe handling and storage have been developed in countries such as Sweden [37, 38] and can easily be transferred to other EU Member States.

General observations include:

- E85 fires spread more slowly and less violently than petrol fires. Using alcohol-resistant extinguishing foam is the best method of extinguishing an ethanol fire.
- E85 poses a smaller explosive risk than petrol or diesel. However, E85 has the same explosion classification as petrol, group IIA.
- E85 produces more flammable vapour in confined spaces at high temperatures than petrol. E85 vapour carries a greater risk of igniting the tank outlet compared to petrol vapour.
- E85 has greater conductivity than petrol, reducing the risk of a build-up of static charge in the fuel. However sparks may still occur and could then ignite the fuel.

Storage tanks that have been used for other types of fuel must be thoroughly cleaned prior to use with E85, to avoid residue and sludge contaminating the ethanol fuel. The Swedish Petroleum Institute has issued recommendations concerning the safety aspects of E85 fuel. The recommendations propose a series of safety measures and can be found in BEST D 4.20, *The BEST experiences with distribution of bioethanol for vehicles* (2009).

37 BEST D4.02 A, *Storing and Dispensing E85 and E95, Experiences from Sweden and the US* (2005).
38 BEST D4.02 B, *Safety Aspects with E85 as a fuel for vehicles, fire safety consideration* (2006).

In-depth

Material recommendations for ethanol fuels

Materials	Metallic materials	Non-metallic materials
Compatible with fuel ethanol.	Unplated steel, stainless steel, black iron and bronze.	Non-metallic thermoset reinforced fibreglass, thermoplastic piping and thermoset reinforced fibreglass tanks, neoprene rubber, polypropylene, nitrile, Viton and Teflon materials.
Non-compatible with fuel ethanol.	Zinc, brass, lead, aluminium, ternary (lead-tin-alloy)-plated and steel lead-based solder.	Natural rubber, polyurethane, cork gasket material, leather, polyvinylchloride (PVC), polyamides, methyl-methacrylate plastics and certain thermo- and thermoset plastics.

Table 3 Non-corrosive materials that are compatible with bioethanol must be used in fuel pump and fuel tank components. Aluminium is one example of a material that should not be used. (Source: BEST D 4.20, *The BEST experiences with distribution of bioethanol for vehicles* (2009).

Satisfied drivers

Surveys of driver and fleet manager attitudes were carried out at BEST sites in 2007 and 2008. The majority of drivers interviewed drove an FFV due to their employer's company policy or out of personal concern for the environment. For fleet managers the environmental aspect was a key stimulus for company policy.

Driver surveys were directed at private FFV owners and drivers of FFVs within city and commercial fleets. Around two-thirds of respondents came from Sweden, where over 70 per cent of the EU's FFVs operate.[39]

The fleet manager survey[40] was answered by 58 fleet operators at seven BEST sites with FFVs and buses in their fleet. Most fleet managers were well informed about bioethanol and indicated that high-quality information has a significant effect on perceptions and purchasing behaviour.

In both surveys, users reported positive experiences with FFVs and satisfaction with the overall performance of the vehicles and the fuel. However, fuel prices and access to refuelling infrastructure were cited as major concerns. A combination of regulatory measures and incentives can help address these concerns and improve conditions for market development.

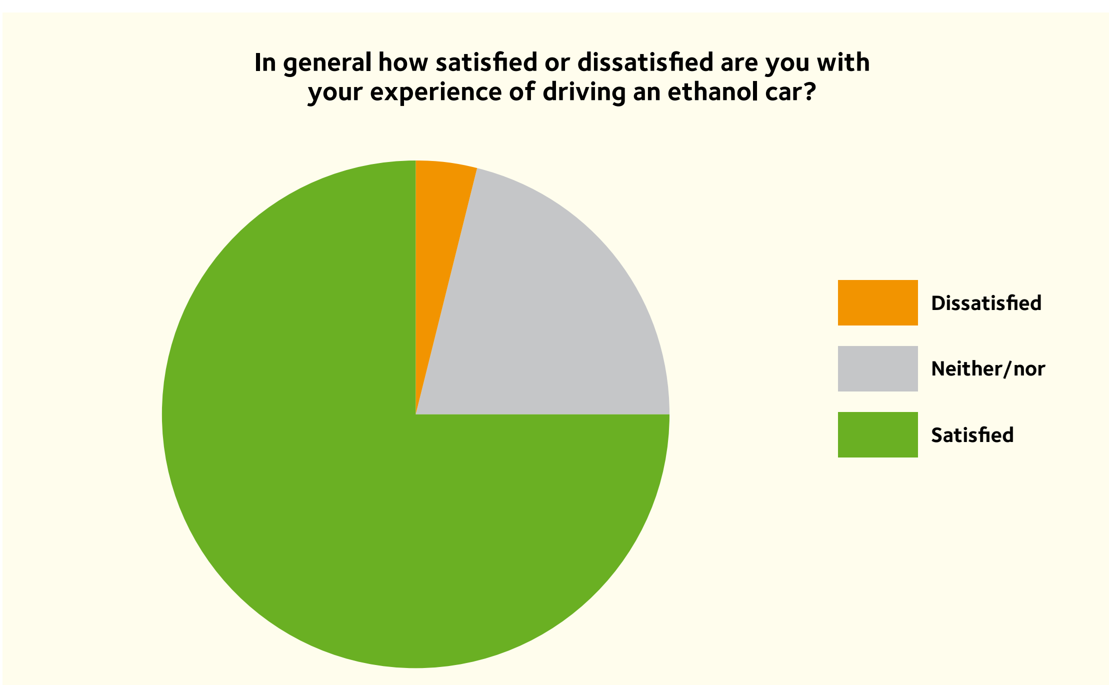


Fig. 12 BEST asked 600 FFV drivers in seven countries how satisfied they were with their cars. The result is convincing: Most drivers are satisfied with driving FFVs. (Source: BEST D 1.14, *Report on driver attitudes towards flexifuel vehicles* (2009).)

[39] BEST D1.14, *Report on drivers' attitudes toward flexifuel vehicles* (2009).
[40] BEST D9.25, *Report on survey of fleet operators' attitudes towards ethanol vehicles and fuel* (2009).

Slightly higher purchase price

A wide range of factors influence the cost of operating an FFV, including purchase price and operating costs, such as fuel, maintenance and insurance.

The purchase price of FFVs varies from country to country. Often, FFVs cost 2% to 5% more than equivalent petrol vehicles. This additional cost is usually less than for other "clean" vehicles such as biogas or hybrid electric vehicles.

FFVs sometimes qualify for special financial incentives aimed at stimulating sales of "clean" vehicles, and the additional purchase cost may then be recouped by the customer. In well-developed markets the additional purchase cost is also reflected in a higher second-hand value.

At some BEST sites, such as Stockholm/BFR, Madrid and Rotterdam, vehicle manufacturers offer FFVs as standard for certain models. In Rotterdam, Ford offers some FFV models even at a lower price. However, a slightly higher purchase price is sometimes a less important factor, e.g. for consumers who are keen to purchase a specific model from a specific manufacturer.

Higher fuel and service costs

The cost of operating an FFV is comparable to that of operating an equivalent petrol vehicle, except with regard to fuel price and service costs. BEST has shown that FFVs are as reliable as their petrol equivalents, but require more frequent regular maintenance if the cars run more than 10,000 kilometres per year (see page 45). This adds a small recurring cost.

The major recurring operating cost is fuel. Though it may be relatively cost-effective to purchase an FFV, the price of E85 causes some drivers to fuel with petrol, while others continue to fuel with E85 despite its higher price.

There are two reasons for the high E85 price:

1. The customs tariffs for bioethanol are higher. This is because bioethanol is classified as a beverage in the international customs system and as an agricultural product by the WTO, rather than a fuel.
2. Taxation by volume – when taxation is calculated by volume, E85 drivers pay a higher tax per kilometre than petrol drivers, if the tax levels per litre are equal.

During most of the BEST project bioethanol has been price-competitive compared with petrol also at oil prices of about USD 70/barrel – if it is treated equal, i.e. is subject to the same customs tariffs and a tax based on energy.

The lower energy content of E85 means higher fuel consumption. Even when E85 has a lower volume price than petrol it can be more expensive per kilometre. This means that taxation must take energy content into account if E85 is to be competitively priced.

If the customs tariffs are kept at a high level, the energy tax must compensate for this, e.g. through setting the same low tax level as for natural gas or LPG.

Table 3 **Taxes and custom tariffs on various fuels to be sold in EU**

	Diesel	Petrol	Biodiesel	Natural gas	LPG	ED95	E85
Custom tariff (€/GJ)	0.00	0.00	1.14	0.00	0.00	9.14	4.39
Fuel tax incl VAT Median EU 27 (€/GJ)	12.22	18.13	13.33	0.42	2.75	20.95	24.95
Total	12.22	18.13	14.47	0.42	2.75	30.10	29.33

The “normal” tax and customs tariffs in the EU impose higher rates on bioethanol fuels than on fossil fuels, biodiesel and gaseous fuels. However, member countries can apply for temporary exemptions allowing lower tax rates. Likewise, importers can apply for a special customs tariff for limited amounts of biofuel. For details and more information about these calculations, see BEST D 2.08, *The BEST experiences with bioethanol buses* (2009).

In-depth

Lower custom tariff possible

It is possible to receive an authorisation from the European Commission for Processing under Customs Control (PCC) which allows import and refinement of a certain amount of pure ethanol to the EU in order to produce specific end products such as E85 or ED95. This enables the use of a custom tariff rate of 6.5 % of the customs value, which results in significantly lower custom fees than for pure ethanol, which is EUR 19.2 per hectolitre.

Each company has to apply for an individual permit, limited to a certain amount of fuel. The last permits given were also limited to one year. As there is no guarantee for a renewed permit it is impossible to set up long-term strategies for market expansion. BEST partner SEKAB is one of few European companies to ever receive such a permit. This complicated and vulnerable process has discouraged other possible importers from applying, and as the permit limits the amount of fuel imported, this whole procedure severely blocks the development of ethanol as a fuel.

Example

In most countries pricing favours driving on petrol over E85

Existing pricing methods strongly favour petrol in most countries. At the end of 2008, when petrol prices were relatively low, untaxed E85 was still a competitive alternative to petrol in all countries except Spain, even when the higher consumption (assumed as 1.38 times higher) was included in the calculation. When the different taxes applied to E85 in the BEST countries were added, driving on E85 was more expensive in all BEST countries. This shows that tax relief can be used as an instrument to ensure that E85 is competitive.

BEST's analysis suggests that the fuel consumption of FFVs is not as great as was previously believed (see page 44). Assuming a Ford Focus FFV requires only a 1.2 times larger E85 volume than petrol, taxed E85 was competitive in Germany and Sweden but remained more expensive than petrol in the other countries (November 2008).

Rising petrol prices increase operating costs for petrol vehicles and during BEST, driving on E85 was sometimes the cheaper option in some countries, for example Sweden (se also fig 23).

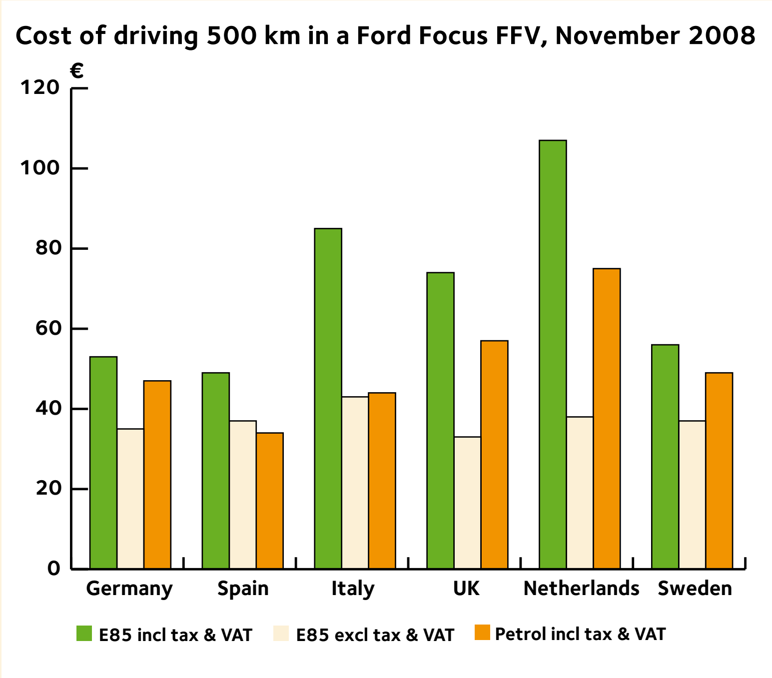


Fig. 13 The graph is only indicative and reflects the taxes and naked price for E85 and petrol in November 2008. Source: BEST D5.14, *Incentives to promote Bioethanol in Europe and abroad* (2009).

Different incentives for different market stages

Short summary

Incentives are very important for achieving market penetration for bioethanol and FFVs. Investors need long term incentives. Incentives can be suspended or removed when the bioethanol production industry has fully developed. The various market stages require different incentives.

Only in Stockholm/Sweden was sufficient data available to make a statistical analysis of the effect of various incentives. This analysis concluded that at the market development stage:

- The single most important incentive is to ensure that the price of bioethanol is equal to or lower than that of petrol (and reflects the different fuel consumption rates).
- Exemption from congestion charging was the second most important instrument to stimulate the use of clean vehicles and bioethanol in Stockholm.
- Incentives impacting on operating costs are more effective then incentives targeting initial costs.
- Free residential parking and a national purchase subsidy influence sales less than fuel price and exemption from congestion charges.

In addition, BEST made the following conclusions:

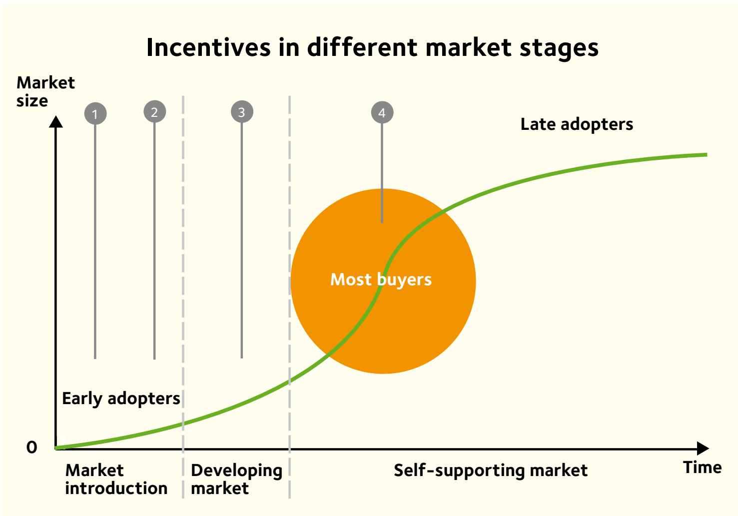
- An environmental bonus offered by car manufacturers proved to be very effective in the Netherlands.
- Competitive fuel prices have the most positive impact on E85 sales.
- The presence of a local/national bioethanol production industry increases opportunities for the introduction of incentives.
- Cooperation with the right stakeholders is crucial.

Monetary incentives are a key part of policy when introducing and promoting clean vehicles and fuels. The single most important incentive is fuel pricing – bioethanol must be priced equal to or lower than petrol to attract many users and thus establish a market for E85 as well as for FFVs. As long as bioethanol is subject to higher customs duties and energy taxes than fossil fuels, other incentives must be used to compensate for this.

The thorough evaluation of incentives in Stockholm suggests that other incentives focusing on operating costs (e.g. exemption from congestion charging) were more effective than incentives reducing initial costs (e.g. purchase subsidies).

The incentives must be relevant to the extent of market development in a specific location. The pre-market stage (addressing the transition from "market introduction" to "developing market") requires so-called preparatory incentives, while the market development stage (from "developing market" to "self-supporting market") calls for incentives that stimulate markets.

BEST partners developed contacts with key decision-makers and stakeholders to stimulate the development of effective incentives. A wide range of incentives were introduced, including a motor tax rebate, local purchase grants, free parking and access to restricted areas. In the following sections, incentives are described as either preparatory or market stimulating, even though there is often no clear distinction between the various market stages, and incentives can support several stages to varying degrees.



