The BEST experiences with bioethanol buses

BEST WP2 Buses Final Report

March 2010, Stockholm
BEST Deliverable No 2.08
This report is produced within the European project BEST - Bioethanol for Sustainable Transport.

BEST deals with the introduction and market penetration of bioethanol as a vehicle fuel, and the introduction and wider use of flexible fuel vehicles and bioethanol cars on the market.

Read more at www.best-europe.org

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<table>
<thead>
<tr>
<th>Table of Content</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioethanol – a diesel substitute</td>
<td>9</td>
</tr>
<tr>
<td>Background on bioethanol buses and fuel stations</td>
<td>10</td>
</tr>
<tr>
<td>Bioethanol bus sites in BEST</td>
<td>14</td>
</tr>
<tr>
<td>La Spezia</td>
<td>14</td>
</tr>
<tr>
<td>Madrid</td>
<td>15</td>
</tr>
<tr>
<td>Nanyang</td>
<td>16</td>
</tr>
<tr>
<td>São Paulo</td>
<td>17</td>
</tr>
<tr>
<td>Stockholm</td>
<td>18</td>
</tr>
<tr>
<td>Rotterdam</td>
<td>19</td>
</tr>
<tr>
<td>BioFuel Region</td>
<td>20</td>
</tr>
<tr>
<td>Experiences from the introduction phase</td>
<td>21</td>
</tr>
<tr>
<td>No regulations for bioethanol fuel in Italy</td>
<td>21</td>
</tr>
<tr>
<td>Alcohol tax on the bus fuel in Madrid</td>
<td>24</td>
</tr>
<tr>
<td>127 bioethanol buses in Stockholm</td>
<td>25</td>
</tr>
<tr>
<td>Bioethanol bus in Sao Paulo</td>
<td>26</td>
</tr>
<tr>
<td>Introduction of BEST bioethanol buses in Nanyang</td>
<td>28</td>
</tr>
<tr>
<td>Conclusions about the introduction phase</td>
<td>29</td>
</tr>
<tr>
<td>Bus drivers and mechanics – important for success</td>
<td>30</td>
</tr>
<tr>
<td>Drivers</td>
<td>30</td>
</tr>
<tr>
<td>Mechanics</td>
<td>32</td>
</tr>
<tr>
<td>Passenger surveys</td>
<td>34</td>
</tr>
<tr>
<td>Results and function of the bioethanol buses</td>
<td>36</td>
</tr>
<tr>
<td>Market development</td>
<td>39</td>
</tr>
<tr>
<td>Recommendations</td>
<td>42</td>
</tr>
<tr>
<td>Annexes</td>
<td>44</td>
</tr>
<tr>
<td>Annex 1 Bus lines</td>
<td>44</td>
</tr>
<tr>
<td>Annex 2 Taxes and Customs Tariffs in EU</td>
<td>47</td>
</tr>
<tr>
<td>Annex 3 Review of WP2 Deliverables Data.</td>
<td>48</td>
</tr>
<tr>
<td>Annex 4 Recommendations for handling of ED95.</td>
<td>52</td>
</tr>
</tbody>
</table>
Summary in English

The demonstration of bioethanol buses in the BEST project shows that the bioethanol technology works. The buses have the same availability as other new buses, the fuel stations function effectively and both drivers and passengers appreciate the buses. 136 bioethanol buses with a modified diesel engine and 2 with flexi fuel otto-engines were tested. The conclusion is that bioethanol is a suitable fuel for public transport. Bioethanol has a potential to replace diesel in compression engines.

The experiences from introducing bioethanol buses at the BEST sites shows that there is little connection between the EU political visions of reducing emissions from road transport through biofuels and real life. The demonstration has shown that few regulations have been changed in order to facilitate the introduction of biofuels. No authorities were negative to the idea of using bioethanol buses but the lack of existing regulations for handling bioethanol fuel and lack of definitions of bioethanol as a fuel caused problems with tax, customs and safety regulations when the buses were introduced.

The main difference between diesel buses and bioethanol buses is the more frequent need for maintenance for the bioethanol engine, every 10,000 km compared to every 20,000 for diesel buses. This leads to increased costs. The bioethanol bus costs about 10 percent more than a comparable diesel bus. Another factor important for the driving cost is the fuel. The bioethanol bus fuel contains about 70 percent less energy per litre fuel compared to diesel which means that the fuel consumption in volume is higher compared to diesel buses. The consumption in energy terms, kWh/km, is the same. The higher fuel consumption can lead to higher costs, depending on how the bioethanol fuel is taxed.
Bioethanol – a diesel substitute

Bioethanol is the most commonly-used biofuel for petrol substitution in the world\(^1\). The BEST demonstration of bioethanol buses aimed to show that bioethanol also can be used to substitute diesel. As the demand for diesel is growing fast there will be an increasing diesel deficit on the European market. Replacement for diesel is needed!

![Graph showing consumption of roads transport in Europe](image)

\(\text{Consumption of road transport in Europe}^{1} \) (kt)

The diesel engine is more energy-efficient compared to the petrol engine. The diesel engine modified for bioethanol is as energy-efficient as the conventional diesel engine in use of kWh/km. However, the energy content of the bioethanol bus fuel is lower compared to diesel. This means that even though the bioethanol engine is as energy-efficient, the bioethanol bus needs about 70 % more volume of bioethanol compared to diesel. For this reason, it is important to tax fuel according to its energy content, not by volume (if the bioethanol is taxed).

Other biofuels can be used in buses, such as biodiesel and biogas. Biodiesel is also used in a diesel engine while biogas buses have an otto-engine. Biodiesel has energy content close to diesel and biogas close to natural gas.

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Background on bioethanol buses and fuel stations

Two different types of bioethanol buses were tested in BEST, one type with a modified diesel engine and one type with an otto engine. The Scania bioethanol bus looks just like an equivalent diesel bus, but has a bioethanol-adapted compression ignition engine that is dedicated 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 percent). The main differences compared to 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 more alcohol resistant materials

A description of the Scania bus is found below:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length [mm]</td>
<td>11,985</td>
</tr>
<tr>
<td>Breadth [mm]</td>
<td>2,550</td>
</tr>
<tr>
<td>Height [mm]</td>
<td>3,177</td>
</tr>
<tr>
<td>Wheel-base [mm]</td>
<td>6,000</td>
</tr>
<tr>
<td>Capacity [litre]</td>
<td>8.9</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>5</td>
</tr>
<tr>
<td>Max Power [kW/hp]</td>
<td>198/270</td>
</tr>
<tr>
<td>Fuel tank [litre]</td>
<td>400</td>
</tr>
</tbody>
</table>

Some specifications of the OMNILINK Scania buses.

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.

The availability of the buses is the same as for diesel buses. Bioethanol buses require maintenance every 10,000 km compared to every 20,000 km for diesel buses. The main differences in service needs are change of motor oil and oil filter. Change of fuel injectors is required at every second service, as pollutants formed in the engine can get stuck in the fuel injector, making the injection pressure fall. Experiences from the Stockholm region show that it is very important to keep the scheduled service. The cost for maintenance of bioethanol buses are therefore up to twice as high compared to diesel buses.

A bioethanol bus from Scania costs about 10 % more than a conventional diesel bus.
Two dual-tank E100 buses developed by the Chinese vehicle producer Dongfeng were tested in BEST. These buses can run on either petrol or hydrous E100 – an innovation within BEST. One of the buses uses a modified petrol engine and the other uses a modified natural gas engine. The bus with the modified petrol engine uses petrol when started and switches to bioethanol after running for a time. The other bus has two ECU controls and fuel injection systems, one for bioethanol, the other one for petrol. The driver can easily choose the fuel system by switch button. The Dongfeng bioethanol buses cost about 10,000 RMB (€1,000) more than comparable conventional petrol buses and have the same availability as conventional buses. Maintenance is needed every 10,000 km at a cost of about 1,500 RMB (€150) each time.
Bioethanol – short background

Bioethanol can be produced from any biological feedstock that contains sugar or materials that can be converted into sugar such as starch or cellulose.

First generation bioethanols are characterised by the fact that only parts of the source plant are used for bioethanol production. The next-generation (or second generation) bioethanol use nearly the whole plant, including waste, for bioethanol production. The process technology for second generation fuels is generally more complex.

The main crops used for the industrial production of bioethanol are sugar cane, corn (maize), wheat and sugar beet. The last two are currently - and will for the foreseeable future be - the main sources of bioethanol in Europe. Brazil is the world market leader in bioethanol production.

Bioethanol can be manufactured from different sources and with different processes. The environmental impact of bioethanol differs according to the variations in the fuel’s life cycle, from the initial source of production to use in a vehicle (the route from “well-to-wheel”). Particularly important issues to consider are greenhouse gas (GHG) balance and energy balance for the life cycle of the fuel, more information can be found in BEST Deliverable D9.26.

Bioethanol bus fuels and fuel stations

Two types of bioethanol fuel have been used in the project: ED95 for the diesel engine and E100 for the otto engine. The bioethanol fuel developed for heavy-duty, bioethanol compression-ignition engines, ED95, consist of 96.5 percent denaturized hydrous bioethanol and 3.5 percent ignition improver. The ignition improver additive is a polyethylene glycol derivative which is supplied by SEKAB. The denaturants are MTBE and isobuthanol.