1. Embed a long term strategy. Organise test rides. Demonstrate low numbers in real world. Start promoting. Find stakeholders to work together.
2. More support to refuelling infrastructure. More clean vehicle models. Continue promotion. Introduce first financial incentives.
3. Shift to include households. Monitor market development. Continue promotion. Supply policy makers with information.
4. Remove incentives carefully. Monitor market delvelopment.

Fig. 14 Incentives must be relevant to the extent of market development.

Preparatory incentives

Preparatory incentives promote vehicle supply and fuel distribution, and identify and remove legal barriers and tax disadvantages. They help establish market conditions that encourage a wider group of buyers than the "early adopters" to consider purchasing FFVs and E85. A small demonstration fleet and test driving is sufficient at this stage.

The Basque Country coordinated the transport and supply of E85 with filling stations and offered financial support for the installation of flexifuel pumps. Rotterdam also offered local subsidies for the installation of E85 pumps, and Nanyang compensated fuel distributors for installing E10 pumps. In addition, E10 is sold at 91% of the manufacturer's regular petrol price in Nanyang, making it attractive to fuel suppliers.

In BioFuel Region the fuel supplier SEKAB for a limited period of time provided up to 20 m^3 free E85 to pump owners installing flexifuel pumps.

The Netherlands introduced a national subsidy for the installation of E85 and CNG pumps, and the UK offered a grant to encourage the installation of alternative fuel pumps.

National incentives were also used to stimulate the production of bioethanol. Tax changes helped boost distribution and supported market development at the pre-market stage. For example, a small subsidy was offered to innovative biofuel technologies in the Netherlands, and in Nanyang, the government paid producers of bioethanol EUR 150/tonne. Fuel tax on bioethanol was also returned to producers in Nanyang. In Sweden, bioethanol imports for highblends were exempt from tax as well as duty tariffs. Spain introduced incentives for bioethanol production prior to BEST.

These measures aimed to support the market introduction of an infrastructure.

Public procurement can be used as a pre-market tool to launch the market and demonstrate vehicles, but can also be used on a recurring basis as the market develops.

Public procurement contracts stipulate clean vehicles in both the Stockholm City and County Administrations, in Madrid and in some municipalities in BioFuel Region. At these sites, FFVs running on E85 are classed as clean vehicles according to local clean vehicle definitions. In La Spezia, FFVs are considered low-emission vehicles and are encouraged in public tenders.

In the Basque Country, FFV owners received a 50% rebate on annual motor tax and in La Spezia, an investment grant was offered to FFV buyers.

Several sites offered improved accessibility. For example, La Spezia offered FFVs access to restricted zones and taxi/and bus lanes.

Free parking for FFVs was offered in La Spezia, BioFuel Region and Nanyang. In Stockholm, a free parking incentive ended in December 2008, as the City believed a market breakthrough had occurred, making the incentive redundant.

Vehicle manufacturers such as BEST partners Ford and Saab only sold FFV models in certain markets, supporting the transition from market introduction to a developing market.

Market-stimulating incentives

At the market development stage, monetary incentives for end-users and reliable information become effective tools. In Sweden, the market for bioethanol vehicles and fuels was evolving from a "developing market" into a mature market.

As a result, incentives in Stockholm and Sweden focused primarily on end-users. For example, exemption from the Stockholm congestion charge and the establishment of a priority lane for clean vehicle taxis at Arlanda Airport. The latter led to rapid procurement of clean vehicles by taxi firms.

The Swedish market was also boosted by the new "pump law" compelling filling stations above a certain size to introduce pumps for alternative fuels. Bioethanol pumps were cost-effective compared to pumps for other biofuels, and this led to a rapid expansion of the E85 supply network. See fig. 15.

The Dutch fuel supplier Tamoil sold E85 at the same price per litre as petrol, as part of a nation-wide strategy to boost clean-vehicle and fuel sales. Ford Netherlands offered an effective "environmental bonus" for FFV customers and Volvo reduced the purchase price of FFVs.

In the Basque Country, a regional EUR 400 purchase grant was available for vehicles emitting less than 120g CO_2/km. The grant also applied to Ford Focus FFVs and was extended to all FFVs in October 2009. A national clean vehicle rebate of SEK 10,000 (approx. EUR 1,000), including FFV models, was used in Sweden to motivate purchase by private consumers.

In the UK, FFVs received a reduction in company car tax of 2% and fuel duty reductions of 20 pence per litre (approx. EUR 0.22). But since fuel tax was calculated per litre and not by energy content, fossil fuels were often cheaper than bioethanol even with the duty reductions.

Fuel pricing most important for consumers

BEST sites concluded that the single most important incentive for consumers is fuel pricing – bioethanol must be priced equal to or lower than petrol.

This can be achieved through taxation, either by providing an exemption for bioethanol or by a fuel tax system that takes into account energy content or emissions.

Taxation proved effective for supporting market development of biofuels in Sweden, where there is no energy or CO_2 tax on biofuels (until 2013) and lower rates of vehicle and company tax for clean vehicles. There is no hydrocarbon excise duty on biofuels in the Basque Country, and Brandenburg has zero tax on second generation biofuels until 2015.

In Netherlands and UK fuel tax was calculated on a per litre basis. In late end 2009, the Dutch parliament changed the excise duty on E85 giving a 27% refund on sustainably produced E85, partly as a result of work by BEST Rotterdam. Duties on fuel and vehicles were also cited as problems in China and Italy.

For further reading about incentives at different market development stages, see BEST D5.12, *Promoting Clean Cars – Case Study of Stockholm and Sweden* (2009).

Example

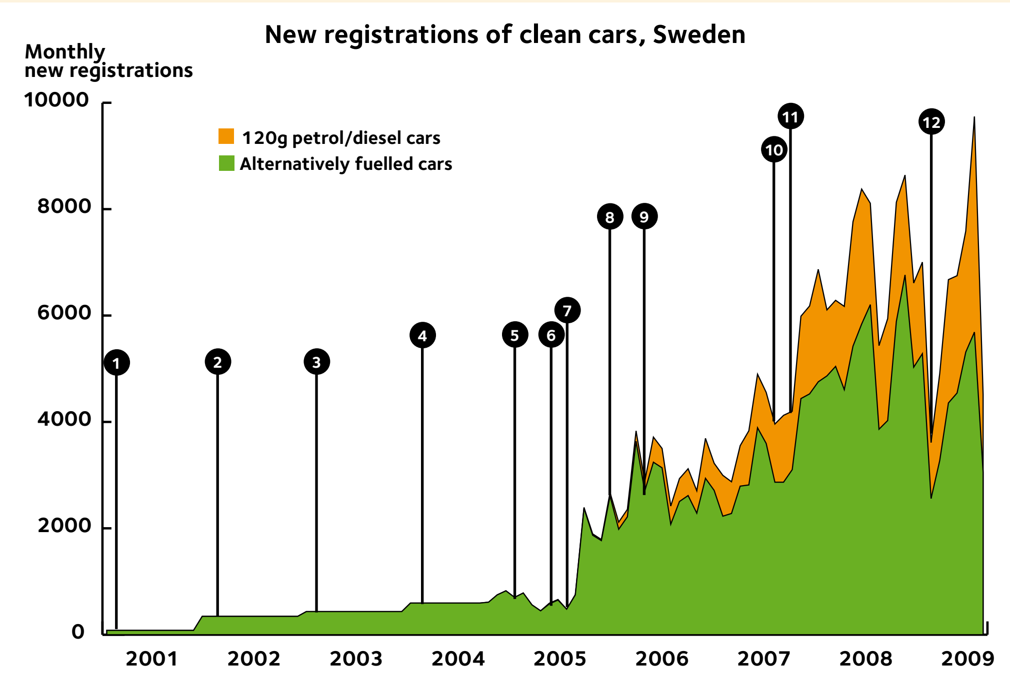
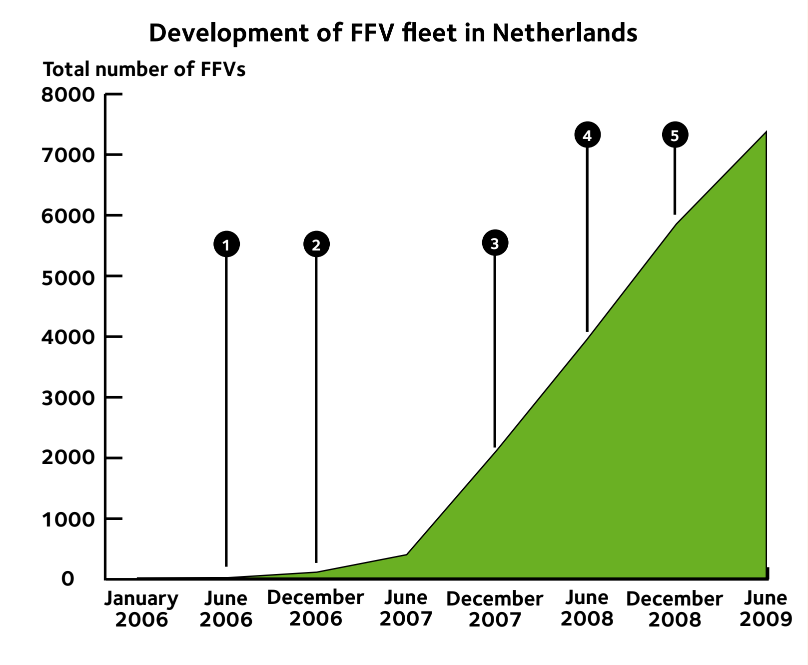


Fig. 15 Monthly clean vehicles sales have increased dramatically in Sweden since 2001. A number of incentives have contributed towards the upward trend, though events such as the financial crisis of 2008 have also caused periodic declines in sales. Source: Environment and Health Administration, City of Stockholm, data from General Agents, Statistics Sweden and BilSweden.

1. Introduction of Ford Focus FFV. Reduced company car tax of SEK 16,000 for electric cars and SEK 8,000 for other alternatively fuelled vehicles, compared to conventional models.
2. Testdriving: Demonstration fleet of loaner clean vehicles financed by the EU-project Trendsetter offered to companies in 2002–2005.
3. General tax reduction on biofuels.
4. Bonus system for clean vehicles used for special transport services (disabled transport).
5. Ordinance on purchase and leasing of clean vehicles by government authorities.
6. Free residential parking (Stockholm inner city).
7. Introduction of Saab BioPower.
8. A separate taxi queue at Stockholm Arlanda airport for clean taxis.
   Congestion tax trial – clean cars exempted from congestion tax.
9. Obligation to supply renewable fuel at filling stations of certain size, requirements increase over time.
10. Rebate of SEK 10,000 SEK on purchase of new clean vehicle.
11. Congestion tax permanent – clean cars exempted.
12. Excemption from congestion tax and rebate on residental parking discontinued.



1. Decision clean city fleet.
2. First E85 pump.
3. Environmental bonus Ford.
4. Tamoil E85 price equal to petrol.
   Volvo reduces price of FFVs.
5. National subsidy for bioethanol and natural gas pumps.

Fig. 16 In Rotterdam, a clear decision was taken to establish a municipal FFV fleet, which was quickly followed by the introduction of the first E85 pump. These pre-market measures were complemented by initiatives by companies such as Ford and Tamoil, addressing the transition from market introduction stage to a developing market. Source: City of Rotterdam.

BEST incentives

BRANDENBURG	
National	Tax rates for biofuels have gradually increased, except for second generation biofuels which are tax free until 2015.
ROTTERDAM	
National	Small subsidy to demonstrate innovative ways to produce second generation biofuels. Subsidy on E85 and CNG pumps.
Regional	Clean-vehicle definition. Training.
Local	Local subsidy on E85 and biogas pumps. Investigation of tools for free parking and access to an environmental zone.
Industrial	Environmental bonus for FFVs.
Tamoil	Subsidy to bring E85 price in line with petrol price.
Counterproductive	Fuel taxation E85 per litre. The trade system for biofuels does not stimulate high blend biofuels.
SOMERSET	
National	Company car tax reduction of 2% for FFVs. Grant for alternative refuelling points. Fuel duty derogation of 20 pence/litre (app. EUR 0.20). A mandatory buy-out price if biofuel mixture requirements are not met.
Counterproductive	Fuel taxation per litre, also with the duty derogation. RTFO is no stimulation for high blend biofuels.
NANYANG	
National	Fuel tax return to producer. EUR 150/ton fuel bioethanol from government to producer. Many research funds.
Local	Compensation for rebuilding pumps to supply E10. E10 is sold at 0.91 x manufacturer's price of regular petrol. No excise for denatured fuel bioethanol. No road maintenance tax for ten FFVs and 2 bioethanol buses. Free parking. Demonstration models E10.
Counterproductive	No clear direction from the government about which technology to invest in. Custom duties on imported cars and buses.
STOCKHOLM	
National	Subsidies/investment grants to production plants. Clean-vehicle definition. Mandatory supply of high blend biofuels at large petrol stations. No energy or CO_2 tax on biofuels until 2013. Lower vehicle tax and company tax for clean vehicles. SEK 10,000 (approx. EUR 1.000) investment grant.
Local	Green procurement. Priority lane at Arlanda Airport (Taxis). No congestion charge. City (and county) procurement stipulates clean vehicles. Free residential parking.

BIOFUEL REGION	
National	Subsidies/investment grants to production plants. Mandatory supply of high blend biofuels at large petrol stations. No energy or CO_2 tax on biofuels until 2013. Lower vehicle tax and company taxes for clean vehicles. SEK 10,000 (approx. EUR 1.000) investment grant.
Local	Own local clean-vehicle definition. Free parking. 20 m^3 E85 to filling station owners opening a flexifuel pump.
LA SPEZIA	
Local	Bioethanol cars considered low-emission vehicles. Investment grant. Access to limited zones and taxi/bus lanes. Free parking in almost all parking areas.
Counterproductive	Fixed duty reduction. Low levels of local production – there is just enough Italian bioethanol to replace ETBE.
BASQUE COUNTRY	
National	No hydrocarbon excise duty on biofuels.
Regional	EUR 400 purchase grant for vehicles with CO_2 <120g/km. Long-term contract with favourable conditions offered to filling stations. Coordination of the transport/supply of E85. Financial support for flexi pumps.
Local	50 % rebate on annual motor tax for FFVs.

Source: Compiled by the BEST project, workpackage 5, with input from all BEST sites.

A European FFV market develops

Short summary

Nine BEST sites have succeeded in introducing over 77,000 FFVs, far exceeding the original aims of BEST. In 2008, there were around 170,000 FFVs in operation and 2,200 E85 pumps installed in the EU. 45 % of the vehicles operate at BEST sites and 80 % of the E85 pumps are found in the BEST countries.

The Swedish sites have reached, or are very close to, a market breakthrough. FFVs represented over 20 % of vehicle sales in 2008 and E85 was available at more than 30 % of filling stations. This has convinced vehicle manufacturers to market nearly 40 FFV models in Sweden. These models can be introduced in other EU-countries through the Common Market.

This development has not been easy to achieve, and several BEST sites still struggle with unfavourable taxes, lacking regulations or an imbalance between vehicle sales and E85 infrastructure. A strong recommendation is to develop a palette of vehicle and fuelling facilities.

When BEST was launched, there were some 12,000 flexifuel vehicles operating in Europe, most of which had been purchased in Sweden. The BEST sites were at different stages of development. Several sites had detailed clean vehicle strategies, whilst others entered BEST with a strong interest and a need to take the first steps. Some sites had experience of different bioethanol blends and operated flexifuel vehicles in city and private fleets, whereas others were making their first attempts to introduce both vehicles and fuels.

BEST's achievements are substantial but vary in scale according to site. By June 2009, a total of over 77,000 flexifuel vehicles had been introduced at nine sites, far exceeding the project's original aim to introduce 10,000 cars. At four sites – Stockholm, BioFuel Region, Rotterdam and Brandenburg – there are signs that the market for flexifuel vehicles has developed rapidly during BEST.

The BEST sites have all made progress up the 'bioethanol staircase', fig. 17, though the rate of progress has varied considerably between sites. This reflects the different starting points and the extent to which stakeholders, regulations, incentives, costs and other factors combined to create better or worse conditions for market development.

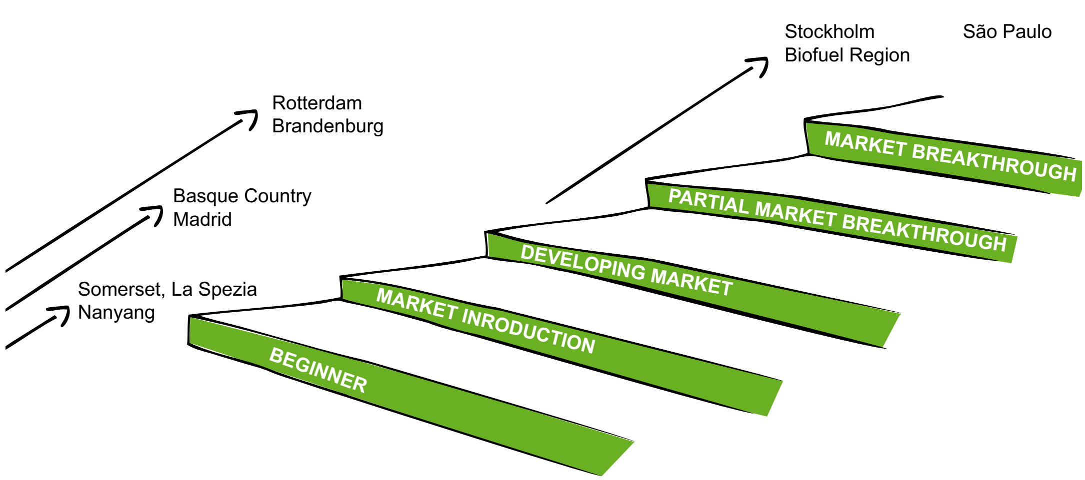


Fig. 17 BEST partners climbing the bioethanol staircase towards a market breakthrough. The position on this staircase is a subjective judgment based on market penetration, type of vehicles in use, additional vehicle price, number of filling stations, type of incentives etc at the site. Sites have moved different much and reached different levels on the staircase during the BEST project.

The two Swedish sites, Stockholm and BioFuel Region, appear to have reached, or are close to achieving a market breakthrough. Sales of FFVs and E85 have increased rapidly during the project period and by the end of 2008, FFVs represented over 20 % of vehicle sales at both sites (see Fig 18). E85 was available at more than 30 % of filling stations at both sites and a large number of FFV models were available on the market.

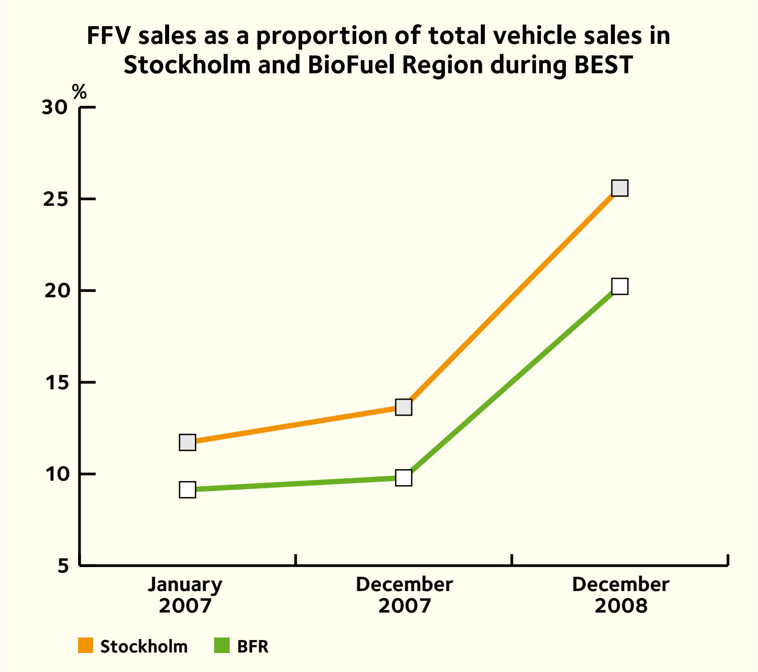


Fig. 18 FFVs as a share of total sales more than doubled from 2006 to 2008 at the two Swedish BEST sites. Source: BEST sites.

FFV sales as a proportion of total vehicle sales at five other BEST sites are illustrated in Fig. 19. Brandenburg and Rotterdam have progressed from beginner to developing markets, although some major challenges must be overcome if these markets are to develop further. FFVs are sold in large numbers at both sites but the price of E85 and counter-productive incentives and regulations have inhibited market development. There is limited access to E85 fuel pumps at both sites. Competitive pricing for E85 could trigger rapid market development.

In the Basque Country and Madrid, solid progress has been made towards market introduction. Sales of FFVs have risen, but fuel supply and pricing remain critical problems. Moreover, FFVs maintain a lower share of the total market than in Brandenburg and Rotterdam. Greater use of incentives, competitive pricing and development of fuel infrastructure could stimulate wider uptake of FFVs and E85.

Somerset, Nanyang and La Spezia have faced a range of difficulties in introducing FFVs and E85. These include lack of political support at national level, cost, regulations and excise tax, and lack of infrastructure. Nonetheless, at each site FFVs and E85 have been introduced and operated. This provides valuable experience and lays the ground for future development.

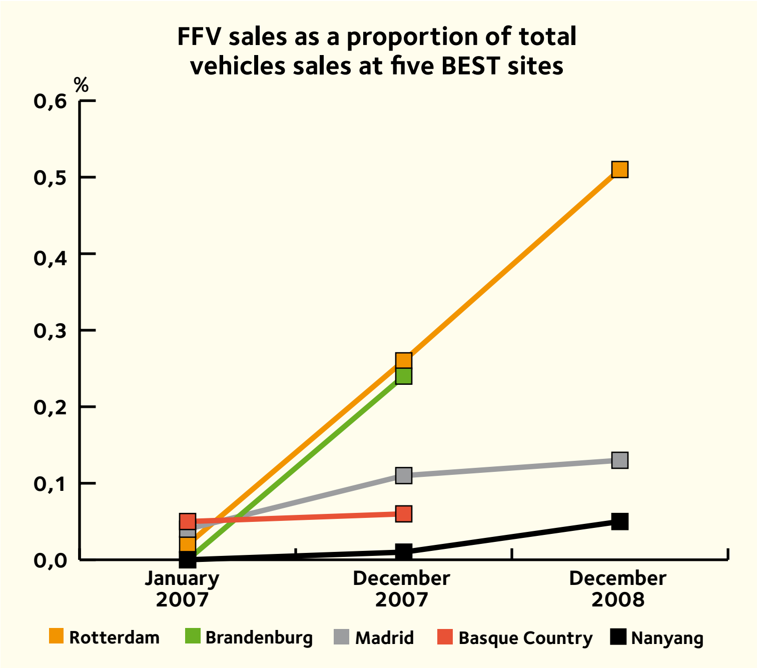


Fig. 19 FFV sales increased in a positive fashion in Rotterdam and Brandenburg. Sales in the Basque Country, Madrid and Nanyang grew at a much slower pace. Source: BEST sites.

Total number of FFVs in the EU

In 2008, almost 79,000 flexifuel vehicles were sold in the EU; contributing to a total fleet of over 170,000 FFVs. Vehicles operating at the BEST sites represent approximately 45 % of this total. By June 2009, over 77,000 flexifuel cars had been introduced at nine BEST sites, far exceeding the project's original aim to introduce 10,000 cars. Over 1,700 E85 pumps are in operation in BEST countries and over 2,200 in the EU.

Two thirds of these pumps are located in Sweden, and in 2008, almost 75 % of EU FFV sales took place in Sweden. This highlights both the more advanced state of the Swedish market prior to BEST and the subsequent speed of market development in the country.

The countries with the next largest total FFV sales were Germany, France and Ireland respectively. France adopted strategies from Sweden and is committed to E85 production, offering significant economic opportunities to the French agricultural sector. Likewise, Ireland is also interested in local production. This sales data was provided by General Motors taken from its internal MIS database and may contain inaccuracies or discrepancies. However, the overall trends appear similar to those observed by the BEST partners.

Across Europe, the market for FFVs and high-blend bioethanol fuels is growing. Table 4 also shows over 2,200 installed E85 pumps, nearly 80 % of which are located in BEST countries and over 60 % in Sweden alone. At the start of BEST, several countries had neither E85 distribution capacity nor operational FFVs, and a wide range of factors, such as EU and national biofuel directives, have influenced this development. By demonstrating FFVs and disseminating information about bioethanol, BEST has contributed directly at the participating sites and their countries and indirectly in Europe as a whole.

As the market for FFVs has grown, the number of manufacturers offering models on the EU market has increased. However, as table 4 shows, the availability of these brands varies considerably within the EU. The availability of various car models influences the development of the market. There needs to be various models on the market to increase the sales volumes.

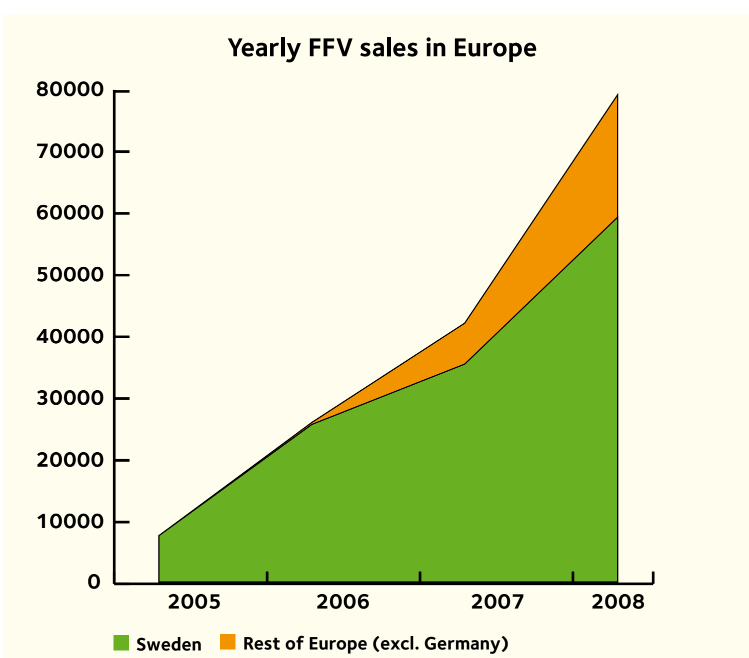


Fig. 20 In 2008, almost 79 000 flexifuel cars were sold in the EU, making a total of over 170,000 registered flexifuel vehicle, the majority of them in Sweden. Source: BEST D1.19, *The BEST experiences with bioethanol cars* (2009).

Table 4 **FFV fleet, sales, brands and E85 pumps in EU early 2009**

Country	FFV units sold in 2008[41]	Approx. FFV fleet size[42]	No of E85 pumps (April 2009)[43]	Available FFV brands[44]
Austria	503		13	Ford, Renault, Saab, Volvo
Belgium & Luxembourg	198		3	Saab, Volvo
Denmark	82			Ford, Saab
Estonia			4	
Finland			3	
France	3,178	7,000	305	Cadillac, Citroën, Dacia, Ford, Hummer, Jeep, Lotus, Peugeot, Renault, Saab, Volvo
Germany	5,694	10,000	255	Ford, Saab, Skoda, Volvo
Hungary			36	
Ireland	2,730	7,000	31	Citroën, Ford, Renault, Saab, Volvo
Italy	96	150	1	Ford, Saab, Volvo
Latvia			1	
Lithuania			1	
The Netherlands	3,679	6,000	29	Cadillac, Chrysler, Citroën, Dodge, Ford, Hummer, Mitsubishi, Peugeot, Saab, Volvo
Norway	452		19	
Poland	34			Ford
Spain	1,546	4,500	15	Citroën, Ford, Peugeot, Renault, Saab, Volvo
Sweden	59,066	130,000	1,440	Audi, Cadillac, Chevrolet, Chrysler, Citroën, Dacia, Ford, Mitsubishi, Nissan, Peugeot, Renault, Saab, Seat, Skoda, Volvo, VW
Switzerland	1,191	5,000	62	Cadillac, Chevrolet Chrysler, Citroën, Ford, Renault, Saab, Volvo
United Kingdom	452	2,000	21	Citroën, Ford, Renault, Saab, Volvo
Total Europe	78,901	171,650	2,239	Audi, Caddilac, Chevrolet, Chrysler, Citroën, Dacia, Dodge, Ford, Hummer, Jeep, Lotus, Mit-subishi, Nissan, Peugeot, Renault, Saab, Seat, Skoda, Volvo, VW

Source: BEST D1.19: *The BEST experiences with bioethanol cars* (2009).

41 Based on information from a GM internal database and BEST D1.04, *Number of ethanol vehicles sold and prognosis for coming year* (2009).

42 Compilation by BEST WP1 leader Eva Sunnerstedt with input from BEST sites and several national stakeholders.

43 www.korridor.se/aryan/acadiane/E85/stationsadmin/stations_search:phtml

44 Compilation by BEST WP1 leader Eva Sunnerstedt with input from BEST sites and several national stakeholders.

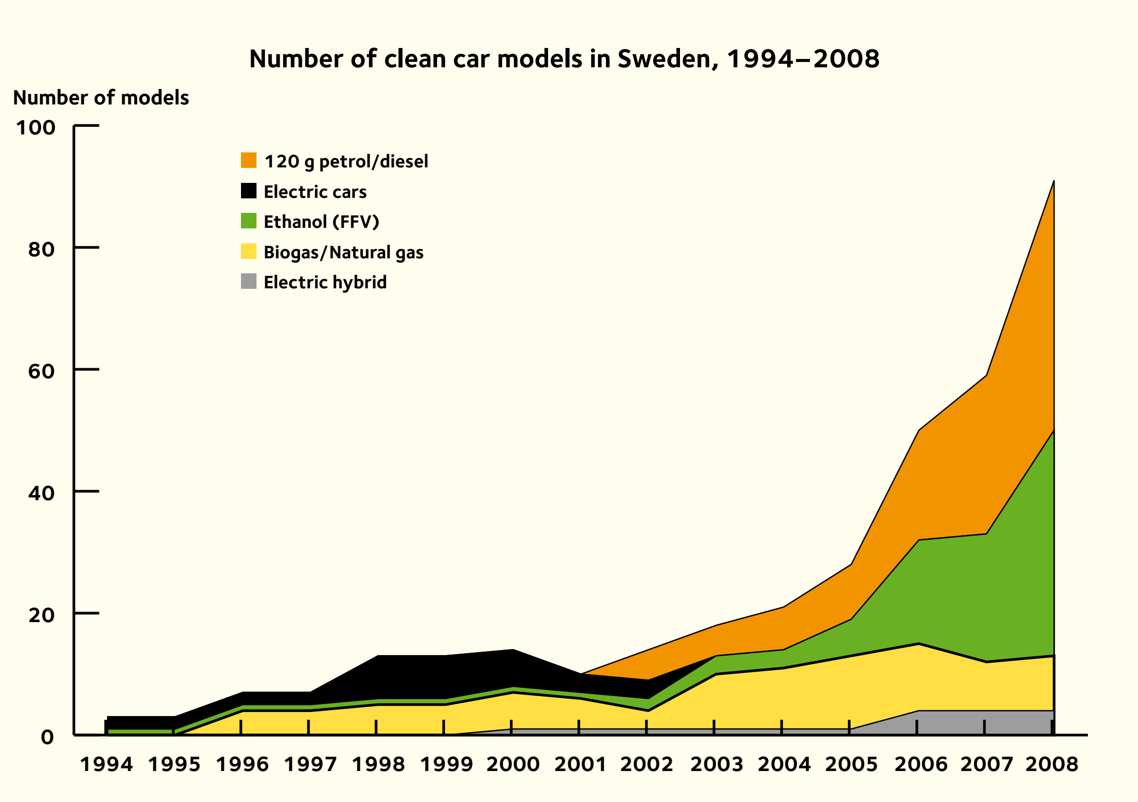


Fig. 21 The availability of clean vehicle models has increased substantially in Sweden.
Source: BEST D5.12, *Promoting Clean Cars – Case Study of Stockholm and Sweden* (2009).

Example

Rapid increase of E85 pumps thanks to Swedish pump law

The rapid increase of E85 pumps in Sweden was strongly influenced by the “pump law”, a national obligation for petrol stations of a certain size to install alternative fuel pumps. This has had a profound effect on the market, signalling to consumers that access to alternative fuel supplies would increase across the country. Between 2005 and 2008, the number of filling stations supplying E85 or biogas/CNG increased from less than 200 in 2005 to over 1,300 at the end of 2008. Around one third of all filling stations in Sweden now offer a renewable fuel.