The engines are dedicated to bioethanol and cannot run on diesel. The bioethanol fuel used for light vehicles, E85, cannot be used in these buses. This means that it is preferable to start with depot-based vehicles.

ED95 has about 70 percent lower energy content compared to diesel, which means that 70 percent more fuel is needed to drive a bioethanol bus the same distance as a diesel bus.

The trade name as produced by SEKAB (Svensk Etanolkemi AB) is ED95. It has a composition of (percentage by volume):

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denaturant</td>
<td>96.5%</td>
</tr>
<tr>
<td>Additive</td>
<td>3.5%</td>
</tr>
</tbody>
</table>

There is no set standard for the fuel according to Swedish or European directives. There is a Swedish standard for the bioethanol part. Within EU there is a standard for a reference fuel to get an emission certification for the bioethanol fuelled diesel engine (Directive 2001/27 EC).

Requirements for an ED95 fuel station

Bioethanol is a liquid and refuelling occurs in the same way as diesel. The fuel stations for ED95 are the same as diesel fuel stations and the refuelling times are equal. The costs of bioethanol filling stations are almost the same as for diesel fuel stations, with the exception of the sprinkler plant, which is needed as bioethanol is more hazardous than diesel. It is possible to convert a diesel tank facility to bioethanol but some important things have to be considered:

- The bioethanol fuel has lower flash point than diesel and the hazard classification is equal as petrol, therefore a sprinkler system in the bioethanol tank area is recommendable. Further, safety information must be given to all employees.

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3 2007, Well - to - Wheels analysis of future automotive fuels and powertrains in the European context, JRC/IES, European Commissions Joint Research Center - Institute for Environment and Sustainability, Italy (ies.jrc.ec.europa.eu)
• The fuel pump has to be approved for a hazard classification equal as petrol.
• All polymer components in the tank and pump facility has to be checked so they are resistant to bioethanol
• The tank should not be painted inside because bioethanol is a very good solvent.
• For commercial use it is assumed that the tank facility has to be approved by a legal authority.

Requirements on an E100 fuel station
The E100 buses demonstrated in Nanyang run on pure hydrous bioethanol, E100. Unlike ED95, this fuel requires no additive. This was an important factor in China, where the ED95 additive is subject to import duties, making the fuel more expensive than E100. The requirements for an E100 pump are the same as for ED95 pumps. E100 is equally flammable and the E100 fuel pumps have to meet the same standard as petrol pumps which mean the refuelling has to take place outside. The resistance of materials in the pump and tank should be checked to ensure they are resistant to bioethanol.

Swedish experience has been useful in the BEST project
There have been bioethanol buses running in Sweden since the 1990s but the technology was not spread to other countries. There has been very little opportunity to drive bioethanol buses outside Sweden before as the producer did not market the vehicles outside of Sweden. Increased focus on climate change and local environmental issues has stimulated interest in bioethanol buses both from PTAs and the bus producer. The BEST project provided an opportunity for other cities to utilise the experiences of Swedish cities, public transport authorities and operators with bioethanol buses. The Swedish experiences with standards and safety regulations have been very valuable for the sites in other countries.
Bioethanol bus sites in BEST

Bioethanol buses have been demonstrated at five BEST sites: Stockholm, La Spezia, Madrid, Nanyang and São Paulo. 138 buses have been introduced all together. Rotterdam and BioFuel Region also aimed at introducing buses but they were not able to fulfill the goals within the timeframe of BEST. The reasons for this will be explained in the report. The bioethanol bus sites are presented below with a description of the site, where the buses have been driven and information about the bus filling stations. Below are information about the number of buses and fuel stations that have been introduced, with and without EU-funding.

<table>
<thead>
<tr>
<th>Site</th>
<th>Number of buses</th>
<th>Starting date</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Spezia</td>
<td>3</td>
<td>January 2007</td>
</tr>
<tr>
<td>Madrid</td>
<td>5</td>
<td>April 2007</td>
</tr>
<tr>
<td>Stockholm</td>
<td>127</td>
<td>February 2006</td>
</tr>
<tr>
<td>Nanyang</td>
<td></td>
<td>December 2007</td>
</tr>
<tr>
<td>São Paulo</td>
<td>1</td>
<td>January 2008</td>
</tr>
</tbody>
</table>

La Spezia

La Spezia is situated on the Italian west coast, not far from Milan. The city has 100,000 inhabitants but the whole La Spezia region consists of 300,000 people. Approximately 250,000 journeys are made within the city each day, 30 percent by public transport, and 45 percent by private vehicles. The main environmental and traffic related problems are an increasing number of vehicles, congestion on many principal roads, noise and emissions from traffic, and low bicycling frequency. There are problems with air quality, due to high concentration of NO\textsubscript{x} and particulate matter. The buses in the fleet are procured and owned by the local bus company ATC.

Bioethanol buses in La Spezia

In January 2007 the three Scania bioethanol buses started their service in the eastern part of La Spezia region. The first year the buses run on suburban and extra-urban lines, which run within the urban borders of the municipality of La Spezia and reach some of the neighbouring towns of the La Spezia province and the nearby Tuscany Region (Municipality of Carrara). During the second year, they continued to be utilized on sub-urban lines, in particular on one line, called “SA” which connects La Spezia to the Municipality of Sarzana, where the ED95 pump of ATC is located. All the lines are quite extensive and their route is mainly flat.

Fuel stations

The first ED95 filling station was built before the buses started to run in January 2007. The filling station was installed inside the depot of ATC in Sarzana. The fuel was bought from SEKAB, as recommended by Scania.

Training of bus drivers and mechanics in La Spezia

Before the buses began their service, ATC provided information to the personnel about the BEST project and the benefits of utilising bioethanol as fuel for buses.
Scania provided a few days training course for the mechanics of ATC before the buses started operate, because these buses were the first ED95 buses introduced in Italy. The drivers also got the opportunity to practice for a couple of days before the buses started to run in scheduled traffic. The drivers got to know the buses and their technical characteristics. Additionally, all the bus drivers were given technical information, a file containing a synthesis of the BEST project and the description of the objectives that ATC and the Municipality of La Spezia had with the bioethanol utilization.

ATC saw the bus drivers as an important contact with the passengers and it was important that they could answer questions from passengers. ATC also prepared a support notebook, which was used by bus drivers to take note of good qualities and flaws of the new vehicles as well as the feelings and comments from the customers. Each vehicle has been equipped with this support notebook which has been properly filled in, especially during the first months.

Madrid

The City of Madrid has a population of approximately 3.2 million inhabitants, being the main urban centre of a metropolitan area of approximately 5.5 million inhabitants. The city has to face significant challenges related to air quality and increased CO2 emissions from rising urban transport. In spite of the important effort made in the last few years for the improvement in public transport, the private vehicle continues to represent a very large percentage in the commuting made in the city. This has consequent impacts on air quality and noise pollution. In BEST, the Madrid Municipal Urban Transport Company (Empresa Municipal de Transporte EMT) decided to demonstrate five bioethanol buses and install one fuel station for ED95 on its own cost (without EU funding).

Bioethanol buses

The five buses were purchased at the beginning of 2007 and started their operation in April 2007. The service route (line 75) assigned to these buses goes through the highly-crowded city centre of Madrid in order to evaluate and estimate a large number of passengers’ opinions. Monitoring of kilometers covered for each bus and fuel consumption has been carried out.
The buses have a special external design with messages related to bioethanol and the Madrid motto of BEST project: Muévete con otra energía – "Move with alternative energy" - in order to take advantage of the high visibility for raising awareness purposes.

Fuel station
The service point set up for these buses has a total capacity of 15,000 litres. The average consumption is approximately 1,000 litres/day.

Training and maintenance
The drivers and mechanics have all been trained by Scania.

Nanyang
The City of Nanyang is located in the southwest in the Henan province in China. There are 10.65 million inhabitants in the Nanyang region. Prior to BEST, bioethanol was used in the city as a low blend in petrol, E10, but not as bus fuel. During BEST, the large difference in cost between the Scania bus and conventional Chinese buses meant it was not possible to import Scania buses to Nanyang. Instead Nanyang started a dialogue with the Dongfeng Auto company. This led to cooperation and the delivery of the first Dongfeng bioethanol bus to Nanyang in December 2007. A second bus was delivered in March 2008. The cost of each bus is €35,000, approximately €1,000 more than equivalent Chinese petrol buses.

The first bioethanol bus in Nanyang
The first bioethanol bus Nanyang purchased has a petrol engine EQ6100-1 and uses hydrous E100. This bus was delivered in December 2007. The size of the bus is 10.2m × 2.5m × 3.0m, with 19 seats and total capacity of 60 persons (seated and standing). The bus contains two fuel tanks, one for petrol and one for bioethanol (hydrous E100). When started, the bus uses petrol and switches to bioethanol after running for a time.

The second bioethanol bus in Nanyang
The second bioethanol bus Nanyang purchased has a natural gas Dongfeng EQ6103PcN engine and uses anhydrous bioethanol E100. The second bioethanol bus was delivered in March 2008. The bus is the same size as the first bus, but is equipped with an air conditioner. The bus has two ECU control and fuel injection systems, one for bioethanol, the other one for gas. The driver can easily choose the fuel system using a switch button.