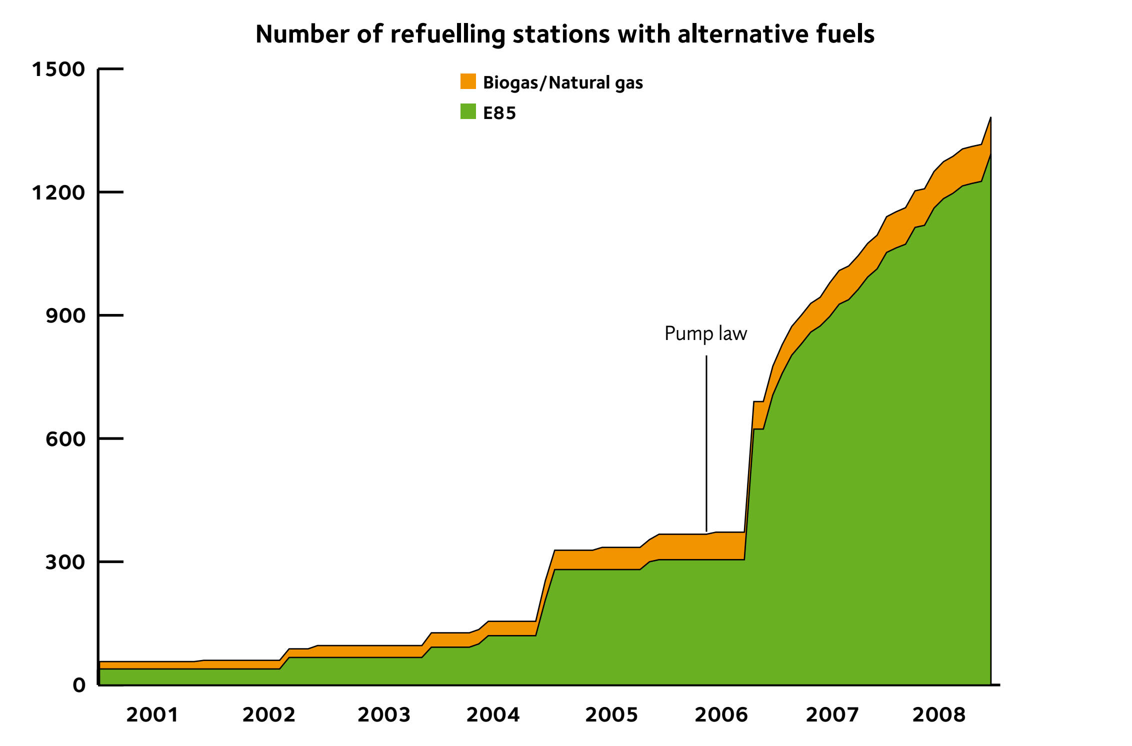


Fig. 22 The number of refuelling stations supplying alternative fuels increased rapidly thanks to the “pump law”. E85 pumps dominate. Source: BEST D5.12, *Promoting Clean Cars* – Case Study of Stockholm and Sweden (2009).

Introducing FFVs and E85 in parallel

One key issue in BEST was to overcome the "first-mover" problem inhibiting the market development of clean vehicles and fuels.

The introduction of FFVs may partially resolve the "first-mover problem". For example, reasonable numbers of FFVs were sold at BEST sites in Madrid, Rotterdam and Brandenburg, where vehicle manufacturers decided to offer FFVs as standard models. This means a potential rapid increase in E85 consumption, but such an increase is hampered by a lack of E85 pumps and the unfavourable price of E85 compared with that of petrol, resulting in FFVs mainly being used as petrol vehicles.

BEST has observed the need to expand alternative fuel-supply infrastructure in synergy with other aspects of market development, such as fuel production and vehicle sales.

The introduction of E85 pumps may be inhibited by a range of counterproductive incentives supporting the development of fossil-fuel distribution facilities. Ultimately, the volume of E85 sold is directly linked to competitive pricing as discussed earlier in this chapter.

The BEST sites delivered mixed results on the introduction of E85 pumps. From January 2006 to June 2009, almost 250 E85 pumps were installed at petrol stations at the nine BEST sites. In total, over 300 E85 pumps are in operation at the BEST sites, of which 267 in Stockholm and BioFuel Region.

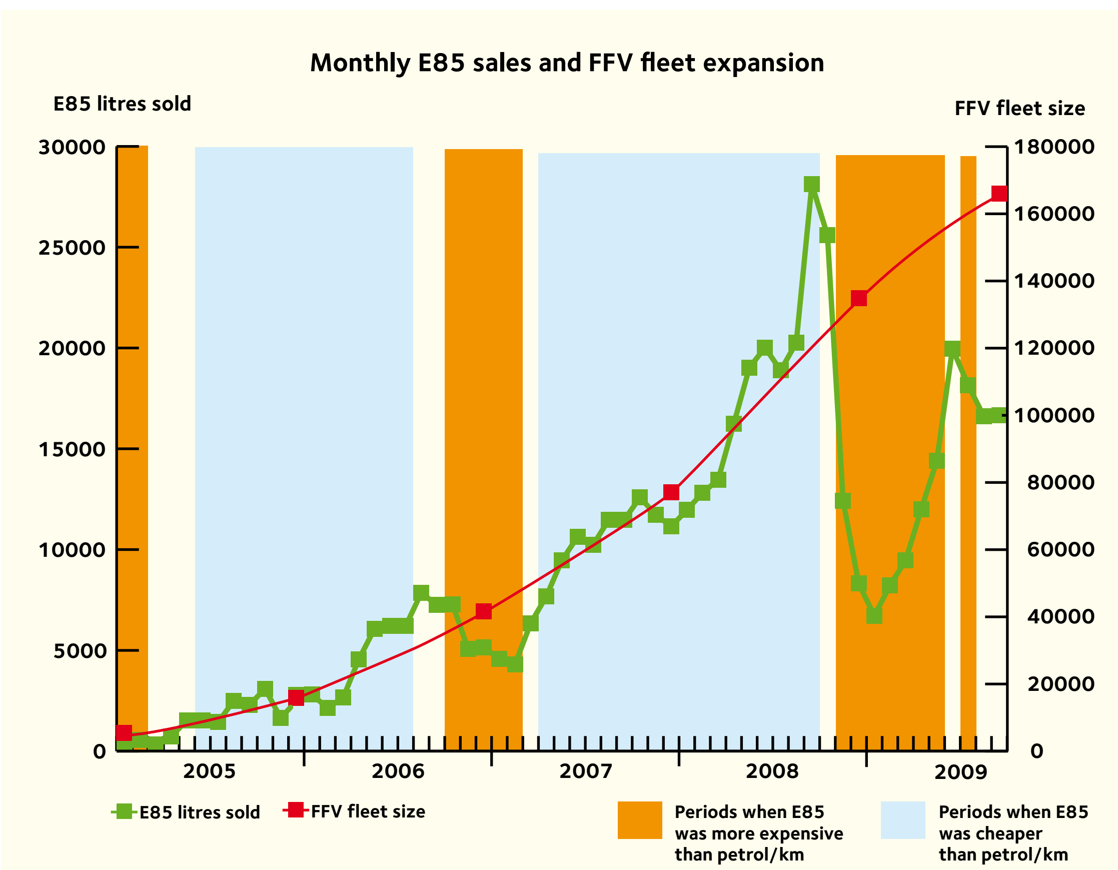


Fig. 23 The renewable fuel obligation meets and stimulates demand. This, combined with the rising number of FFVs in Sweden, has led to a rapid increase in sales of E85. However, an increased FFV fleet does not automatically increase E85 as sales are still closely linked to price in relation to the price of petrol. For example, a dramatic fall in E85 sales occurred in November 2008 when the price of petrol per kilometre was less than that of E85. Sources: BilSweden, Swedish Petrolium Institute and The Swedish Transport Agency.


9-4X Power Concept

Buses and bus fuels

Short summary

Bioethanol blends such as ED95 and E100 can be used to substitute diesel and petrol in heavy vehicles such as buses and trucks. BEST demonstrated bioethanol buses at five sites – Stockholm, Madrid, La Spezia, São Paulo and Nanyang.

The experience shows:

- Bioethanol buses can reduce greenhouse gas emissions and local air pollution.
- Bioethanol buses are reliable and appreciated by drivers and passengers.
- Bioethanol buses cost more to purchase and operate than diesel buses.
- Bioethanol buses require more scheduled maintenance than diesel buses.
- Taxing fuel by volume instead of energy content penalises bioethanol buses.
- ED95 can be safely handled at depots and has potential for wider use in heavy vehicles such as trucks.
- Using bioethanol buses is one way to implement the Clean Vehicles Directive, but municipalities must help Public Transport Authorities (PTAs) and operators to spread investment risks.

“Normal” buses modified to run on bioethanol

Short summary

138 bioethanol buses were demonstrated at five sites – three in Europe, one in Brazil and one in China - in the BEST project. The project included demonstration of two types of bioethanol buses – a diesel engine Scania bus running on ED95 and a Dongfeng bus capable of running on both E100 and petrol. Fuel pumps were also installed at bus depots.

- There were almost 500 bioethanol buses in regular traffic in Stockholm and seven ED95 pumps: 127 of the buses and five fuel stations were funded within BEST.
- Five buses in regular traffic in Madrid and one fuel pump.
- Three buses and one fuel pump installed in La Spezia.
- One bus and one fuel pump operational in São Paulo, Brazil.
- In Nanyang, a new type of bioethanol bus capable of running on petrol or E100 was developed by Dongfeng. The buses look like conventional buses and have two fuel tanks, one for petrol and one for E100. Two buses were demonstrated by local bioethanol producer Tianguan, who also supplied E100 for the buses. One fuel pump was set up.
- Demonstration of a Scania bus in China during the 2008 Beijing Summer Olympics.

All Scania buses used sugar cane-based bioethanol with an ignition improver (ED95) in a bioethanol-adapted diesel engine. The ED95 was supplied by fuel distributor SEKAB as part of their “verified sustainable ethanol” initiative, i.e. the bioethanol is both environmentally and socially sustainable.

A Scania bioethanol bus looks just like an equivalent diesel bus, but has a bioethanol-adapted compression ignition engine that is designed to run on bioethanol. Diesel engines are more energy efficient than petrol engines, and the engines used in bioethanol buses have the same energy efficiency as a conventional diesel engine (approx. 44%). The main differences compared with diesel engines are:

- Raised cylinder compression ratio.
- Larger injector holes.
- Modified injection timing.
- Fuel pump with larger flow capacity.
- Gaskets and filters in the fuel system exchanged for ones made from more alcohol resistant materials.

The Scania buses used in BEST met the Euro IV emission standard. This version of the bus is, however, no longer marketed. Scania now offers a new generation of bioethanol buses that meet the EEV (Environmentally Enhanced Vehicle) emission standard.

Two dual-tank E100 buses developed by the Chinese vehicle producer Dongfeng were tested in BEST. These flexible buses can run on either petrol or hydrous E100 – an innovation within BEST. The bus uses petrol when starting and switches to bioethanol after running for a while. One of the buses uses a modified petrol-engine and the other uses a modified natural-gas engine.

Bus fuels and filling stations

Scania bioethanol buses use a fuel known as ED95, which consists of 96.5% bioethanol and 3.5% ignition improver. ED95 contains 60% of the energy in diesel if compared per liter. This means that an ethanol bus consumes almost 1.7 times more ED95 than an equivalent diesel bus. The fuel pumps for ED95 are the same as diesel fuel pumps and cost around the same, although the materials in the tank and dispenser must be bioethanol resistant. Refuelling bioethanol buses takes no longer than refuelling with diesel. Bioethanol buses usually operate locally and use individual pumps based at depots. An extensive network of filling stations is not required.

ED95 has the same classification as petrol and must be handled as such. Refuelling must take place outdoors. A diesel tank facility can be converted to bioethanol but:

- A sprinkler system must be installed at the bioethanol tank and pump area, as ED95 has a lower flash point than diesel and shares the same hazard classification as petrol. All employees should receive safety information.
- The fuel pump has to be approved for a hazard classification equal to that of petrol.
- All polymer components in the tank and pump facility have to be checked.
- The tank should not be painted on the inside since bioethanol is a powerful solvent. Today, all new tanks are painted with alcohol-resistant paint.
- The tank facility should be approved for commercial use by a legal authority.

The Dongfeng buses demonstrated in Nanyang run on pure hydrous bioethanol, E100. Unlike ED95, this fuel requires no additive. In China, the ED95 additive is subject to import duties, making the fuel more expensive than E100. The E100 fuel stations follow the same standards as normal petrol stations, but materials in the pump and tank are checked to ensure they are resistant to bioethanol.

More bus and fuel suppliers required

In Europe, there is a huge difference between the market for FFVs and E85 and the market for bioethanol buses and ED95. At present, there is only one supplier of bioethanol buses (Scania) and one supplier of ED95 (SEKAB), which owns patents for the ignition improver added to ED95 and for the additive manufacturing process.

The E100 buses used in Nanyang were tested for the first time within BEST. They are manufactured by Dongfeng and represent a low-cost alternative to Scania buses for Chinese cities seeking to introduce bioethanol into their public transport systems. The buses were used in the company fleet of the Tianguan Group, the local bioethanol producer, to collect and drop off employees travelling to and from work. As the Tianguan Group supplies bioethanol for the buses, there were no problems accessing fuel supplies.

The lack of suppliers inhibits the development of standards, which in turn restricts the opportunity for market development and the emergence of a stable second-hand market. The lack of a second-hand market makes leasing buses more expensive, forcing public transport operators to purchase buses instead. This is a large obstacle to market development, since many operators prefer leasing to buying.

Example

BEST at the Olympics

Scania and Nanyang cooperated with the Beijing Public Transport Fleet to demonstrate a Scania bioethanol bus during and after the 2008 Summer Olympics. The bus operated on three two-hour circuits each day, from the start of the Olympics until the end of the year. Nanyang was responsible for providing the bioethanol and blending it with the ignition improver. The BEST logo and the fact that it was a bioethanol bus appeared on the bus exterior and passengers could read about the fuel and the technology inside the bus.

Bureaucratic difficulties for pioneers

Bioethanol buses were introduced in Sweden in the mid-1980s, mainly to help reduce emissions of PM and NO_X. The Stockholm Public Transport Authority then decided to increase the use of biofuels to reduce greenhouse gas emissions. Their present goal is to achieve 50 % biofuels in the fleet by 2011 and 100 % by 2025. Bioethanol buses will play a major role in reaching these goals.

When BEST was launched in 2006 there were around 250 bioethanol buses operating in several Swedish cities, but none outside Sweden. BEST aimed to change this and show that bioethanol bus technology is transferable to other sites.

However, with the exception of Stockholm, the introduction of bioethanol buses to fleets proved difficult at all sites. The pioneering actions in the different countries encountered a number of problems due to the absence of regulations, procedures and guidance on how to import, handle and supply bus fuel.

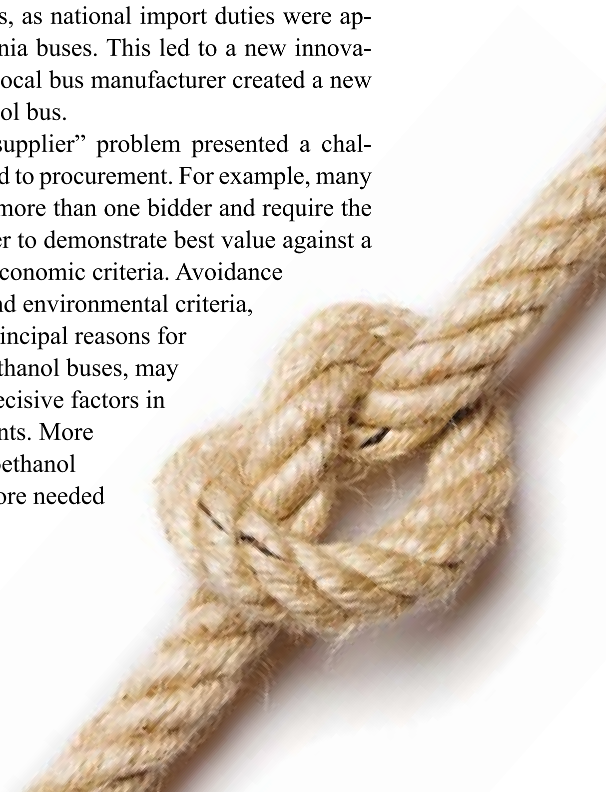
For example:

- La Spezia – no regulations for importing or using ED95 existed prior to BEST.
- Madrid – ED95 was initially subject to beverage alcohol tax.
- Nanyang – high price and import taxes meant Scania buses were not affordable compared to local producers. This led to the development of the Dongfeng bus.
- Rotterdam – the lack of supportive national taxation measures, in combination with higher fuel consumption, meant no sound business case for bioethanol buses could be made.
- BioFuel Region – lack of formal targets for biofuels in bus fleets meant that no operator wanted to pay higher costs to increase the number of bioethanol buses.