Operation of the bioethanol buses in Nanyang
The two BEST bioethanol buses are the only bioethanol buses in Nanyang. The buses are used in the fleet of Tianguan Group, the bioethanol plant, to pick up its staff to go to work and home. The buses operate on a 15km route (one way) from downtown residential communities to the new bioethanol plant, which is located in a suburb of Nanyang. The buses are sometimes used to collect visitors from the airport or railway station.
Scania bus in Beijing
Though Nanyang cannot purchase or rent the Scania bus for demonstration, Scania cooperated with Nanyang and Beijing Public Transport Fleet to achieve the demonstration of a Scania bioethanol bus in Beijing during the 2008 Olympic Games until the end of 2008. The bus was used on the 654 route, driving 3 two-hour circuits each day.

Scania ethanol bus in Beijing
Nanyang provided the bioethanol fuel and had responsibility for blending with the ignition improver. The ED95 was transported by truck from Nanyang to Beijing. The BEST logo was printed on the bus and inside the bus, there was information on bioethanol and bioethanol buses. Scania provided data on the Beijing bus to BEST and conducted surveys of drivers, mechanics and passengers.

Training and maintenance
Dongfeng gave a training course for drivers before the buses were put into operation. Only trained drivers are permitted to drive the bioethanol buses. The course included how to start the bus, introduction to the switch system, filling, etc. A brief introduction of fuel bioethanol, bioethanol buses and the BEST project was included.

Two Dongfeng mechanics stayed in Nanyang to provide technical service and maintenance during the first month of operation. The bus was checked everyday after operating, as required by the Tianguan fleet. In the following months, the buses were checked every week. There have not been any bioethanol related problems.

São Paulo
The City of São Paulo is the fourth largest city in the world; 16 million people live in the city and its metropolitan area. Every day, nearly 3.2 million people use 13,726 buses in the fleet, which is mainly fuelled by diesel oil. The main environmental and traffic related problems are an increasing number of vehicles, congestion on many principal roads, noise and emissions from traffic, and low bicycling frequency. There are big problems with air quality in inner city areas, due to high concentration of NOx and particulate matter.

In BEST, São Paulo has become the first city in Americas to demonstrate bioethanol buses.
The Bioethanol bus in São Paulo

São Paulo has only one bioethanol bus which travels on a segregated bus lane. The segregated bus lane is called Jabaquara-São Mateus, and it passes through Diadema, São Bernardo do Campo, Santo André and São Paulo districts. The extension is over 35 km, its height average is 700 metres above sea level. Over 6 million passengers are transported per month. The average speed in the segregated bus lane is 20 km/hour, compared to 12 km/hour outside the segregated bus lane; its speed limit is 50 km/hour.

The chassis and the engine was shipped to Brazil, and a new chassis was constructed by Marcopol. Engineers found it difficult to adapt the Swedish Scania chassis to the standard Brazilian bodywork, but these problems were overcome. The engine installed in the vehicle was the Euro 4 generation Scania bioethanol engine. The bodywork is 12 metres long. With a Padron low-entry floor and air-conditioning, the bus has a transport capacity of 77 people, 29 seated and 48 people standing. One-side doors mean the bus can be used only in segregated bus lanes (in São Paulo the bus fleet must have both sides doors if used out of the segregated bus lane).

The diesel bus

In Brazil, the BEST project aimed to evaluate and compare the operational costs of the bioethanol bus in comparison to a standard bus fuelled by diesel oil. An equivalent bus was selected and data collected was used as the parameter to demonstrate the bioethanol usage in urban transport. The equivalent bus was also a Scania, similar to the bioethanol bus. The diesel bus used the same itinerary of the bioethanol bus, enabling comparable data to be gathered.

Fuel Stations

Only one bioethanol bus was introduced in the São Paulo bus fleet. Petrobras was chosen to be responsible for the additive importation from Sweden to Brazil, the bioethanol-additive mixture and providing the fuel station equipment to BEST Brazilian coordinators.

Stockholm

City of Stockholm has 0.74 million inhabitants but the metropolitan area consists of 1.8 million people. Approximately 6.7 millions trips are made within the city each day, 60 percent by public transport, and 25 percent by private vehicles. In peak hour as many as 73 percent of the trips are made by public transport in the city. Air quality in inner city districts is a significant environmental and traffic-related problem. Stockholm Public Transport Authority, SL, purchases the bus service through a tender procedure. SL is owned by Stockholm County Council, the regional authority.
Bioethanol buses

The total number of buses in the public transport system in Stockholm is 2014. 127 of the total 400 bioethanol buses received funding from BEST. These BEST buses operate in the outskirts of Stockholm, in the areas Huddinge/Botkyrka and Söderort. The buses are run by the operators Swebus and Busslink.

All the buses are used daily in the public transport system in Stockholm. The operators purchase the fuel. Both Swebus and Busslink buy ED 95 from Sekab. The price of the fuel is not known by SL. The vehicle tax for bioethanol buses is 23 €/annum compared to the € 2600 vehicle tax for diesel buses per annum.

The fuel stations

Bioethanol fuel stations have been built at the following depots: Märsta, Lidingö, Söderort/Nyboda, Huddinge/Botkyrka och Rästa. There have been no problems with the refuelling during the period. The size of the fuel stations are:

<table>
<thead>
<tr>
<th>Depot</th>
<th>Bioethanol (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Söderort/Nyboda</td>
<td>100</td>
</tr>
<tr>
<td>Rästa</td>
<td>150</td>
</tr>
<tr>
<td>Botkyrka</td>
<td>50</td>
</tr>
<tr>
<td>Märsta</td>
<td>50</td>
</tr>
<tr>
<td>Lidingö</td>
<td>50</td>
</tr>
</tbody>
</table>

The size of a diesel fuel station is between 10 to 150 m³ depending of the size of the bus fleet.

Rotterdam

Around 1.1 million people live in the Rotterdam region. Industry and logistics contribute towards significant air quality problems and emissions of greenhouse gases. These problems are enhanced by the region’s location, at the centre of Europe’s industrial heartland. Rotterdam has ambitious plans to reduce CO₂ emission by 50 percent before 2025, via reuse of waste heat from industry, carbon capture and sequestration and projects directed towards use of clean vehicles and fuels. The BEST project aimed to contribute towards the strategic climate and environmental goals and the introduction of biofuels to the Netherlands.

The city of Rotterdam aimed to introduce 3 bioethanol buses within BEST. A feasibility study was carried out, which identified a number of obstacles hindering achievement of this aim. For example, local policies describe that buses should be at least Euro 5 and have particle filters; there were no goals for renewable fuel in the bus fleet; and the local bus operator RET was privatised during this period, making it more difficult to raise interest for an investment in renewable fuel buses.

There were also a number of obstacles at the national level. Firstly, there were no tax incentives for biofuels in the Netherlands; secondly, the use of natural gas and LPG are stimulated through purchase taxes and there is also a tax deduction for particle filters. The presence of these obstacles made it impossible to introduce bioethanol buses in the city of Rotterdam within the time frame of the BEST project.
BioFuel Region

Biofuel Region (BFR) is located in Sweden and includes two counties, Västerbotten and Västernorrland, in which 500,700 people reside across 77,100 km² territory. 18 out of 22 municipalities in these counties are members of Biofuel Region, together with seven small-medium enterprises and three universities. The National Road Authority and the two County Administration Boards are also affiliated members of the BFR.

BFR had good conditions for market development, as clean vehicles and alternative fuels were increasing their market share in Sweden and a range of national incentives and instruments were being used. Moreover, many actors in BFR were committed to developing local production of sustainable energy sources to boost economic development.

The first bioethanol buses in Sweden were introduced in Örnsköldsvik. 15 bioethanol buses still operate there, as well as biogas buses and buses running on synthetic diesel (from natural gas) operating in the region. BAFF and Sekab had extensive dialogue with regional public transport about the prospect of procuring additional bioethanol buses within BEST, but this proved impossible as a large, long-term procurement of bus services was conducted by the two regional Public Transport Authorities just before BEST started. This meant that any new bioethanol buses would have to be introduced on top of the existing contract, which the PTAs were reluctant to do. A lack of formal targets for use of biofuels in bus fleets meant it was impossible to force PTAs to accept higher costs.

The debate on the sustainability of biofuels increased reluctance among municipalities in the region, even though Sekab presented the new Verified Sustainable Bioethanol during the period. This resulted in no further introduction of bioethanol buses or fuel stations in BioFuel Region within BEST.
Experiences from the introduction phase

Bioethanol buses were demonstrated at five sites in the BEST project. Seven sites planned to introduce buses but two were unable to do so (see previous section).

All sites in BEST, apart from Stockholm, ran into different kind of problems in the implementation phase of the bioethanol bus demonstrations. Many of the problems occurred because the sites were introducing the first bioethanol buses and bioethanol fuel stations in their respective countries. This meant there was a lack of experience, knowledge and procedures for fuel stations and handling fuel within local and national authorities.

This showed it is important to contact the local authorities as early as possible in the process. Experiences from other countries, where the rules and regulations are in place, was very helpful.

No regulations for bioethanol fuel in Italy

The public transport authority in La Spezia, ATC, introduced three bioethanol buses within the BEST project. The buses have run since the beginning of 2007. The planned start of operation was in September 2006. The delay was caused by problems during construction of the fuel station and problems with the import of the fuel.

Fuel station

La Spezia ran into problems when ATC wanted to set up a fuel station for the bus fuel. The problems were the following:

- No general regulations for bioethanol fuel stations
- No safety regulations
- No requirements for the design
- No equipment supply
- No regulations for equipment approval
In Italy there was no legislation or regulations applicable for the building of a bioethanol fuel station. That made it impossible for the authorities to give an immediate approval to an application from ATC to build a bioethanol fuel station at the bus depot, even if they were positive to the project. Furthermore, there were no safety regulations or requirements of design and what kind of equipment that could be allowed. The authorities also had questions about how wastewater from the stations should be treated.

**The solution in La Spezia**

ATC had an extensive dialogue with the Italian authorities at all levels in order to establish regulations for bioethanol fuel stations. Experiences from Sweden and the regulations applied by the Swedish authorities were presented to the Italian authorities. See Annex 4 for Swedish recommendations for bioethanol fuel stations. As bioethanol had not been used as a fuel before in Italy, new regulations had to be decided at all levels. The local authorities decided that a special collection and drainage system for rain water had to be built around the fuel station. This was done in order to take care of wastewater and to prevent mixing with bioethanol. In case of leakage a sealed trap takes care of the ED95.

The advice from ATC is to contact the local authorities as soon as possible to discuss how the fuel station should be built. It is also recommended to show cases from other countries, and if necessary present contact persons at authorities at an equal level in a country with experience from the new fuel.

**The fuel – bioethanol bus fuel**

ATC also had problems getting permission for importing, handling and storing the fuel- The problems connected with the fuel:

- Lack of general regulations,
- Lack of safety rules
- No decisions made regarding classification and excise duty rates for bioethanol fuel

In the beginning of the project, the bioethanol bus fuel was not classified as a fuel and the authorities had problems to know how to classify the bus fuel. The handling of the applications became more difficult because of this.

ED95 Fuel station, La Spezia. Photo ATC
The solution

ATC met the Italian customs authorities together with the BEST partner SEKAB who is also distributing the bus fuel. The reason for the meeting was to decide how the fuel should be classified and the excise duty rate for the fuel. The company that imports the fuel has to have a tax warehouse licence, a registered trader licence or a non-registered trader licence for the fuel from the national customs authorities so that the authorities in the exporting country know that the goods will be taxed somewhere else in the EU.

SEKAB described that the Swedish customs authorities’ classed the bus fuel as an energy product under CN code 3824 90 98 99 and that the Swedish tax authority exempted the product from alcohol tax since it was used as a fuel, and discussed what documents that were required for export to countries within the EU. It was important to achieve consensus that the bus fuel is a fuel and not technical alcohol. The tax level for technical alcohol is much higher than fuel tax. It is also more difficult to get a tax warehouse licence for bioethanol than for energy products, which would be required if the fuel was classed as bioethanol (a chemical) and not as a fuel.

In Sweden, the bus fuel is classed as an energy product under CN code 3824 90 98 99 in a Binding Tariff Information (BTI)\(^\text{5}\) based on the following EU regulations:


The information worked as a guideline for the Italian rules and regulations. The Italian customs authority could take a decision to classify the bus fuel as a fuel and give ATC a registered trader licence.

The taxation of bioethanol bus fuel in Italy

The tax value is the same as for diesel: 0.416 € per litre, but the energy content of Bioethanol is 60 percent lower per litre so taxing per litre actually corresponds to 70 percent higher tax for bioethanol, preventing competition between the fuels.

In Italy there is a certain volume of renewable fuel that can get tax subsidies every year and in the beginning of the project ATC had to apply for tax reduction every year. In 2009, no incentives or taxes reduction for biofuels were in place in Italy.

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5 A BTI is a tool to assist economic operators to obtain the correct tariff classification for goods they intend to import or export. Binding Tariff Information is issued on request to economic operators by the customs authorities of the Member States. It is valid throughout the Community, regardless of the Member State which issued it.
Alcohol tax on the bus fuel in Madrid

Fuel tank and bus in Madrid, photo EMT

Five bioethanol buses were introduced in the EMT Madrid bus fleet. The buses have operated since the beginning of April 2007. The operation was planned to start in October 2006. The reason for the delay was a decision by the customs and tax authority to impose alcohol tax on the fuel.

EMT Madrid started the project in the beginning of 2006. The planning for the fuel station met some problems because there were no regulations for bioethanol fuel stations. EMT decided to classify the fuel as chemical bioethanol. That made it easier for the authorities to find the rules and regulations for the fuel pump.

EMT bought the chassis from Scania and the bodies were built by a local body builder, Castrosua. EMT received information from the customs and tax authority that everything was in order for import of the bioethanol for the buses.

At the last minute, the authority decided that the chemicals used as denaturants (to avoid drinking) of the bus bioethanol (MTBE and Isobutanol) were not allowed to be used if the bioethanol was to be classified as a chemical in Spain. The authority therefore decided that the bioethanol should be imposed with alcohol tax (8 €/litre). This delayed the operation of the bioethanol buses.

The solution

All the involved parties (EMT, Scania, the city of Madrid and Sekab) worked hard to show the customs and tax authority that the bioethanol was meant to be used as a fuel. EMT sent a written communication to the authority to explain the background to the project. The issue was debated in the newspapers in Madrid. SEKAB sent information from the Medical Products Agency in Sweden, responsible for the chemicals to denature fuel in Sweden. The customs authority also received information about the Swedish customs classification of the fuel as an energy product under CN code 3824 90 98 99 in a Binding Tariff Information, BTI (as in La Spezia).

This lead to a reclassification of the fuel in Madrid, and when it was classed as a fuel, the product was totally exempted from tax as all alcohol used for fuel in Spain is tax exempted. EMT received a non-registered trader licence for the fuel and then began the fuel order process. Everything was ready at the end of March and the buses have operated since April 2007.
Bioethanol has a long history in Sweden. The first buses were introduced in the late 1980s. Since then a Swedish standard for the bioethanol part of the bus fuel has been developed. The bioethanol fuel for buses is exempted from tax (all bioethanol used for fuel is exempted from tax). The bioethanol buses are almost exempted from the yearly road tax, it is about €25 instead of €2500. 127 bioethanol buses and 5 fuel stations were introduced in Stockholm within the BEST-project. There were no problems reported in connection with the introduction of the bioethanol buses in the depot, even if the operators in charge of the traffic in these areas had not used bioethanol before. The bus drivers and mechanics received introductions from Scania with regards to the special issues connected to bioethanol buses. The funding of the 127 buses has been very important for SL to get closer to the goal of 50 percent biofuels in the bus fleet by 2011. It has also provided an opportunity to receive study visits from all around the world. The number of visits has increased very fast since the beginning of BEST to around 2 international visits per month or even once a week in some periods.
Regulations for fuel stations

Bioethanol fuel station for buses, Stockholm, Swebus fuel station, photo SL

Bioethanol fuel is a class 1 flammable liquid and must be handled like petrol, i.e. highly flammable compared to diesel which is classified in the lower hazard class Flammable. Everyone that wants to set up a fuel station for bioethanol fuel in Sweden has to present a risk analysis to the authorities that shall be included in the application for a building permit. The basis for an application for authorisation should always be an assessment of the risks of fire and explosion and the likely injuries and damage that could occur.

The bioethanol bus fuel station has to be built outside (the same requirements as for petrol). It also has to be equipped with a fire extinguisher, according to the regulations from the Swedish insurance company.

Bioethanol bus in Sao Paulo

According to the plans in BEST project, the bus in São Paulo should have started its service in 2007 but bureaucratic problems delayed the local demonstration activities. The involvement of several important companies and stakeholders was necessary to pave the way for a successful implementation with long-term impact on the public transport sector in Brazil and Latin America. The major long-term goal is to raise significant awareness about the promising ED95 technology. However this was only possible through several agreements that need to pass through the internal and legal departments of several local demonstration partners.

Another barrier was the agreement in view of the fuel additive to be imported from Sweden that caused further delays within the local demonstration activities of the BEST Project. The contractual and legal requirements of a large scale importation of ignition improver from SEKAB turned out to be another issue to be solved. The import of fuel additive also included financial and fiscal issues as the bus company is a public company that is not allowed to acquire the fuel directly.

The acquisition of two other ED95 buses for the local demonstration activities in São Paulo was not feasible within the remaining timeframe of the BEST project.

Problems regarding the supply and provision of ED95

The partners of local demonstration activities - BR Distributor and Petrobras - were both involved in the supply and provision of ED95. Petrobras was responsible for importing ignition improver from SEKAB while BR Distributor was responsible for the blending procedure and distribution of ED95.
Within this process, serious problems between SEKAB and Petrobras/BR occurred, as the additive is patented by SEKAB, who also owns exclusive rights of the additive production process. It was necessary to negotiate an official declaration from Petrobras that BR is one of its subsidiaries in order to overcome legal barriers.

At the beginning of the BEST project, the first batch of ED95 was imported by Copersucar in 2007 in order to start the demonstration activities. The amount comprised 9 Intermediate Bulk Containers of 950 litres each. The second batch of another 9 containers of ED95 was imported by Scania to continue the activities in 2008. Due to the limited availability of ED95 fuel, it was necessary to reduce the bus demonstration to 100 kilometers per day. As the amount of ED95 fuel was only 700 litres by the beginning of September 2008, the bus operator EMTU informed all partners that the bioethanol bus needed to stop operation until the new batch of ED95 fuel arrived.