The Swedish BEST partners, who had prior experience of operating bioethanol buses, played a mentoring role for the other sites and provided relevant advice and examples on issues such as safety regulations, guidelines for storing and dispensing, and how to categorise ED95 in legislation. Swedish information and knowledge from helped accelerate bureaucratic processes in other countries.

For example, customs authorities initially classified ED95 in different ways in different countries, resulting in a variety of taxes and tariffs. This had an impact on fuel supply and fuel costs. When national customs authorities were informed about the existing Swedish BTI (Binding Tariff Information, CN code 3824 90 98 99), these problems were overcome. A BTI is legally binding in all EU Member States and must be used in all countries. Nanyang encountered similar problems, as national import duties were applied to the Scania buses. This led to a new innovation whereby a local bus manufacturer created a new type of bioethanol bus.

The “single supplier” problem presented a challenge with regard to procurement. For example, many tenders require more than one bidder and require the successful bidder to demonstrate best value against a range of socio-economic criteria. Avoidance of fossil fuels and environmental criteria, which are the principal reasons for purchasing bioethanol buses, may not always be decisive factors in such procurements. More producers of bioethanol buses are therefore needed in the market.



Reliable buses – but more maintenance

Extensive experience of operating bioethanol buses in Stockholm shows that bioethanol buses require maintenance every 10,000 km compared to every 20,000 km for diesel buses. It is essential to keep to the scheduled service plan, and the main difference in service requirements is the change of motor oil and oil filter. A fuel injectors change is required at every second service, as pollutants formed in the engine can become stuck in the injector, causing a fall in injection pressure.

Within BEST, collection of maintenance data was not possible in Stockholm, as bus operators in the city view this information as company secrets. Nonetheless, bus depots in Stockholm were asked about the performance of bioethanol buses and no major problems were reported. Starting problems at extremely low and high temperatures were observed in articulated buses, and power failures may occur if filters clog. These risks are reduced with regular maintenance.

The BEST sites of La Spezia, São Paulo and Madrid gathered extensive information relating to maintenance.

No significant problems were reported in La Spezia. Three buses were monitored over a two year period and were available for the majority of the total 718 days in service. Some unscheduled maintenance was required, although it is unclear to which extent this was caused by using bioethanol. This accounted for short periods of lost service, which were less significant than delays caused by problems linked to accidents or bodywork issues.

In São Paulo, some modifications were required to the test bus due to the tropical climate. Even when operating at idle speeds, the fuel stream temperature was too high. The bus, designed for cooler climates, has a fuel heater to ensure good engine performance in countries such as Sweden. In Brazil, this component was unnecessary and the bus was modified so that the fuel stream was directed straight from the engine to the fuel tank. The experience highlights the importance of incorporating local considerations into vehicle design.

In Madrid, the bus operator EMT found that the main difference between bioethanol and diesel buses was the amount of scheduled service maintenance which followed the same pattern as for the bus fleet in Stockholm. EMT reported that scheduled maintenance costs for bioethanol buses were on average EUR 69.59 per km in 2007 and EUR 58.66 per km in 2008 compared to EUR 39.05 per km for diesel buses. Nonetheless, EMT reported positive experiences. Bioethanol buses broke down much less frequently than the average bus in the EMT fleet (which contains diesel, natural gas and biodiesel buses), which means that bioethanol buses were more reliable. The ED95 fuel pump also worked efficiently throughout BEST.

Greenhouse gas savings and fewer particles

The CO_2 reduction potential of bioethanol depends on the feedstock used and how the fuel is produced. The fuel used in the Scania bus demonstrations was made from Brazilian sugar cane. BEST's analysis of E100 produced from Brazilian sugar cane suggests that use of ED95 in bioethanol buses can reduce greenhouse gas emissions by around 79 % compared with diesel across the lifecycle. [45]

The bioethanol buses in the demonstration meet the requirements of Euro IV. There are relatively few studies on ED95 emissions and the studies analysed by BEST show reductions in PM and NO_X, increases in HC and inconsistent results for CO. (More information about local bioethanol emissions can be found on page 29 ff.)

[45] BEST D9.21, *Report on life cycle greenhouse gas impacts of bioethanol supply chains at BEST sites* (2009).

Example

1,000 buses on ED95 save 72,000 tonnes CO_2
A fleet of 1,000 ethanol buses (with each bus running 70,000 km per year using 0.4 l/ km) emits 85,000 tonnes fossil CO_2 per year (3.04 kg/l diesel from well-to-wheel). If all these buses were to run on bioethanol instead (using 0.67 l/km), fossil CO_2 emissions would be reduced to 13,000 tonnes (0.27 kg/l ethanol from well-to-wheel), a reduction of 72,000 tonnes fossil CO_2 per year.

Higher costs for bioethanol buses

Bioethanol buses give radical reductions of CO_2 but the operational costs are higher than for conventional diesel buses. The reasons behind the higher costs are:

Higher purchase price

The purchase price of a Scania bioethanol bus is around 10% higher than that of an equivalent diesel bus. The buses developed by Dongfeng cost around EUR 35,000 per bus in total (EUR 1,000 more than a conventional petrol bus). Nanyang had planned to import Scania buses, but Chinese import duties pushed the price up to around ten times more than for locally-manufactured buses. For this reason, Nanyang worked with Dongfeng to develop the E100 bus-technology and conduct an alternative study.

Scheduled maintenance more expensive

At the European demonstration sites, the operational costs of bioethanol buses were higher than those of diesel buses (although costs varied between sites)due to more frequent maintenance. The costs of scheduled maintenance are twice as high as for diesel buses and it is essential to keep to the schedule recommended by Scania. However, Madrid's experience suggests that unscheduled maintenance costs were lower for bioethanol buses than for other bus types.

Higher fuel costs and taxes

Fuel costs are significantly higher for bioethanol buses. One important reason is that the energy content of ED95 is lower than that of diesel. The difference in energy content means that a bioethanol bus needs around 70% more fuel in terms of volume compared to a diesel bus. If the taxation is the same as for diesel and set by volume, this has a negative effect on fuel costs.

BEST monitored fuel consumption in energy content per litre. Few sites had comparable diesel buses, and it is therefore proved difficult to compare performance. Moreover, many factors influence fuel consumption including geography (topography), traffic intensity, number of passengers and driving style. The only way to achieve comparable results is to test equivalent bioethanol and diesel buses in exactly the same test conditions, but this was not possible in BEST.

Fuel consumption varies considerably depending on traffic. The fuel consumption of buses that operated in heavy city traffic (Madrid) and on hilly routes (São Paolo) was between 0.97 and 1.32 l/km. The Scania buses that operated in suburban traffic in La Spezia and Stockholm, used between 0.59–0.74 l/km and 3.51–4.39 kWh/km. Fuel consumption rates also depend on how the buses are built. The buses in Stockholm, La Spezia and Beijing were all full Scania buses. The buses in Madrid and São Paolo had Scania chassis and local bodywork. The smaller Dongfeng buses had an E100 consumption of 0.47 l/km, which equals 2.75 kWh/km. Of the four sites using Scania buses, fuel consumption was much higher on urban and hilly routes.

In the future, fuel consumption may be reduced in bioethanol buses through use of hybrid techniques and development of more efficient bus engines.

Taxation by energy and emissions needed

In some countries, such as Spain and Sweden, bioethanol is exempt from fuel tax. However, in countries where tax applies, fuel is often taxed per litre and not based on energy content. Therefore, a bioethanol bus requiring 70 % more fuel by volume will pay 70 % more tax than a diesel bus. This was the case in La Spezia, where bioethanol and diesel are both taxed per litre.

BEST findings suggest that taxing bus fuels by energy content and CO_2 emissions may be appropriate if the market for alternative fuels such as bioethanol is to grow, as energy performance is a more appropriate measure for comparison than fuel consumption.

Table 5 **Test results – Buses**

Type of bioethanol bus	Site	No of ED95 buses included in data collection	Total distance travelled (km)	Litre ED95/km	kWh/km	Comment
Full Scania Bus	Stockholm	3	238,965	0.74	4.39	Suburban traffic
	La Spezia	3	400,000	0.59	3.51	Suburban traffic
	Beijing	1	5,725	0.67	4.00	Suburban traffic
Scania chassi, local body work	Madrid	5	392,332	0.97	5.74	Cityline, heavily used
	São Paolo	1	12,244	1.32	7.82	Cityline, hilly topography
Dongfeng E100 bus	Nanyang	2	40,600	0.47	2.75	Dongfeng E100 bus (Otto technology): Bus with 19 seats, is smaller than the Scania bus.

Source: BEST D2.08, *The BEST experiences with bioethanol buses* (2009).

Drivers and passengers see both pros and cons

Short summary

Bioethanol buses are accepted by key stakeholders.

Drivers and mechanics regard improved working conditions and reduced emissions as key benefits.

Passengers are satisfied with the performance of the vehicles and highlight reduced emissions as an important factor for using the buses.

91 drivers in Italy, Sweden, Spain and Brazil responded to a questionnaire about their attitudes towards bioethanol buses. The majority of drivers were positive. Many praised bioethanol buses for reducing pollution, exhaust emissions and odour, and improving comfort for drivers. However, reduced acceleration and speed were cited as major problems with bioethanol buses.

19 mechanics in Sweden, Spain and Brazil also responded to a questionnaire on bioethanol buses. Interestingly, 53 % of these were positive to the technology prior to introduction, but over time this percentage rose to 63 %. As with the drivers, mechanics were most enthusiastic about the reduced emissions offered by bioethanol buses but most negative about reduced acceleration.

Passenger surveys were conducted in Madrid (336 respondents) and Nanyang (50 respondents). Passengers perceived no obvious difference in the quality of service compared to other types of buses, but were impressed by the decrease in pollution and smoother running of bioethanol buses. The odour aspect was found to be both negative and positive, whilst noise during operation and (not related to the buses) timetables and delays were cited as major problems.

The Nanyang respondents cited concerns about climate change and emissions as a positive argument for using bioethanol. Most passengers were satisfied with the technical performance and design of the bioethanol bus, and 98 % indicated a willingness to use the bus again.

Public Transport Authorities can reduce risks for bioethanol bus operators

The BEST sites had mixed experiences with bioethanol buses and fuels. From a technical and user perspective, the buses function effectively but are more expensive to operate than diesel buses.

This makes the introduction of bioethanol buses and ED95 largely a question of political will. Bioethanol buses are a proven tool to reduce CO_2 emissions resulting from public transport. However, without political decisions that resolve cost issues and tendering dilemmas, it is difficult for transport operators to introduce bioethanol buses and ED95. This problem is likely to grow if the service is sub-contracted to private operators, who are primarily motivated by cost and may lack the incentive to "voluntarily" introduce more expensive bioethanol buses into their fleets.

When politicians decide to procure bioethanol buses, the increased purchase and operational costs must be included in the budget. Public Transport Authorities (PTAs) are usually organised in two ways – either they deliver transport services themselves or they procure services from operators in competition. When PTAs own the bus fleet, buses are purchased through the normal procurement procedure.

When PTAs procure services from competing suppliers they can introduce requirements on renewable fuels in the procurement process. Bioethanol buses cannot compete in terms of price, but are appreciated by drivers and customers and demonstrate strong environmental performance. However, the absence of a second-hand market poses a financial risk for operators if they cannot transfer the buses to other operators in the event of losing a service contract.

PTAs can thus support operators by, for example, owning buses and fuel pumps and leasing them to operators during a contractual period, or by providing guarantees that successive contractors will take over the buses should an operator lose its contract. Financial guarantees to leasing companies can also be provided. Long-term contracts are another way of reducing risks for operators, as the buses have a lifespan of approximately 12 years.

An expanding market for bioethanol buses

Short summary

All BEST sites will continue to use their bioethanol buses in regular traffic and Stockholm is expanding its fleet.

Further demonstrations are likely in São Paolo. Nanyang will also continue to drive bioethanol buses and Dongfeng is looking into opportunities for expanding fleets elsewhere.

Meanwhile, a number of follower cities are introducing bioethanol buses.

Bioethanol trucks and hybrid trucks are being tested and more manufacturers are announcing or introducing models to the market.

The expansion of the fleet in Stockholm is a result of the political goal to achieve 50 % renewable fuels in the bus fleet by 2011 and 100 % by 2025. Renewable fuels are required in the procurement of bus services. Local politicians in La Spezia are also keen to add more bioethanol buses to their local fleet, but are concerned about fuel costs. At present, there is no tax exemption for bioethanol in Italy, and fuel costs are approximately 70 % higher as a result.

The Madrid bus operator EMT has decided not to expand the bioethanol bus fleet at this stage, partly due to cost. In São Paolo, an agreement among all local project partners, including the Brazilian Environmental Agency (CETESB) and the Environment Secretariat of São Paulo, will enable further demonstration activities following the completion of BEST.

Spin-off users outside BEST

By demonstrating bioethanol buses in public transport fleets, BEST has helped to increase knowledge of bioethanol buses in Europe, Brazil and China. In China, the participation of Nanyang in BEST led to the development of a new type of bioethanol bus, based on the Otto engine. Dongfeng is now seeking new markets for this model and have started discussions with regions in India and contacts in Brazil about the possible use of dual-fuel bioethanol buses in these countries.

Bioethanol buses are now used at a number of other locations and are internationally accepted as an effective means of reducing greenhouse gas emissions and local air pollutants resulting from public transport.

More buses and bioethanol trucks

A wider spin-off effect is that there is now increased interest in the use of bioethanol in other heavy vehicles. Scania now offers bioethanol-driven waste collection and distribution trucks. In 2008, Fiat Powertrain Technologies announced that they will launch a bioethanol engine in Brazil by 2010 for use in trucks and agricultural machinery. A small amount of diesel will be needed to combust the bioethanol, but the two fuels will only mix when injected into the combustion chamber from separate tanks to avoid potential risks caused by mixing the fuels.

The arrival of more bioethanol bus manufacturers will be an important step forward for the use of bioethanol in heavy vehicles. The technology is developing and Scania is introducing the third generation of bioethanol engines. The objective of this development is to decrease the need for maintenance and thus lower driving costs. SEKAB is also developing an improved fuel for bioethanol engines. The new bioethanol engine generation meets the EEV (Enhanced Environmentally-friendly Vehicle) emission standard without a particle filter.

Example

The bioethanol hybrid bus – a promising concept

Stockholm Public Transport Authority, Scania and the bus operator Swebus are now performing the world's first fleet demonstration involving bioethanol hybrid buses. This bus includes serial hybrid technology with a super capacitor as the energy storage. The technology is expected to reduce fuel consumption by 25 %. Six bioethanol hybrid buses and one reference bioethanol bus will be used in regular passenger traffic in Stockholm from 2009 to 2011, as part of the demonstration.

Outlook

Replacement of diesel is an urgent priority

Diesel is the world's most important strategic transportation fuel for on-highway, off-highway, farm, marine and railroads. In Europe, diesel fuel consumption for road transport is dominant and growing, whilst petrol consumption is declining. In the context of Peak Oil (see page 14), this consumption pattern appears to be unsustainable and will lead to higher prices and shortages in diesel in the near future.

This is because every litre of diesel fuel oil produced, results in more than two litres of petrol. According to Exxon, one barrel of oil contains 159 litres and produces 70 litres petrol, but only 34 litres of distillate fuel oil (including diesel).[45]

This means that, when diesel consumption represents more than one third of petrol consumption, the market is unbalanced and there is an excess of petrol on the market. In 2004, Europe had a net surplus petrol production of about 33 million tonnes and a shortage in diesel supplies of more than 19 million tonnes. Most of this surplus petrol was exported to the USA in exchange for diesel.

Increasing low blends of biofuels in diesel and use of biofuel highblends, as replacement for diesel could substantially reduce the diesel shortage on the EU market in the short-term.

ED95 is a biofuel that can replace diesel. However, the current cost of using ED95 means this alternative is rarely used.

A longer-term strategy to reduce and replace diesel consumption on the EU market needs to be drawn up to avoid shortages and price rises in the medium-long term.

Such a strategy would need to address uncertainties concerning the ED95 price, increase the number of filling stations and identify ways to increase energy efficiency in vehicles, e.g. reduce the level of fuel consumption in biofuel buses with use of the hybrid technique, which is being tested in Stockholm and the UK. The logistics and environmental impacts of moving larger volumes of biofuels fuel instead of diesel must also be assessed.

It is important to note that – in spite of these uncertainties and challenges – replacing diesel with biofuels is preferable to production of diesel using coal, a technique used in South Africa and China. The production of coal-based diesel results in massive emissions of greenhouse gases.

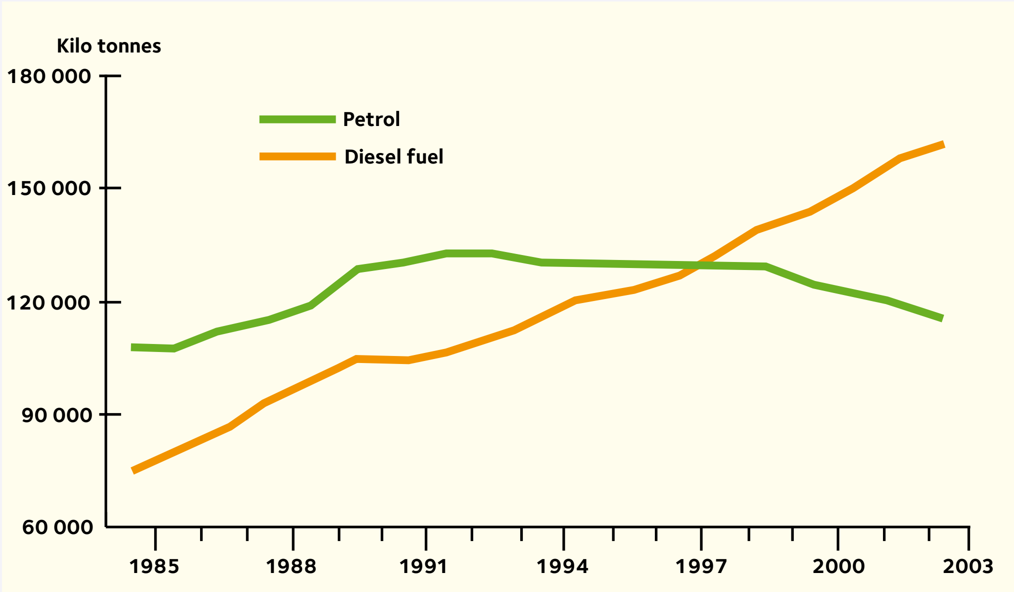


Fig. 24 Consumption of road transport fuel in Eurogpe, incl. Switzerland, Norway, Turkey and Iceland. Source: CPDP.IFP/economic studies (2004).

45 ExxonMobil Australia Pty Ltd, *A Simple Guide to Oil Refining* (2006).

Low blends

Short summary

Low blends function well in vehicles and require no modifications to engines or other components. Vehicles in BEST using low blends were as reliable as vehicles running on other blends. By replacing a proportion of the fossil petrol or diesel fuel with bioethanol, low blends can reduce greenhouse gas emissions.

Independent petrol stations (i.e. non-oil producing companies), such as private or franchise operations, may be more willing to accommodate both low and high blends. Smaller independent stations may see the installation of bioethanol pumps as a way to market their station and become pioneers in their region.

BEST identified several issues as being unresolved or requiring further research. For example:

- Fuel standards for low blends are not harmonised in the EU (though there is a standard for bioethanol mixed in petrol).
- There are no standard safety and operating procedures for diesel low blends.
- The urgent need to reduce diesel consumption in the EU means that the development of an infrastructure grid to supply both diesel low blends and ED95 should be a priority.

Low blends reduce emissions and costs

Petrol and diesel blends with a low percentage of biofuels have been used in Europe since the 1990s. The use of low blends represents a quick way to reduce consumption of fossil fuels and cut greenhouse gas emissions. It is unlikely that use of low blends alone will enable the EU to meet its climate and energy targets, but a number of alternative low blends can make a contribution towards fulfilment of these goals. Production of these low blends will have to be scaled up.

The 2009 Fuel Quality Directive approved the use of blends including up to 10% bioethanol in petrol in the EU.[46] This means that blends such as E5 and E10 can be marketed and sold as petrol in the EU using existing petrol pumps. Market introduction of other low blends is challenging as HE15, E-diesel and ED-diesel fuels require different types of petrol and diesel pumps, have high vapour pressures, different levels of complexity and increase costs for distributors. BEST shared knowledge and experience about the use of low blends, including information on factors such as vehicle performance, maintenance, service, emissions and market potential.

BEST tested several low blends in a variety of situations and locations, measuring a range of indicators including fuel consumption, maintenance and emissions to assess the potential of low blends and the type of regulations and recommendations necessary for large-scale use.

[46] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009.

Petrol low blends used in BEST:

- E5 – 5 % anhydrous bioethanol, 95% petrol used in normal petrol cars and supplied via existing (petrol) fuel pumps. In Sweden this is the normal petrol sold and tests on E5 were sometimes included in BEST as a reference to compare with other low blends.
- E10 is a fuel mixture containing 10 % anhydrous bioethanol and 90% petrol. It can be used in most modern petrol cars and light-duty vehicles. E10 was approved for wider use in the EU in the 2009 Fuel Quality Directive and can be supplied using existing petrol pumps.
- HE15 is a petrol-bioethanol blend containing 15 % hydrous bioethanol and 85% petrol. The total water content in the fuel blend is around 0.6 %. It can be used in most standard petrol cars without modification to the engine or fuel system. This fuel is not recognised as petrol by the Fuel Quality Directive and cannot be marketed as such, although it can be sold under the specific name HE15. HE15 has been subject to large-scale tests in Germany and the Netherlands.

Diesel low blends used in BEST:

- E-diesel is a blend of anhydrous bioethanol and diesel. An emulsifier or solubiliser additive must be added to achieve a stable blend suitable for use as a fuel. The amount of bioethanol in E-diesel varies in different tests and depends on what type of additive is used. The bioethanol content in E-diesel can vary from 5 % to 15 % and the additive content from 0.5 % to 5 %. The E-diesel used in BEST was a blend of 7.7 % anhydrous bioethanol and around 0.6% additive and diesel.
- ED-diesel is a new type of low blend fuel. Instead of using pure bioethanol in diesel, which requires a stabilising additive, a bioethanol derivative is used. This component is a molecule developed from bioethanol which has more hydrophobic properties. It mixes easily with diesel without the risk of separation. This special derivative can be mixed up to 50 % in diesel and still form a stable blend, but for practical use about 15% is optimum. The ED-diesel composition used in BEST was a blend of 10% bioethanol derivative and 90% extra low sulfur diesel (Mk1), including 5 % FAME.

Safety regulations and handling procedures vary for all of the low blends. The use of bioethanol and bioethanol derivatives in low blends of diesel lowers the flashpoint of the fuel. This is particularly true for E-diesel, which must be handled as petrol. Flame arrestors should be mounted on the fuel tank to avoid fire risks. In contrast, ED-diesel has a slightly lower flashpoint than conventional diesel, but can be handled in the same way.

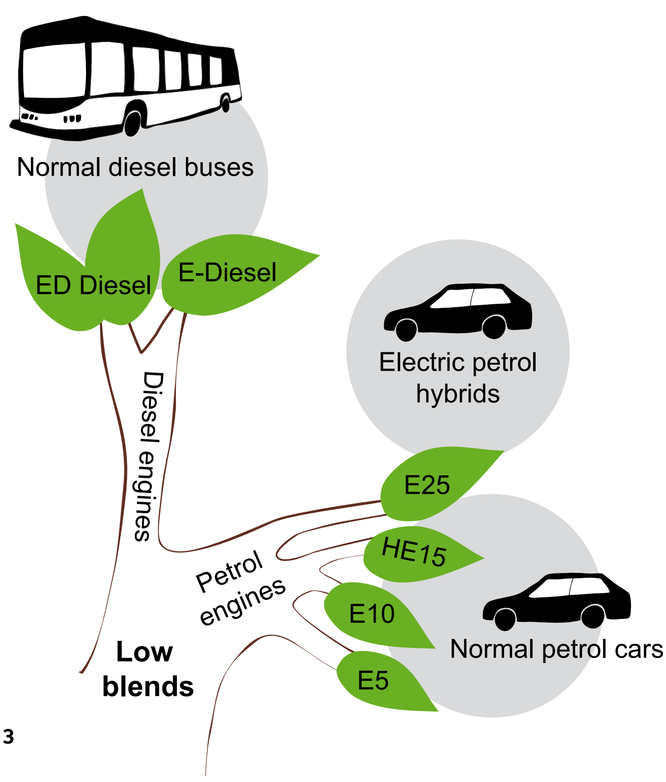


Fig. 23

Petrol low blends

Short summary

BEST suggests that E10 should be considered as a viable alternative when bioethanol is used in petrol low blends. E10 can be used in unmodified petrol vehicles and in FFVs.The blend can be supplied using existing infrastructure or via flexifuel pumps, which can also offer E85.

Wider use of E10 and flexifuel pumps would offer the opportunity to integrate E85 into filling station forecourts, thereby expanding the E85 supply network.

Therefore, BEST recommends wider use of E10 and flexifuel pumps as practical and flexible ways to reduce petrol consumption.

E10 – a legal low blend since 2009

BEST assessed the performance of cars using E10, the impact of flexible E10 distribution and attitudes of auto manufacturers, fuel providers and users towards E10. The outcomes were important for the acceptance of E10, as the blend was not a legal fuel when BEST began it's work. The proposal to allow 10% bioethanol content, which was approved in the 2009 Fuel Quality Directive, meant that BEST changed focus slightly and worked increasingly on high blend issues.

E10 offered flexibility in the Basque Country

E10 was trialled in the Basque Country, where 14 flexifuel pumps were installed at public petrol stations. E10 can be supplied via existing fuel pumps, but flexifuel pumps create a flexible mechanism for consumers to choose between various blends and for fuel distributors to offer several bioethanol blends from the same pump. Eight of the pumps in the Basque Country provide both low blends and E85, and six supply low blends only.

E10 emissions well below European norms

Emissions tests were conducted by BEST in Stockholm. The pattern of results indicates that E10 is a viable transport fuel that meets regulated standards for local air emissions.

Studies of low blends of bioethanol in petrol (E5 and E10) report both increased and decreased emissions of regulated pollutants compared with petrol. Most of these studies show that CO and HC emissions decrease and NO_x emissions increase with increased ethanol content in low blends. However emissions testing in BEST showed higher levels of regulated emissions with E10 than with petrol but still well below Euro norm. Evaporative emissions of volatile organic compounds increased with bioethanol low blends compared with petrol.[47, 48]

HE15 introduced in Netherlands

HE15 requires the installation of separate and dedicated fuel pumps at petrol stations, and should be seen as a complement to other alternatives such as E10. HE15 was successfully introduced and studied in Rotterdam. Local and national subsidies helped the company HE Blends to open 19 HE15 pumps at four stations in the Rotterdam region. HE Blends aims to install pumps at further 16 stations in the Netherlands in 2010.

To assess the impact of hydrous bioethanol, a limited number of tests were performed on an unmodified passenger car using a chassi dynamometer. Tests indicated a mix of results and further study of the blend is required.

HE Blends asked HE15 users at a filling station near Rotterdam questions relating to both technical and marketing issues. The majority of HE15 users experienced no difference between HE15 and petrol and two thirds stated that fuel consumption was the same as with petrol. Around 20% of respondents had switched back to their previous fuel prior to the survey taking place, but the reasons for this are not clear from the results.

Read more in BEST Deliverable 3.15, *The BEST Experiences with ethanol low blends in diesel and petrol fuels* (2009).

47 BEST D3.15, *The BEST experiences with ethanol low blends in diesel and petrol fuels* (2009).
48 BEST D1.21, *Emission measurements on vehicles fuelled with E10* (2009).

Diesel low blends

Short summary

BEST tested two types of diesel low blends – E-diesel and ED-diesel. E-diesel demonstrated a greater effect on emissions, but has a very low flashpoint and must be handled like petrol, i.e. it is more difficult to handle than standard diesel. ED-diesel has a slightly lower flashpoint than diesel, but can still be handled as such, and the same equipment and infrastructure as for standard diesel can be used. BEST conducted extensive on-road testing of ED-diesel in captive fleets and can recommend its further use in a wider context. A standard for the use of bioethanol and derivatives for low blends in diesel is urgently required.

Safety issues a barrier

The use of low blends in diesel adds some technical complexity for vehicle manufacturers. Any blend of bioethanol in diesel decreases the flashpoint of the fuel from 55–60°C down to about 12°C, making ignition more fuel intensive. The fuel blend must be stored and handled like petrol. Use of bioethanol also changes the vapour lock characteristics of the fuel. Previous tests have shown that this may cause unintentional engine failure, particularly in common rail injector systems.

As E-diesel has a much lower flash point, it must be treated as a new fuel or categorised as ED95, which has similar properties, and must be handled as petrol. To date, only France has approved the use of E-diesel.

ED-diesel has a reduced flashpoint (33°C) compared to diesel, but a higher flashpoint than E-diesel (12°C). Since ED-diesel fulfils the Swedish fire regulations classification IIB, it can be handled as diesel and it is permitted for vehicles to refuel indoors. Whilst emissions from ED-diesel are slightly higher than those from E-diesel, the fuel is easier to handle.

Unchanged performance

An increase in fuel consumption approximately equivalent to the reduction in energy content of the fuel can be expected when using E-diesel and ED-diesel. Operators have reported no noticeable differences in performance when using ED-diesel compared to running on diesel fuel.

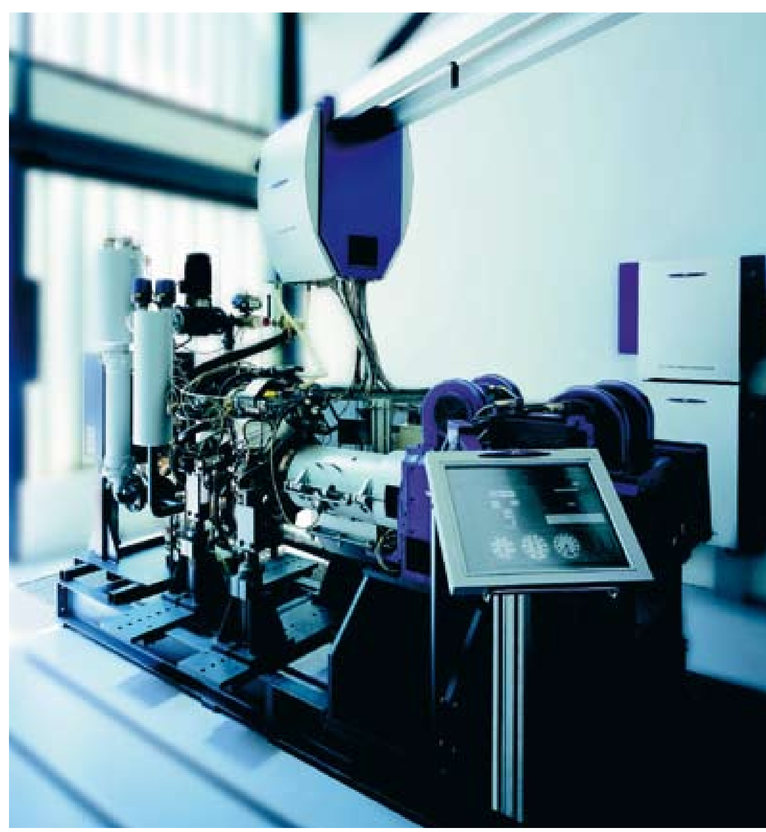
Standard needed for bioethanol in diesel

A standard for bioethanol use in diesel – similar to the standard permitting 7 % FAME in diesel – needs to be approved for large-scale commercial use of diesel low blends in Europe. Moreover – as with all new fuels – manufacturers must give their approval for the use of diesel low blends, as they must provide consumers with guarantees about the function of the engine when using the new fuel.