On 10 September 2008, a high level meeting was scheduled between Scania Latin America, CENBIO and the Metropolitan Urban Transport Company EMTU in order to discuss several issues including the delay in ED95 supply. At the meeting it became clear that the ignition improver for the ED95 formulation had already been imported to Brazil. However, the specialists preparing the ED95 blend did not receive instructions from BR on time, as the necessary Material Safety Data Sheet for the blending procedure was not available. This was probably a problem of internal communication, as all necessary information was provided by SEKAB. Nevertheless it caused another delay of the demonstration activities.

The bioethanol fuel station

In March 2008, Petrobras provided a fuel tank with automatic meter in order to perform accurate measurement of the ED95 fuelling process. As the equipment was previously used to deliver biodiesel, it was not used, in order to prevent engine damages that could be probably caused by biodiesel residues.

After further negotiations it was achieved to get a new fuel tank with proper equipment. Finally, the fuel tank was replaced on 25 August 2008. The new fuel tank is similar to the first one in size and mechanical characteristics, but it is in perfect condition for the ED95 demonstration activities. As it was previously filled with petrol, there are no problems. The partner of local demonstration UNICA provided 5000 litres of bioethanol and pumped it through the pipes and the tank to remove potential petrol residues.
Introduction of BEST bioethanol buses in Nanyang

The demonstration of high blends of fuel bioethanol and bioethanol buses was new in Nanyang and in China. Nanyang planned to introduce four bioethanol buses within the BEST project.

There were no problems in providing fuel bioethanol in Nanyang. However, Nanyang encountered the following problems in implementing the bioethanol bus demonstration at the beginning of the project. The main problems were:

- No regulations for the ED95 fuel;
- No regulations and safety regulations for the fuel station;
- No commercial bioethanol buses in Chinese market;
- High price of Scania buses;
- High import tariffs for the bioethanol buses and ignition improver additive.

Solution

At the start of the project, Nanyang had extensive dialogue with Scania about the delivery of buses. However, the price of a Scania bioethanol bus is 10 times the price of a conventional petrol bus produced in China and Nanyang could not afford to purchase the Scania buses.

Scania and Nanyang agreed on a leasing contract instead. However, it turned out that the Chinese Government did not exempt the bus from import duty and VAT (approx. €100,000) was too expensive for the project. Another obstacle was that there was no ignition improver produced in Nanyang. This meant that imports subject to high duties were required, leading to an escalation of costs. Moreover, the operator of the buses was very worried about the continuous supply of the ignition improver.

As a consequence, Nanyang had to give up the idea of demonstrating Scania buses. Instead, the site contacted the Chinese auto company Dongfeng. Dongfeng has researched on bioethanol buses for many years, in cooperation with Tianjin University and other research centres. The company has a ‘Bioethanol buses research and demonstration base’ in Shiyan City, Hubei Province, which is about 250 km from Nanyang. An agreement was reached and Dongfeng delivered the first bioethanol bus to Nanyang in December 2007. The second bus was delivered to Nanyang in March 2008. These buses make use of a different technology to the Scania buses, as they are dual-fuel buses based on the spark-plug engine. The buses need petrol during start-up, but switch over to bioethanol E100 soon after. The work in Nanyang led therefore to the market introduction to a totally new type of bioethanol vehicle.

The Dongfeng bioethanol buses use E100 as fuel. No additive is needed. E100 is provided directly from Tianguan Group, the bioethanol producer. In China, it takes a long time to apply the authorisation of setting up a fuel station, as many municipal and provincial government agencies are involved. To support BEST, a pump was set up near the bioethanol plant and fuel (E100) is transported to the pump through pipeline.
Conclusions about the introduction phase

The experiences of the different sites show that it is important to contact local authorities as early as possible in the process of establishing bioethanol bus services. In the process, experience from other countries where the rules and regulations are in place can be very helpful.

Customs authorities had different ways of classifying the bioethanol fuel, creating a lot of difficulties regarding tax issues and tariffs. When the authorities in EU countries received information that the Swedish customs authority has issued a Binding Tariff Information, BTI, for the fuel bioethanol under CN code 3824 90 98 99, the problems were solved. A BTI is legally binding in all member states and therefore must be used in all countries. It means that a company that wants to use bioethanol for the buses applies for a license to receive the fuel in a tax warehouse, or become a registered trader or a non-registered trader for the fuel. The companies apply for the license from their local customs and tax authorities.

The level of tax on bioethanol can also be a great obstacle. It is up to different countries to apply a tax exemption or tax reduction on the fuel. In Italy, bioethanol is taxed as diesel whilst in Spain it is tax exempted, because Spain has exempted all alcohol used for biofuels from tax until 31 December 2012. The fuel is exempted from tax in Sweden as well. In Rotterdam, the tax is as high as for diesel and incentives are given to buses running on natural gas or LPG, which meant that it was impossible to get any interest from the operators to run bioethanol buses. See more about tax legislation in the EU in Annex 4.
Bus drivers and mechanics – important for success

Bus drivers are very important for successful introductions of new technologies. Many drivers have long experience from driving diesel buses and have to be properly introduced to the new technology. Drivers also respond to questions from passengers and have a key role in spreading knowledge and experience about the new technology. Mechanics are also very important and have to be given a thorough introduction to the new technology and how to maintain the buses.

All drivers and mechanics were given an introduction to the bioethanol buses and technology by Scania and Dongfeng (in Nanyang) and the company where they were employed. They had the possibility to drive the buses before they started running on timetable. The views of the drivers and mechanics were followed up through questionnaires at all sites.

Drivers

Within BEST, a survey was carried out among drivers of bioethanol buses. 91 drivers in Italy, Sweden, Spain and Brazil answered a questionnaire (13 in Italy, 54 in Sweden, 15 in Spain and 9 in Brazil). Most of the drivers had driven buses for longer than 5 years, 13 had been driving buses for more than 30 years.

For how many years have you been a bus driver?

Opinion towards bioethanol buses

The drivers answered questions about their opinion towards bioethanol buses before the project and during the project. The majority of the drivers were very positive or rather positive both before and during the project, 72 percent before and 70 during. Both the numbers of drivers that were very positive and very negative increased during the project, even though the change was very limited. Very positive increased from 40 to 44 drivers and very negative from 0 to 3 drivers.
Attitude to drive ethanol buses

There were some differences among the four countries. In Italy, Brazil and Sweden the majority of the drivers had a positive opinion before the project, i.e. were very positive or rather positive. In Italy it was 92 percent, in Brazil 100 percent and in Sweden 83 percent. In Spain it was 6 drivers that were very positive or positive (40 percent) and 7 drivers that were neither/nor (47 percent).

During the project, the drivers in São Paulo became even more positive. 5 drivers went from rather positive to very positive. In Italy the drivers stayed the same and in Sweden and Spain the drivers became slightly more negative. A large majority was happy about the buses.

Comparison between bioethanol buses and diesel buses

The drivers also answered questions about the performance of the buses compared to diesel buses. They were most positive to the lower emissions and most negative to the deteriorated acceleration. Many drivers were also positive to the smell, which they thought were better with bioethanol buses, but at the same time quite a big group thought the smell were worse.

In respect to the following statements, are ethanol buses in your opinion better, equal or worse than conventional diesel buses?
One can see some differences in the answers from the different countries. In Brazil the drivers thought that all aspects of bioethanol buses were better than or equal to diesel buses. In Spain the number of drivers that thought the acceleration, smell and speed were worse in bioethanol buses were larger than the numbers who thought these factors were the same or better. In Italy 5 of 13 drivers thought that the acceleration was worse. Otherwise, the drivers found the bioethanol buses better or equal compared to diesel buses. In Sweden there was also a group of drivers that thought acceleration, speed and smell were worse in the bioethanol buses than diesel buses; Acceleration 27/54, speed 16/54 and smell 13/54.

**Mechanics**

Within BEST a survey was performed among mechanics of bioethanol buses. 19 mechanics in Sweden, Spain and Brazil answered a questionnaire (13 in Sweden, 4 in Spain and 2 in Brazil).

**Opinion towards bioethanol buses**

The majority of the mechanics were very positive or rather positive towards bioethanol buses both before and during the project, 53 percent before and 63 during. Both the number of mechanics that were positive and those that were negative increased during the project, even though the change was very limited. Very positive increased from 3 to 4, rather positive from 7 to 8 and rather negative from 0 to 2.

![Attitude chart](chart.png)

**Comparison between bioethanol buses and diesel buses**

The mechanics also received questions about the performance of the buses compared to diesel buses. As with the drivers, mechanics were most positive to the lower emissions and most negative to the reduced acceleration.

About half the number of the mechanics thought that the convenience, duration and costs for maintenance were worse with bioethanol buses compared to the diesel buses. However, 3 mechanics thought that the convenience was better and 2 mechanics thought that the duration and costs were better.
In respect to the following statements, are ethanol buses in your opinion better, equal or worse than conventional diesel buses?
Passenger surveys

Passenger surveys were conducted in Nanyang, Madrid, São Paulo and Stockholm. The questionnaires in the cities did not contain the same questions so the results are presented for each city. One conclusion from the different surveys is that the majority of the respondents were very positive to bioethanol buses.