Low blends in diesel reduce emissions

The advantage of using low blends in diesel is the reduction of regulated emissions. Both types of low blends reduce NO_X, HC and CO emissions as well as fossil CO_2.

E-diesel was tested in a EuroII engine and reduced NO_X by 17 %, CO by 28 % and particulates by 19 %. ED-diesel tested in a EuroIII engine reduced NOx by 3 %, CO by 8 % and particulates by 6 %. Low blends does not improve performance as much in EuroIII engines as in EuroII engines.[48, 49, 50]



49 BEST D3.15, *The BEST experiences with ethanol low blends in diesel and petrol fuels* (2009).
50 BEST D3.07, *Short report on vehicle demonstration tests using low blend of ethanol derivatives in diesel fuel* (2009).
51 BEST D3.08, *Short report from emission test using low blends of ethanol derivative in diesel fuel* (2009).

Refuelling ability and fuel price most important for consumers

Consumer preferences are an important factor in the development of a bioethanol market. In an attempt to better understand public attitudes toward various blends of bioethanol, a survey was carried out in Somerset in collaboration with Imperial College London. A questionnaire was sent by mail to 1,250 Somerset residents. The total adjusted response rate was 18 %.

In most cases, respondents did not have a preference for either E10 or E85, but both bioethanol blends were preferred to petrol. Similar trends were evident for E-diesel. Individuals indicated a willingness to purchase E-diesel, provided there was sufficient refuelling capacity and reasonable pricing. The results suggest that refuelling ability and fuel price are the most significant factors influencing consumer choices. In addition, income, education level, type of knowledge and personal beliefs relating to biofuels and the severity of environmental problems were found to influence consumer preferences.

Example

Diesel bus on diesel fuel with 10 % bioethanol derivative

In May 2007, tests of ED-diesel in two Scania Omni City buses were launched in the Swedish town of Örnsköldsvik. The test was planned to last for twelve months but was extended into 2009. The buses operated seven days a week across all city routes, and were thus tested under a wide range of conditions.

The driving mileage of each of the two buses was around 60,000 – 70,000 km per year. The buses followed the same service schedule as other buses, although a sample of engine oil was taken at each service opportunity.

The buses were equipped with Euro III engines, and emissions tests were made comparing the results to those of an identical engine in a standard bus. The tests showed that a standard heavy-duty diesel engine can run on low blend diesel fuel containing 5 % RME and 10 % bioethanol derivative without increasing fuel consumption. Maximum power was reduced slightly when using the lower blend, but this did not impact on vehicle performance as experienced by drivers.

Compulsory low blending

Fuel suppliers appear to favour the low blend option as a cost-efficient way of implementing EU targets for renewables.

A low blend of 10% (by volume) bioethanol in petrol gives a renewable share of 7% (by energy) in the fuel (as a result of the lower energy content of bioethanol). In combination with the limitation of 7% low-blending fatty acid methyl ester (FAME) in diesel, a renewable share of maximum 7% in road transports will be achieved solely from low-blending. This means fuels with higher renewable shares, such as E85 and ED95, are needed.

If low blends are not compulsory, they must be competitively priced for consumers. Tax differentiation could be used to ensure that the price of low blends is comparable to that of neat diesel and petrol. Taxation on low blends varies in different EU Member States. In Germany, for example, bioethanol E5 blends are exempt from tax, but not E10 blends.

Excise is another factor influencing the uptake of low blends. For example, EU import duties penalise hydrous bioethanol imports from Brazil, which boosts the competitiveness of EU-produced biofuels but does little to accelerate market development of products such as HE15.

However, it is questionable whether the use of tax exemptions for the bioethanol part of low blends is effective policy. Making low blends compulsory, or increasing taxation on the fossil content of fuels, may well be a better approach, as it would create a level playing field and a pricing system that deters use of fossil fuels.

Setting a compulsory quota for fuel distributors, combined with penalties for non-compliance, is an efficient way of quickly introducing biofuels as a transport fuel. However, there is no incentive to go beyond the level defined by the quota, as excess biofuel sold does not bring further credit to the distributors. As biofuels are normally more expensive than their fossil equivalents, distributors will actually lose money by providing more than the quota stipulates.

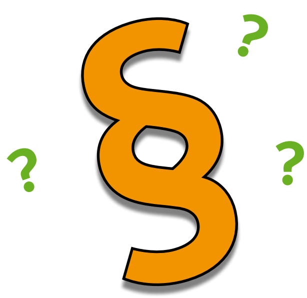
This is also true for producers, who will be reluctant to invest in new production when the quota is almost reached. If the quota demands higher levels of biofuels than can be supplied, the result is an extra penalty on petrol and diesel. But this may not necessarily stimulate increased provision of biofuels. The efficiency of a quota system is dependent both on the quota being set to the optimum level and use of financial penalties that discourage non-compliance. However, a quota system is less appropriate for developing high blends and vehicles optimised for high blends.[52]

52 Wiesenthal. T, et.al, *Assessment of biofuel policies in Europe – lessons learnt and future policy options*. Policy-synthesis of the Premia project (2007).

Standards still needed

Lack of standardised fuel specifications and definitions

- Makes it difficult for vehicle manufacturers to allow the use of bioethanol in their vehicles, as they are responsible for both the emission performance and the durability of the vehicles. It is difficult, or even impossible, to adapt a car to a wide variety of fuel compositions.



- Makes applying custom tariffs and sometimes also tax discounts a complicated task, as there are no set categories that take into account the specific properties of the fuel. For example, BEST experienced that custom authorities wanted to apply the tariff for beverage alcohol on the bus fuel ED95.
- Makes it difficult for heavy-duty vehicle manufacturers to develop dedicated bioethanol engines.

Standard fuel specifications for the various high and low blends need to be adopted and the fuel must be recognised in all relevant legislation.

Lack of fuel/fuel distribution standards

- Makes it difficult for authorities to apply appropriate safety, security and environmental regulations for handling and storage. For example, Italian authorities could find no rules applying to E85 storage in their legislation. The closest applicable legislation prohibited non-beverage alcohols to be stored at petrol stations. Brandenburg legislation did not include rules on how petrol stations should handle a spillage of E85. Bioethanol bypasses the oil separator and no other means of protection was listed in the legislation.

The standardised fuels must be recognised in all relevant legislation and other standards relevant to fuel storage and dispensing.

Vehicle (performance) standards

- The lack of vehicle performance standards has so far made it impossible to type-approve cars for using bioethanol fuel. Since cars had to be type-approved for using petrol, it has not been possible to adapt cars to exploit the full potential of bioethanol as a fuel. From 2009 it is possible to get a type-approval on E85.
- Cold-starting on E85 emits significantly more hydrocarbons compared to petrol cold starts. However, a considerable part of the hydrocarbon emissions are non-combusted bioethanol usually considered less harmful than hydrocarbons resulting from petrol and diesel. The current emission standard does not recognise this difference.

Emission standards and type-approval standards must allow for vehicles to be type-approved on high blends of bioethanol. The standards should recognise the special properties of bioethanol and i.a. introduce the concept of non-bioethanol hydrocarbons, similar to the concept of non-methane hydrocarbons used for gas vehicles.

- Tailpipe emissions of CO_2 from bioethanol vehicles do not vary greatly compared with those of vehicles operating on fossil fuels. But even though bioethanol can substantially reduce the greenhouse gas emissions resulting from transport, current EU-legislation does not take well-to-wheel emissions into account. By using tailpipe emissions as an indicator, the Clean Vehicle Directive actually gives preference to vehicles which emit more greenhouse gases than biofuelled vehicles. The regulation Nr. 443/2009 on emission performance of new cars (requiring i.a. an average of 120 g CO_2 /km tailpipe emissions from new cars by 2015) and tax regulations in some Member States contain the same anomaly.

The concept of well-to-wheel emissions should be adopted in all legislation concerning greenhouse gas emissions resulting from transport. BEST proposes that biofuels should merit a climate bonus equivalent to the minimum greenhouse gas savings stipulated in Directive 2009/28/EC when e.g. tailpipe emissions are compared.

- The manufacturer is responsible for the emission performance of new cars for the first 5 years, or 80,000 km. If someone tampers with the engine or the exhaust system, manufacturers are no longer responsible for emission standard compliance. The directives offer no guidance as to how and under which conditions a transfer of responsibility could be made. This lack of standard hampers the conversion of conventional cars to run on bioethanol.

It should be possible to transfer the emission performance guarantee to the company converting a conventional car into a bioethanol-compatible vehicle, provided that the regulated emissions do not exceed the limits set for a corresponding conventional vehicle.

- The lack of a common definition of environmentally enhanced vehicles (EEVs) makes it difficult for national and local governments to provide incentives for such vehicles. This lack of harmonisation also hampers the development of the E85 market and the development of cars optimised for this fuel.

A common EU-definition of EEVs, based on well-to-wheel performance with regard to greenhouse gas emissions, should be developed and implemented in all relevant legislation.

In-depth

Applicable standards and ongoing standardisation

There are already some standards applicable to bioethanol as a fuel, but joint standardisation at EU level is often inexistent.

BEST partner SEKAB has worked with the development of standardisation for bioethanol as a fuel by taking part in the European CEN TC19/WG21 taskforce on E85, with the aim to agree on a technical standard.

SEKAB has also participated in WG1-5 under the CEN TC383 – Sustainably Produced Biomass for Energy Applications, chaired the WG4: Economic and Social Aspects, and been part of, the Technical Committee and the national work led by the Swedish Standardisation Institute.

SEKAB has also launched the provisional certification scheme "Verified Sustainable Ethanol" on the Swedish market and been involved in Sweden's work on standardisation of ED95 as a fuel for heavy-duty transport.

Fuels standards

Low blends of bioethanol in petrol

The specification for 100% bioethanol (E100) as a blending component at up to 5% for petrol is available since 2007 in EN 15376 Automotive fuels – Ethanol as a blending component for petrol – Requirements and test methods. The use of 5% bioethanol (E5) in petrol is included in EN228. This limit will be increased to maximum of 10% bioethanol following the revised Fuels Quality Directive. EN 15376 also needs to be reviewed to allow 10% bioethanol, and the long-term aim is to adjust the specification to allow blending at all ratios.

E85

There is ongoing work to standardise E85 at EU level. SEKAB is part of the European CEN TC19/WG21 taskforce on E85. The latest version of the proposed standard is found in DRAFT prEN 15293, version April 2009, Automotive fuels – Ethanol (E85) automotive fuel – Requirements and test methods, a revised version of CWA 15293. The document was sent for comments in June 2009.

There are also existing national standards for E85 in a number of countries: Sweden: SS 15 54 80:2006 – Automotive fuels – Ethanol E85 – Requirements and test methods; France: XPM 15-029 (2006) Automotive fuels, Petrol – Superethanol – Requirement and test methods; Germany: DIN 51625 Automotive fuels – Ethanol (E85) automotive fuel – Requirements and test methods; Hungary: MSZ CWA 15293:2006 Automotive fuels – Ethanol E85 – Requirements and test methods; USA: D5798 Standard specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines. There is also a quality requirement for E85 in Poland.

ED95

There is no standardisation at EU level for the bioethanol fuel ED95 for diesel engines. There is, however, a Swedish standard that covers the bioethanol part of the fuel. This standard, SS 15 54 37 – Motor fuels – Fuel Alcohols for high-speed diesel engines, is being revised at present and a new version is planned for autumn 2009. At this point there are no plans to create a European standard based on this. Discussions taking place in the CEN/TC 19 New Fuels coordination group suggest that the use of ED95 (95% bioethanol + additives) in diesel engines is only suitable for captive fleets, and that specifications can be covered by a CWA. However, this is not the full picture since plans are made for ED95 infrastructure grids to cover trucks. This could eventually lead to a need for an EN standard.

At present reference directives for bioethanol fuel in diesel engines are available in the European Parliament and Council directive 2005/55/EG, with the latest changes in the Commissions Directive 2008/74/EG, July 2008.

Filling station standards

There is a lack of joint standards in the EU for filling stations offering an alternative fuel.

However, the European standards for oil separating systems can be of use, even if they do not focus specifically on the use of bioethanol as a fuel – EN 858 EN 858:1 Separator systems for light liquids (e.g. oil and petrol). Principles of product design, performance and testing, marking and quality control and EN 858:2 Separator systems for light liquids (e.g. oil and petrol). Selection of nominal size, installation, operation and maintenance.

The guide for good housekeeping standards can also be of some use – CEN/TR 15367-1 Petroleum products – Guide for good housekeeping – Part 1: Automotive diesel fuels, Part 2: Automotive petrol fuels, Part 3: Prevention of cross contamination.

There is no joint standard in the EU relating to vapour recapturing systems for petrol or bioethanol fuels. Some of the participating countries have mandatory vapour recapturing systems for petrol gases emitted from the pump nozzle. Vapour recapturing from bioethanol pump nozzles is not mandatory. Due to ongoing discussions on regulations, pump manufacturers are uncertain as to how the nozzle and vapour recovery should be designed, which can delay development. This is also an issue in the development of flexifuel pumps. Since these pumps can offer various blends of bioethanol and petrol, it is uncertain whether the vapour should be led back to the bioethanol tank or the petrol tank.

Sustainability standards

The current certification and verification systems available in Europe and worldwide are already influencing policy in Member States and in the European Commission regarding the sustainable production and use of biofuels. The main concerns relate to the current reporting methodologies and the fact that these do not adequately reflect the actual impacts of increased production of biofuels.

There is a need for tools and methodologies that can be used to meet the new demands with regard to awareness of social, economic and environmental impacts for all transport fuels to evolve and mature as the market continues to develop – not only in Europe, but also worldwide. This will contribute towards the development of a level playing field for all transport fuels in which life-cycle costs are accurately represented.

In order to raise consumers' trust in bioethanol, as well as increasing the quality of bioethanol production, there is a need for a joint standardisation of biofuels on the market. Some of the ongoing, extensive work is presented below. Work on sustainability has also been also initiated by ISO.

CEN Committee on Sustainable Biomass For Energy

The work of CEN TC383 – Sustainably produced biomass for energy applications – has been divided in six different work groups; WG1 – Terminology, consistency of evaluation methods, other crosscutting issues, WG2 – GHG and fossil fuel balance, WG3 – Biodiversity and environmental aspects, WG4 – Social and economic aspects, WG5 – Verification and auditing, and WG6 – Indirect effects. BEST partner SEKAB has participated in groups 1-5, chaired WG4, and been part of the Technical committee and participated in the national work led by the Swedish Standardisation Institute.

WG2, 3 and 5 will present draft standards to the Commission before November 2009. The Commission will then decide whether or not to include the draft standards into RED after December. The other WGs have been put on hold until the January 2010 CEN TC 383 meeting, when it will be decided whether CEN will continue to work on standards in all WGs.