Nanyang

In Nanyang the results are based on 50 respondents. A large majority of the passengers were satisfied with the performances of bioethanol buses when starting, accelerating, absorbing shocks, climbing ramps or hills, braking, etc. Most of the passengers were impressed and satisfied with the design and environment of the bus. 98 percent of the responders showed their interest to take the bus again.

The majority of the respondents were concerned about climate change and CO\textsubscript{2} emissions. All of them accepted bioethanol as a clean fuel and supported the government’s demonstration of new energy. More than half said that they will recommend bioethanol vehicles to their friends. From the general information we can see most of the respondents were young people (78 percent are less than 50 years old). This shows that more and more young people, who are the main consumers of cars in China, are concerned about the environment and fuel issues. Fuel bioethanol was accepted as clean fuel by them. This indicates potential development of bioethanol vehicle in China.

Madrid

The questionnaire in Madrid had 336 respondents of which 64 percent were female and 36 percent were male.

Knowledge and satisfaction

Half of the users knew about the use of bioethanol as fuel on the bus line. Users who took the bus often had a higher knowledge about the bioethanol fuel than infrequent bus users.

Focusing on users who knew they were travelling on a bioethanol bus, most of them got this information from the big stickers on the bus, rather than through other ways of information.

Assessing differences in quality service of bioethanol run buses (opposite to other fuel sources), 90 percent of those polled did not find any differences, 5 percent found the service quality worse and 5 percent thought that the bioethanol buses run better.

Most of positive perceptions focused on less pollution and smoother driving compared to conventional diesel buses. The negative perceptions focused on increased noise. The smell was found to be both negative and positive by the respondents. The variable age of respondents was linked to perception, with higher percentages of negative answers from people older than 60.

General knowledge and opinion on bioethanol use

58 percent of those polled knew about bioethanol as an alternative fuel to petrol, and 53 percent found some advantages, in opposite to 5 percent who found some disadvantages. Once again, age had significant influence on this knowledge (less knowledge for people older than 60).

The most frequent answers about advantages were less pollution (53 percent) and the most frequent for disadvantage were that it increases use of arable land (34 percent) and that it affects world food crises. The latter was in focus for the biofuel debate in Spain when the questionnaires were distributed.
São Paulo

Bioethanol has been used as automotive fuel for light vehicles in Brazil on a large scale since the 1970s, meaning the fuel itself was not new to the bus passengers. However, bioethanol is seldom used in heavy vehicles. 202 passengers were interviewed onboard of the bus in São Paulo. 64 percent of the respondents didn’t know the bus ran on bioethanol, even though the bus looked very different to other buses in the area. A large majority, 82 percent were aware that diesel creates more pollution than bioethanol and 95 percent of the respondents wanted the diesel buses to be replaced by bioethanol buses. The same number supported the city’s work to replace diesel buses and a majority (62.3 percent) were optimistic of very optimistic (25.3 percent) about the use of bioethanol in public transport.

The use of bioethanol in urban public transport achieved a good approval from passengers. The introduction of a new technology of compression ignition engines and its usage in public urban transport is supported by the people who were interviewed as part of the BEST Project.

Stockholm

The Stockholm Public Transport Authority regularly sends out questionnaires to a number of their passengers. In May 2009, two questions on bioethanol fuel were included in the questionnaire which was answered by 1104 persons. 72 percent of these knew about the bioethanol buses in the Stockholm bus fleet. 82 percent thought the introduction of bioethanol buses in the fleet is very good.

La Spezia

Customers were able to make comments in the log book onboard the buses. Passengers perceived the buses as comfortable and elegant. It is clear that the buses made the passengers curious. The green colour, which makes them completely different from the other buses in service, pushed many people to ask for information and to positively comment the decision to use bioethanol.

At the same time, the green colour became a problem for some, especially in the very first days. Some were not sure whether the buses were in service or not. Many of the comments were very positive. One female customer was astonished to learn her bus ran on bioethanol and spontaneously exclaimed it was “wonderful!”

One driver noted in the log book that “I was about 20 minutes late but when I reached the bus stop, people did not get angry but were favourably impressed by the buses, their beauty and comfort”. Some passengers have asked ATC to publish information about bioethanol and the benefits of its use.
Results and function of the bioethanol buses

After bureaucratic barriers were overcome, the buses went into service in all sites. All the buses have run as planned and maintained the same levels of availability as the other buses in the bus fleets at the five sites. The fuel use per km was monitored for three buses at each site (less when there were fewer buses). The maintenance need and cost were followed and compared with diesel buses. It was intended to compare bioethanol buses with the same type of Scania buses with diesel engines, but this has only been possible in Sao Paolo. At all other sites it was impossible to find comparable Scania diesel buses. In Stockholm for example, there are no more investments in new 12 meter diesel buses. La Spezia has no Scania diesel buses and have instead compared with the other diesel buses.

The buses in the test that ran on ED95 used sugar cane bioethanol. Sekab has set up a limit for the lowest CO$_2$ eq-efficiency of sugar cane bioethanol they buy. This is done within the project “Verified sustainable bioethanol” (more information can be found in D 4.20 “The BEST experiences with distribution of bioethanol for vehicles – BEST WP4 Distribution”). The minimum level is set to 77 percent reduction of CO$_2$ eq over the lifecycle for ED95.

The Dongfeng buses have used E100 from produced in China. The feedstock is not known to the BEST project.

Fuel consumption varies considerably depending on the kind of traffic. The fuel consumption of buses that operated in heavy city traffic (Madrid) and on hilly routes (Sao 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 or 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 Sao Paolo have 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.

<table>
<thead>
<tr>
<th>Type of bioethanol bus</th>
<th>Site</th>
<th>Reporting period</th>
<th>Number of ED95 buses included in data collection</th>
<th>Total distance travelled (km)</th>
<th>Total ED95 usage (l)</th>
<th>Litre ED95/km</th>
<th>kWh/km</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scania bus</td>
<td>Stockholm</td>
<td>0801-0812</td>
<td>3</td>
<td>238965</td>
<td>175948</td>
<td>0.74</td>
<td>4.39</td>
<td>Suburban traffic.</td>
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<td>La Spezia</td>
<td>0701-090319</td>
<td>3</td>
<td>400 000</td>
<td>237000</td>
<td>0.59</td>
<td>3.51</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Beijing</td>
<td>0712-0812</td>
<td>1</td>
<td>5725</td>
<td>3862</td>
<td>0.67</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Scania chassis, local bodywork</td>
<td>Madrid</td>
<td>0701-0812</td>
<td>5</td>
<td>392332</td>
<td>380147</td>
<td>0.97</td>
<td>5.74</td>
<td>City line, heavily used.</td>
</tr>
<tr>
<td></td>
<td>São Paolo</td>
<td>0801-0808</td>
<td>1</td>
<td>12244</td>
<td>17100</td>
<td>1.32</td>
<td>7.82</td>
<td>City line, hilly topography</td>
</tr>
<tr>
<td>Dongfeng E100 bus</td>
<td>Nanyang</td>
<td>0712-0812</td>
<td>2</td>
<td>40600</td>
<td>19053</td>
<td>0.47</td>
<td>2.75</td>
<td>Dongfeng E100 bus (otto technology): The bus, with 19 seats, smaller than the Scania bus.</td>
</tr>
</tbody>
</table>
Maintenance and function of the buses

The long 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 are the change of motor oil and oil filter. Change of fuel injectors are required at every second service, as pollutants formed in the engine can get stuck in the injector, causing a fall in injection pressure.

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

No significant problems were reported in La Spezia. ATC followed the service intervals recommended by Scania. 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 missed 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 including local considerations into vehicle design.

In Madrid, the bus operator EMT found that the main difference between bioethanol and diesel was the increased need for maintenance, every 10,000 km for bioethanol and 24,000 km for diesel.

Main operations on the bioethanol bus:

- Motor Oil and Filter replacement frequency: 10,000 km
- Prevent injector circuit replacement: Each 60,000 km, due to high bioethanol corrosion power.

Except for these differences in the engine maintenance, the rest of the maintenance was the same as for other Scania buses. EMT reported that scheduled maintenance costs for bioethanol buses were on average €69.59 per 100 km in 2007 and €58.66 per 100 km in 2008 compared to €39.05 per 100 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 station also worked effectively throughout BEST.

Within BEST, collection of maintenance data was not possible in Stockholm, as bus operators performing service for Stockholm Transport 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 failure may occur if filters clog. These risks are reduced with regular maintenance.

Dongfeng bioethanol bus possesses the same reliability and maintainability as the conventional buses. The average breakdown rate is twenty thousand kilometers. Generally, the maintenance is ten thousand kilometers per time, costing 1500RMB per time

Costs

The price for the Scania bioethanol bus was about 10 percent more than the price of a conventional diesel bus. The big difference in cost for driving bioethanol buses was connected to the increased cost for maintenance and on the taxation of the bioethanol. The demonstrations in BEST show that the costs are very different from site to site.
Comparison with diesel buses

The evaluation also aimed at comparing the fuel consumption bioethanol buses with diesel buses. This proved to be very difficult as few of the sites have comparable Scania diesel buses. Sao Paolo had a Scania diesel bus (slight difference in cylinders and size (6 cylinders and 9.11 L)) that followed the bioethanol bus on the same line. La Spezia has compared with other Iveco and Bredamnarini diesel buses in the fleet. The result in consumption per volume and energy is shown in the table below. The results show it to be very difficult to find conditions that are exactly the same to enable comparison of the diesel and bioethanol bus. A lot of factors can influence the result: number of passengers, driving style, and volume of traffic, route etc. A real comparison would probably only be made at a test site where the conditions can be set to be exactly the same!

<table>
<thead>
<tr>
<th>Site</th>
<th>Fuel consumption bioethanol</th>
<th>Fuel consumption diesel</th>
<th>Difference in energy use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L bioethanol/km</td>
<td>kWh/km</td>
<td>L diesel/km</td>
</tr>
<tr>
<td>La Spezia</td>
<td>0,59</td>
<td>3,50</td>
<td>0,43</td>
</tr>
<tr>
<td>Sao Paolo</td>
<td>1,32</td>
<td>7,82</td>
<td>0,7</td>
</tr>
</tbody>
</table>

Bioethanol buses - lower CO₂ emissions

The reduction of CO₂ from using bioethanol instead of diesel or petrol depends on the feedstock used and how the fuel is produced. The fuel used in the demonstration with the Scania bus was made from Brazilian sugar cane. A fleet of 1,000 bioethanol buses (with each bus running 70,000 km per year using 0,4 l/km) emits 85,000 ton fossil CO₂ per year (3.04 kg/l diesel from well-to-wheel, Concawe, Well to tank report Version 2 c, mars 2007). If all these buses were running on bioethanol instead (using 0.67 l/km), fossil CO₂ emissions would be reduced to 13,000 ton (0.27 kg/l bioethanol from well-to-wheel), a reduction of 72,000 ton fossil CO₂ per year.

The bioethanol buses in the demonstration meet the requirements of Euro 4. The bioethanol has a positive effect on emissions of particles, PM, which are low even without particle filters.
Market development

In Stockholm and the BioFuel Region in Sweden, bioethanol buses have run since the mid-1990s. Knowledge about the possibility to drive on bioethanol in diesel engines had not been spread outside Sweden so the market was very small. When BEST started, there were about 250 bioethanol buses running in 9 Swedish cities but none outside the country. The cities that have demonstrated bioethanol buses within BEST have shown many other cities that it is possible to drive on bioethanol in heavy vehicles. The combination of increased knowledge, very high oil prices during the BEST-period and a strong focus on the climate issue has made the public transport sector look for other solutions than fossil diesel. This has made bioethanol an interesting alternative for Public Transport Authorities. According to Scania, who remains the only producer of bioethanol buses with a diesel engine, there have been a number of followers to the BEST sites:

### Bioethanol buses

<table>
<thead>
<tr>
<th>City</th>
<th>Number of buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nottingham, UK</td>
<td>3 buses</td>
</tr>
<tr>
<td>Oslo, Norway</td>
<td>20 buses</td>
</tr>
<tr>
<td>Milan area, Italy</td>
<td>3 buses</td>
</tr>
<tr>
<td>Slupsk, Poland</td>
<td>5 buses</td>
</tr>
<tr>
<td>Namur, Belgium</td>
<td>3 buses</td>
</tr>
<tr>
<td>Östersund, Sweden</td>
<td>20 buses</td>
</tr>
<tr>
<td>Stockholm, Sweden</td>
<td>34 new bioethanol buses during 2008 and 6 bioethanol hybrid buses</td>
</tr>
</tbody>
</table>

### Bioethanol trucks

Scania has recently also introduced bioethanol fuelled distribution and waste trucks. The trucks have the same engine as the buses.

<table>
<thead>
<tr>
<th>City or company</th>
<th>Number of trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROTRA, The Netherlands</td>
<td>1 bioethanol truck</td>
</tr>
<tr>
<td>RagnSells, Stockholm, Sweden</td>
<td>1 bioethanol waste truck</td>
</tr>
<tr>
<td>Schenker, Stockholm, Sweden</td>
<td>1 bioethanol truck</td>
</tr>
<tr>
<td>Brazil</td>
<td>2 bioethanol trucks</td>
</tr>
<tr>
<td>Oslo, Norway</td>
<td>1 bioethanol truck</td>
</tr>
</tbody>
</table>

### Bioethanol buses recommended to the C40 cities

The Clinton Climate Initiative provides strategic advice on how to reduce greenhouse gas emissions to the C40 Large Cities Climate Leadership Group, in which 40 of the world’s largest cities are represented. The Clinton Climate Initiative identified bioethanol buses together with hybrid buses and fuel cell buses as a way to reduce emissions from public transport, leading to increased knowledge about bioethanol bus technology around the world.
**Future in the BEST cities**

The bioethanol bus sites in BEST will all keep their buses after the end of BEST. Stockholm will continue to invest in bioethanol buses, together with biogas buses, in order to reach the goal of 100 percent renewable fuels in the bus fleet 2025. Madrid will continue to drive the five buses but because of the complicated bureaucracy that surrounds the fuel (applications for tax reduction every time the fuel station is refilled) they will only maintain five buses for now.

Nanyang will continue to drive the BEST buses after the project. The government's policy on bioethanol vehicles will decide whether to invest in more buses in the future. ATC in La Spezia would like to continue to use and drive the buses, and they also want to invest in more buses, but the problem is the price of ED95, which is more expensive than diesel at the moment. ATC can not justify additional investments in ED95 buses if the price of ED95 does not decrease.

The BEST Project activities in São Paulo are in progress. The bioethanol bus is being operated normally and BEST is working with partners for inclusion of another bioethanol bus. The BEST project partner Scania recently provided a second bioethanol engine of the new type (DC9 E02 model with 270 hp and Euro 5 EEV emission standard). The new engine and chassis are already at “CAIO Bodywork Manufacturer” to be assembled. The construction of the body work will be finalized in the first week August 2009. Within the further demonstration activities, an additional agreement among all local project partners - including the Brazilian Environmental Agency – CETESB and the Environment Secretariat of São Paulo - is under preparation. Finally, in May 2009, a new law regarding climate change was approved by the São Paulo Council Chamber, which foresees among other things, that all captive bus fleet in São Paulo (roughly 15,000 buses) will be substituted by electrical buses or bioethanol buses by year 2018.

**Future for bioethanol buses**

Bioethanol buses are available today and function very well. Bioethanol fuel in the bus fleet can lead to large reductions of CO2-emissions from public transport. BEST has led to increased knowledge of bioethanol buses around Europe as well as in Brazil and China. BEST has also led to the introduction of a new type of bioethanol bus, based on the otto-engine, in China. In the middle of 2008, Fiat Powertrain Technologies announced that they will launch an bioethanol-powered engine in Brazil by 2010 for use in trucks and agricultural machinery A small amount of diesel would be needed to combust the bioethanol, but the two fuels would not mix until injected into the combustion chamber from separate tanks, which developers say avoids dangers inherent in mixing the fuels.

The arrival of more producers of bioethanol buses will be an important step forward for the use of bioethanol in heavy vehicles. One barrier for a broader introduction might have been the fact that there has only been one producer of bioethanol buses as well as one producer of the bus fuel. The non-existent competition can be a problem for local authorities and public transport authorities when they procure public transport services or vehicles.

Scania is now introducing the 3rd generation of bioethanol engines. One of the aims with the new engine is to decrease the need for maintenance which will lower the driving costs. Sekab is also involved in the development of an improved fuel for the bioethanol engines (see in BEST WP 4 Distribution, report D 4.20). The new bioethanol engine generation from Scania meets the emission standard of EEV without particle filter.
Scania has also introduced the world’s first fleet demonstration of bioethanol hybrid buses in cooperation with Stockholm Public Transport Authority and Swebus. This bus includes serial hybrid technology with a super capacitor as the energy storage. The technology is expected to reduce fuel consumption by 25 percent. Six bioethanol hybrid buses and one reference bus will run between 2009-2011. Another important step taken by Scania is that they now offer bioethanol driven waste trucks and distribution trucks. When the fleet still is small these can use the already established bioethanol fuel station in the bus demonstration cities, which reduces the costs for the test.

The future for the bioethanol buses from Dongfeng is not clear at the moment. As the market for E85-E100 is widespread, more than ED95 at the moment, there are large possibilities for Dongfeng to find markets outside China.
Recommendations

Policy makers and politicians
Cities and regions in Europe can play a major role in achieving the necessary reduction of greenhouse gas emissions. The public transport system is a vital part of the solution and it is therefore important to introduce alternative fuels such as biofuels to this sector. Public transport bus fleets are depot-based which reduces the need for a large number of fuel stations.

The demonstrations in BEST show that use of bioethanol in diesel engines can be one important step towards sustainable public transport. Bioethanol buses are an efficient and convenient way to reduce emissions of greenhouse gases from public transport. The problems BEST sites encountered in the introduction phase can be reduced through thorough preparation and success depends on having an available regulation system and an adapted taxation policy which includes:

- Regulations for bioethanol fuel stations
- Regulations for storing bioethanol fuel
- Regulations for importing bioethanol
- Decision that bioethanol is a fuel and shall be handled as a fuel in tax and tariff systems
- Tax policy that makes the use of bioethanol bus fuel competitive with diesel

When the buses and the fuel stations are in place they function as any other buses apart from the need for extra maintenance.

Cities can also be an important driving force for producers of bioethanol buses, as the larger the market, the more interesting it is for other producers. The technology exists so the ball is with decision-makers to take the necessary decisions for a biofuelled bus fleet.