Advice and recommendations from BEST

Advice and recommendations

Lessons learnt and next steps

After four years of large-scale testing and continuous monitoring and evaluation of bioethanol-fuelled vehicles, the BEST partners conclude that:

- Bioethanol is a reliable vehicle fuel and can be used in both low and high blends.
- Bioethanol-fuelled vehicles are reliable alternatives to fossil fuel vehicles. FFVs are at least as reliable as equivalent petrol vehicles. Bioethanol buses require additional scheduled maintenance but are at least as reliable as equivalent diesel buses. Conversion of petrol vehicles to FFVs is possible and has no impact on vehicle reliability if performed by a licensed mechanic.
- Bioethanol can be an energy efficient alternative to fossil fuels and can improve the energy efficiency of petrol engines. Bioethanol has a lower energy content than petrol, but data collected by BEST indicates that FFVs are more energy efficient when operating on E85 than petrol, and that fuel consumption increases are smaller than stated by many manufacturers. Low blends display mixed results with regard to energy performance.
- The energy efficiency of bioethanol-fuelled vehicles can be increased. BEST tested hybrid electric vehicles running on E25 in São Paulo, results indicate this is a promising technology that should be researched further. BEST partners in Stockholm are currently testing hybrid bioethanol buses running on ED95 and a range of other potential improvements – such as standardised and bioethanol-dedicated FFV engines, or downsized car and bus engines with less horsepower – which offer potential for future energy efficiency increases.
- Bioethanol can reduce greenhouse gas emissions compared to fossil fuels, although the extent of these benefits depends on the feedstock and how the fuel is produced, used and measured. BEST assessed different bioethanol supply chains and identified a wide range of opportunities for greenhouse-gas emission reductions (4%–79%).
- Bioethanol offers other environmental benefits (e.g. lower amounts of regulated pollutants). Emission tests on different bioethanol high and low blends have shown reduced emissions of particulates. In the limited no of tests both increases and reductions in NO_X, CO and HC have been observed, however even when levels have increased they have been within the limits outlined in the Euro IV standard.
- Sustainable bioethanol production can provide social benefits in the EU and in other countries. BEST contributed directly to sustainability processes attempting to realise such potential. Changes in the project meant BEST focused less than originally anticipated on the socio-economic benefits of bioethanol use. However, the experiences of BEST sites and the work carried out within the project correlates with findings of other assessments.
- Direct benefits of production may include job creation, stronger rural economies, new markets for agricultural products and more efficient use of existing agricultural land, improved working conditions, strengthening the global market for sustainable products and supporting free trade to enable economic development in developing countries. Direct benefits of consumption may include increased price security and improved air quality and public health.

Recommendations to local governments

Local governments can take initiative and shape strategies that maximise social, economic and environmental improvement opportunities in their communities. BEST demonstrated that bioethanol vehicles and infrastructure are as reliable as fossil fuel equivalents and can help reduce greenhouse gas emissions and local air pollutants. Moreover, production of sustainable bioethanol may generate socio-economic benefits such as job creation and improved working conditions.

The use of bioethanol vehicles and fuels can help raise the profile of local governments and help improve public perceptions of the public transport system. However, it is essential that local authorities prepare properly in order to avoid delays and overcome potential obstacles. Based on their experiences from the project, the BEST sites have outlined some recommendations for local players:

Smart strategies

Identifying and involving positive key stakeholders throughout the process. As the market expands, the number of stakeholders will increase.

Working with vehicles and filling stations in parallel, tailoring the approach to suit the needs of various vehicle and fuel users (e.g. private consumers versus captive fleets).

Increasing knowledge and awareness about bioethanol vehicles and fuels. Sustainability and safety are two important issues to consider here.

Learning from peer communities – the BEST sites have gathered a large amount of knowledge and experience. Municipalities, Public Transport Authorities and other stakeholders can make study visits to BEST sites and learn from the BEST experience, or visit: www.best-europe.org

Adjust incentives and policies to the stage of market development

Local governments in a pre-market phase should concentrate on removing barriers to the introduction of clean vehicles and fuels. Development of a climate change action plan will provide a municipal framework for action, and adoption of a clean vehicle strategy can structure work and develop the market in a coherent, systematic way in the long-term. If no national clean vehicle definition exists, a local definition based on well-to-wheel greenhouse gas emissions should be introduced. All necessary regulations and standards should be established as early on as possible in the process. Local governments should also begin work on the procurement of clean vehicles and fuels to municipal fleets or services.

Local governments in a market development phase should concentrate on economic incentives to accelerate the uptake of clean vehicles and fuels; utilise a wide range of methods and instruments to enable market development and continually monitor the impact of actions and assess what needs to be done, with who and when; use analysis to assess whether and when incentives can be introduced or suspended.

Example

Adopt clean vehicle strategy and move towards large scale implementation of clean cars

There are many possible routes towards introduction of clean vehicles and fuels. This is an example of how Stockholm has worked, and how your city can follow.

Introduce clean cars into the municipal fleet and make sure that the city leases clean vehicles. Set targets for the introduction and strict requirements for employees to refill with alternative fuel. Start the demonstration and then demand clean vehicles in all types of procurements, such as taxi services, school transports, courier services, security services.

Older diesel-driven heavy vehicles such as public transport buses and waste collection trucks are large polluters. Set criteria for the procurement of alternatively-fuelled heavy vehicles. When operating in fleets, heavy vehicles use their depot filling station, which eliminates the need for a large network of filling stations.

Inspire others to obtain followers. Work with information and incentives. Arrange seminars and workshops with test driving for key target groups (e.g. private companies with large fleets and an environmental profile). Work to obtain favourable fuel prices.

Recommendations to national governments

National governments and agencies have the power to influence and set the agenda, by emphasising the importance of reducing fossil fuel consumption and greenhouse gas emissions to benefit their national energy situation, economy and environment. By doing so, they can guide stakeholders in their country towards a successful, lasting and accelerated introduction of clean vehicles and fuels.

BEST recommends that national governments and agencies:

- Adopt a clean vehicle definition and criteria for sustainable transport fuels (including biofuels). This will make it easier to introduce incentives and systems to enable rapid change.
- Ensure procurement of clean vehicles and fuels for public fleets and when buying or hiring transport services, and cooperate with wider EU and international schemes supporting clean vehicles and fuels.
- Clarify, and where possible transpose, existing regulations concerning filling stations, fuel storage, imports and classification from other Member States. National environmental and fire safety authorities can amend safety and environmental protection regulations to include all bioethanol fuels. Finalise legislation concerning safety and vapour-recovery systems in flexifuel pumps.
- Make it possible for manufacturers to certify their models as FFVs, and to distinguish FFVs from other vehicles in national car registries. This will facilitate incentive administration.
- Introduce carefully selected incentives to stimulate market introduction. These incentives must reflect and be adjusted to the relevant stage of market development, and must be removed when they are no longer required.
- Remove counterproductive incentives that actually support the use of fossil fuels. According to the World Bank, "global subsidies to petroleum products amount to some USD 150 billion annually".[53] A further USD 61 billion in loans, grants and guarantees are provided by the International Financial Institutions.[54] These subsidies far exceed the existing financial support for renewables.
- Focus on the price mechanism for different transport fuels, as the price at the pump determines sales volumes. All transport fuels should be priced in a clear and competitive way, with taxation reflecting the energy content of transport fuels.
- Support research and development into technological development and enable training and dissemination of information to stakeholders. Governments providing financial stimulus support to the vehicle industry can demand development of energy-efficient vehicles that use alternative fuels.
- Assess the impact of diesel shortages and prepare strategies for replacing diesel.
- Recommend that E-diesel be used in captive fleets due to safety issues and fund further research into the blend, incorporating results from studies carried out in the USA.
- Continuously benchmark research findings, comparing them against examples from earlier, current and future low blend tests.

53 *"Overview – Changing the Climate for Development"*, 'World Development Report 2010' (Advance Press Edition), The International Bank for Reconstruction and Development / The World Bank. (2010).

54 Friends of the Earth et al, *Poverty, climate and energy: the case against oil aid* (2008).

Recommendations to the EU

If the EU is to meet its ambitious climate and energy targets – which include the aim to achieve 10 % share for renewable fuels in transport – a wide range of actors will have to increase their use of renewable fuels in their vehicle fleets. The EU should enable the use of all possible alternatives to petrol and diesel and support production of sustainable biofuels.

BEST demonstrated that bioethanol is a functional alternative. It can be quickly introduced to large numbers of vehicles via petrol or diesel low blends or conversion of existing petrol vehicles to FFVs running on E85. Bioethanol buses and trucks running on ED95 can also be used. BEST showed that, when produced sustainably, bioethanol can deliver substantial reductions of greenhouse gases from a lifecycle perspective.

Thus, bioethanol can help the EU achieve its "20-20-20 by 2020" strategy. To enable market development for bioethanol, BEST recommends:

- A uniform and coherent regulatory framework to be established. BEST experienced significant variations in legislation, regulation, and interpretation and implementation of EU Directives between different Member States. This has a clear impact on fuel pricing.
- Flexifuel vehicles should become the standard for all petrol cars in the EU. This can be achieved through new production and conversion of existing vehicles. The mandatory obligation to run on a renewable fuel can be included in the next environmental standard Euro VI.
- Provision of low and high blends of renewables at filling stations should be mandatory. Both low and high blend biofuels should be used to meet the EU target of 10 % alternative fuels in transport by 2020.
- The EU should facilitate processes and identify solutions (for issues including fire safety and environmental protection standards, excise, tax warehouses, fuel classification etc). Legislation must be well-defined and uniformly applied. For example, legislation concerning safety and vapour recovery systems in flexifuel pumps must be clarified.
- Fuel standards in Europe should be harmonised.
- Certification processes for sustainable transport fuels (including fossil fuels) should be finalised and implemented and a single EU standard established. All sectors (e.g. timber, livestock, agriculture) should be subject to the same standards as biofuels to ensure and promote sustainable land use change.
- National experts developing sustainability criteria should ensure that the criteria can be accepted and implemented by small and independent bioethanol producers, both inside and outside the EU. Members of the European Parliament should scrutinise this aspect to ensure the criteria achieve this goal.
- Fuel taxation should reflect energy content and well-to-wheel CO_2 emissions. This can be included in the forthcoming Energy Tax Directive, to be implemented by all Member States in 2013.
- The EU should not limit the ability of national governments to use taxation as a tool. The EU can learn from its research projects and apply the lessons in reality. Taxation was identified by BEST as the most important incentive for stimulating market introduction of renewable fuels, yet the proposed amendments to the Energy Tax Directive will limit the ability of national governments to use taxation as a tool.
- Research and development into compression ignition engines and hybrid electric technology should be scaled-up, in order that a fuel-efficient, downsized car that meets all tailpipe and well-to-wheel requirements can be developed.
- Replacement of diesel should be a priority. National strategies to replace diesel and detailed plans for ED95 infrastructure should be prepared. Further studies on the impact of diesel fuel shortages should be conducted.
- As it is essential to reduce greenhouse gas emissions immediately, the EU and national bodies should encourage oil companies to make E10 the standard petrol by introducing measures to accelerate production or import of sufficient volumes of bioethanol.
- The EU should guide producers (domestic and external) towards production of larger volumes of sustainable bioethanol, to ensure rising demand is met.
- Customs and excise tax should not impede or restrict imports of sustainable biofuels from outside the EU in favour of unsustainable domestic products. Supporting free trade of sustainable biofuels will also contribute to economic development in developing countries.
- The EU should enable accelerated market introduction of biofuels and rapid achievement of its 2020 target. The twin challenges of Peak Oil and climate change mean the 2020 target should be seen as a target to be surpassed. A long-term approach based on principles of free trade and competition will enable the EU to achieve a rapid and lasting transition to a low-carbon transport system.

Advice to other projects

BEST has achieved, and in many ways exceeded, its aim to demonstrate and validate the performance of bioethanol vehicles and fuel through a wide range of actions. In doing so, BEST faced many challenges, some anticipated and some unexpected. These challenges occurred in isolation at specific sites, repeatedly across different sites, and – in the case of the sustainability debate – simultaneously at all sites.

These challenges influenced the changing form and scope of BEST, sometimes adding value to existing activities, and sometimes obstructing implementation of tasks. The sustainability debate challenged the core principles of BEST and led to increasing communication activities at all sites, and new tasks within project evaluation.

Expect the unexpected

BEST advises other projects that the unexpected can occur and a project must be flexible enough to adjust to new circumstances, whilst determined to persist with its original objectives. Strong project management and effective communication between partners can support a project through periods of crisis. Moreover, challenging periods can be used as platforms for action.

For example, when media scrutiny of sustainability issues was most intense, the Swedish BEST partners' informal network of bioethanol stakeholders joined forces to proactively engage with the media and offer a balanced picture of sustainability issues related to bioethanol. Such activities reinforce the strength of a project, both at local and European levels.

Understand stakeholder needs

There are many ways to work actively with market expansion. In order to reach potential buyers, correct target groups must be identified and selected. Activities and processes should be sensitive to the needs of the target groups and aim to engage stakeholders in constructive dialogue.

For example, BEST identified existing fuel suppliers that were interested in supplying alternative fuels, including bioethanol, and found that small independent fuel distributors can become pioneers in supplying E85. These chains have no own interests in oil fields and therefore have greater scope to supply alternative fuels, if sufficient numbers of vehicles and customers exist in the market. It is therefore in the interest of this stakeholder group to participate in a project like BEST.

To take another example, BEST observed that bus operators with short-term service contracts are unlikely to purchase bioethanol buses if they are also obliged to install fuel infrastructure. This means that local governments must enable Public Transport Authorities to spread risks by, for example, securing refuelling infrastructure independently of operator services or by obliging contractors to take over vehicles from outgoing service providers. This approach is now being implemented in Stockholm and other BEST sites.

Strategic (internal) communication

Dissemination plays a strong role in increasing public awareness of a technology. Cooperative communication can ensure that key stakeholders are engaged with and committed to a process. For example, BEST found drivers to be critical actors when introducing new buses to public transport fleets, partly because they are the public face of the company and interact continuously with customers, but also because they have extensive experience of driving diesel buses.

Appropriate information and training opportunities should be offered, so that drivers can embrace the new technology and act as ambassadors towards their peers and the public. In the same way, mechanics are important and must receive detailed information on how to maintain the buses. Well-maintained buses cost less to operate and provide higher levels of safety and comfort to passengers, increasing the quality of service delivery and the likelihood of acceptance for the new technology amongst all stakeholders.

Be pragmatic – change takes time

It is also important that projects are realistic about what can be achieved and how quickly. Demonstration projects may encounter difficulties during the beginner stage of market development. These may include technical problems, an underdeveloped refuelling network, difficulties with fuel supplies, insurance or warranty issues, costs and tax disadvantages.

The number of vehicles in operation is of secondary importance until barriers have been overcome, although testing and demonstrating vehicles can help identify and reduce legal barriers. Experiences should be documented and communicated to relevant local, national and EU stakeholders.

A selection of reports from BEST for further reading

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BEST D1.12, *Report on the experiences of Hybrid Electric Vehicles on ethanol - test results and drivers experiences* (2009).

BEST D1.14, *Report on driver attitudes towards flexifuels vehicles* (2009).

BEST D1.19, *The BEST experiences with bioethanol cars* (2009).

BEST D1.20, *Emissions and experiences with E85 converted cars in the BEST project* (2009).

BEST D2.08, *The BEST experiences with bioethanol buses* (2009).

BEST D3.15, *The BEST experiences with ethanol low blends in diesel and petrol fuels* (2009).

BEST D4.20, *The BEST experiences with distribution of bioethanol for vehicles* (2009).

BEST D5.12, *Promoting Clean Cars – Case Study of Stockholm and Sweden* (2009).

BEST D5.14, *Incentives to promote Bioethanol in Europe and abroad* (2009).

BEST D7.01, *Communication programmes in BEST: 2006-2009* (2009).

BEST D8.09, *Transfer of knowledge* (2009).

BEST D9.14, *Review of fuel ethanol impacts on local air quality: A literature review of available evidence for effects of ethanol fuels on air pollutant emissions from motor vehicles* (2008).

BEST D9.21, *Report on life cycle greenhouse gas impacts of ethanol supply chains at BEST sites* (2009).

BEST D9.23, *Updated Sustainability Assessment: A comparison of BEST sites 2007-2008* (2009).

BEST D9.24, *A comparative report about consumers' attitudes, world views and purchase intentions for clean vehicles* (2009).

BEST D9.25, *Report on survey of fleet operators' attitudes toward ethanol vehicles and fuel* (2009).

BEST D9.26, *BEST Final Evaluation Report* (to be pubished end 2009).

BEST D9.28, *Sustainability analysis of biofuels production and use* (to be published end 2009).

All the reports are available at

www.best-europe.org

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Final report

This report is the conclusion of BEST – BioEthanol for Sustainable Transport – a four-year project to demonstrate the use of bioethanol in cars and buses at ten sites in Europe, Brazil and China.

The results are clear: bioethanol can substitute a significant part of the fossil fuels currently used for transport in Europe. The technology is available and works, the fuel can be produced in a sustainable way, whether it is imported or produced in Europe. The project also clearly shows that the market will only develop rapidly if certain market barriers are dealt with on both the European and national levels. Advice to local governments, national governments and the EU are included for those who would like to speed up the shift from fossil fuels to renewables.

The results of this report can contribute to the development of more sustainable transport in Europe. Bioethanol is well suited to become an important part of the future fuel mix.

BEST
BioEthanol for Sustainable Transport
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