User experiences from other cities and countries in the EU
The BEST sites have had good support from the Swedish experiences, especially for the classification of ED95 as an energy product under CN code 3824 90 98 99, which means that bioethanol cannot be classified as drinking alcohol. The bus fuel has also got a Binding Tariff Information in Sweden which means that the same tariff classification can be used in any other EU member state. Other kinds of experiences connected to use and maintenance can be transferred through study visits to the BEST sites.

Tax by fossil CO₂ emissions
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 by energy content. Therefore, a bioethanol bus requiring 70 percent more fuel by volume will pay 70 percent more tax than a diesel bus. This was the case in La Spezia, where bioethanol and diesel are both taxed per litre. The situation becomes even more difficult when, as in The Netherlands, the tax for bioethanol is as high as for diesel and incentives are given to buses running on natural gas or LPG.

BEST findings suggest that tax exemption for renewable fuels for buses or taxing bus fuels by energy content and fossil CO₂ emissions may be an appropriate instrument if the market for alternative fuels such as bioethanol is to grow.
Public transport authorities can facilitate introduction

The higher costs connected to taxes, a single supplier of the bus and increased need of maintenance 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 from public transport. However, without political decisions that overcome cost factors and resolve tendering dilemmas, it is difficult for transport operators to introduce bioethanol buses and ED95. This problem is likely to increase if service delivery is sub-contracted to private operators, who are primarily motivated by cost factors and may lack the incentive to “voluntarily” introduce more expensive bioethanol buses to their fleets.

When politicians decide to choose 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 procure services from operators in competition. When PTAs own the bus fleet, buses are purchased through the normal procurement procedure.

When PTAs procure services in competition 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.

Therefore, PTAs can support operators by, for example, owning buses and fuel stations 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 buses have a lifespan of approximately 12 years.
Annexes

Annex 1 Bus lines

The bus lines used by the buses in La Spezia
Here below, please find the lines on which the buses have run during the first 9 months of 2007:

- Line La Spezia – Sarzana – Carrara (return):
  Flat route, about 5 km, within the whole urban borders and suburbs; light gradient, about 1.5 km, at the edge of the territory of the Municipality of La Spezia; again flat route, about 20 km, within the Municipality of Sarzana and Carrara;

- Line La Spezia – Fornola – Sarzana (return):
  Flat route, about 5 km, within the whole urban borders and suburbs; light gradient, about 1.5 km, at the edge of the territory of the Municipality of La Spezia; again flat route, about 10 km, within the Municipality of Sarzana;

- Line Sarzana – Lerici – Station:
  Initially flat route, 2 km, within the Municipality of Sarzana; afterwards, light gradients alternate with descents and short stretches of plain for about 10 km within the Municipality of Lerici; finally a flat route again, about 6 km, within the Municipality of La Spezia;

- Line La Spezia – Bocca di Magra:
  Flat route, about 6 km, within the whole urban borders and suburbs; afterwards, gradients alternate with descents for about 8 km, within the Municipality of Lerici; finally a flat route again, about 10 km, within the Municipality of Ameglia (Bocca di Magra);

From October 2007 until today the buses have run on the same line: as said before, the line “SA” which connects La Spezia to Sarzana running, for a short stretch, on the slip road:

- Line “SA”: La Spezia, Piazza Caduti del Lavoro (nearby the central railway station) – slip road – Sarzana (return):
  The route, almost entirely flat, stretches for 11 km within the urban borders of La Spezia and Sarzana, for 8 km on the above mentioned slip road. (Please find below attached the route map of line “SA”, with its main stops).
The route map of line “SA”, with its main stops.

The bus line in São Paulo

The following picture shows the segregated lane layout.

Picture 1: Jabaquara- Sao Mateus bus lane shown in blue.

The bus route in Madrid

The area where the Stockholm buses operate
Annex 2 Taxes and Customs Tariffs in EU

Taxes
The Energy Tax Directive\(^6\) set minimum taxes for different fuels, but Member states are free to charge higher taxes and most Member states also do. Taxes are set by litre and fuels that are not regarded as mainstream fuels (e.g. bioethanol) should be taxed in accordance to what mainstream fuel they are replacing. Hence E85 should be taxed as petrol and ED95 should be taxed as diesel. As Bioethanol contains less energy per litre than both petrol and diesel, this set-up gives a much higher tax per kilometre driven for bioethanol fuels than for fossil fuels.

The directive opens up for different tax levels for special use – e.g. commercial diesel and diesel for use in off-road vehicles or in the agriculture is normally lower taxed than diesel for passenger cars. There are also several exemptions from the minimum levels – e.g. for diesel in the New member States, as they had very little influence on the negotiations of the Directive. In addition, Member states can apply for special tax exemptions for e.g. biofuels. Such exemptions has to be limited in time and amount and the Member state needs to show that there is no overcompensating and that this tax reduction is not violating the different EU-rules on State aid.

Customs tariffs
Imported Bioethanol is subject to import tariffs of € 0.192/litre for pure bioethanol and € 0.102/litre for denaturant bioethanol.

The different Member states have not harmonised their views on what is an acceptable level of denaturant. In some Member states blending petrol into bioethanol is a good enough denaturant and hence E85 can be imported at the lower custom tariff rate. However, in most member states with a lower tax for E85, this does not apply for imported E85, i.e. you may import to a lower tariff, but then you will not receive tax reduction.

The current specification of ED95 includes methanol as a denaturant, which would be regarded sufficient for many member states. Methanol is however forbidden as a denaturant in Brazil, which means that the bioethanol for ED95 must be imported as pure and hence need to pay the highest custom tariffs.

It is possible to receive an authorisation from the European Commission for “Processing under Customs Control” (PCC) which allows for blending a certain amount of E85 or ED95 outside EU and import it as “chemical product”, thus being able to use a custom tariff of 6.5 percent of the value, i.e. approximately €0.034/l fuel. Each company has to apply for an individual permit, limited to a certain amount of fuel and it has to be renewed yearly. 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 two 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 bioethanol as a fuel.

\(^6\) Directive 2003/96/EC
Annex 3 Review of WP2 Deliverables Data.
Collated and Presented in the same format by Mark Workman, Imperial College

The following reports were reviewed:

- D2.4 - A short report on 20 years of experience from bioethanol buses in the BFR Dated June 2007
- D2.01 / 2.02 - Experiences from introduction of Bioethanol Buses and bioethanol fuel stations dated June 2007
- D2.02 - Annual Report on function of bioethanol buses and fuel stations - La Spezia dated Feb 2009
- D2.02 - Annual Report on function, performance, maintenance and environmental effects of buses - Nanyang dated Dec 2008
- D2.02 - Annual Report on function of bioethanol buses and fuel stations - Sao Paulo dated May 2008
- D2.02 - Annual Report on function of bioethanol buses and fuel stations - Madrid Undated and unfinished
- EMT presentation given on 28th April to SGM in Madrid.
- D2.02 - Annual Report on function of bioethanol buses and fuel stations – Stockholm dated December 2008
- Spreadsheet of data from Stockholm Bus Fleets covering 2007 and Jan to June (inclusive) fuel and distance data.
- D2.3 - Experiences from bioethanol buses - drivers, users and mechanics in La Spezia dated December 2007
- D2.6 - Short report on experiences of bioethanol buses (maintenance, fuel use etc. etc) – Sao Paulo dated June 2008
- D2.07 - Report on experiences of bioethanol buses and fuel stations in Sao Paulo dated December 2008
- D2.07 - Experiences from bioethanol buses and fuel station report - Nanyang dated May 2009
- D2.07 - Experiences from bioethanol buses and fuel station report in Las Spezia dated M38

<table>
<thead>
<tr>
<th>Assessment Criteria</th>
<th>Stockholm</th>
<th>La Spezia</th>
<th>Madrid</th>
<th>Sao Paulo</th>
<th>Nanyang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baselevel Collected Data</td>
<td>Stockholm provided total fuel usage figures for 90 buses every 6 months January 07 to June 08</td>
<td>3 x Scania Omnilink buses. Data collected every fill up. Jan 2007 to April 2009 Delay in operations from Sep 06 (D2.01-02)</td>
<td>5 buses brief summary of fuel use and maintenance from April to December 2007 Delay in operations from Oct 06 (D2.01-02)</td>
<td>1 bioethanol bus summaries of monthly fuel use and detailed maintenance data. Dec 07 to May 08</td>
<td>2 bioethanol buses (E100) - estimate of fuel use and no quantitative maintenance information. Scania Bus in Beijing (Aug 08 to Dec 08 (D2.07))</td>
</tr>
<tr>
<td>No of Buses / Types of Buses</td>
<td>2114 total buses of which 424 Bioethanol Buses of which 127 EU &amp; BEST funded and data collected for 24 Low Entrance (LE) and 26 LE articulated.</td>
<td>Scania Omnilink Model. First ED95 buses adopted in Italy. 11.98m length bus (D2.02 p6)</td>
<td>EMT bought chassis from Scania and bodies by local builder Carsa (SGM Present’n) 12 m bus with standard EMT design (SGM Present’n)</td>
<td>Omnilink chassis and Euro 4 generation bioethanol engine 230 HP 9 L. from Sweden (no longer available by Scania) and body work in Brazil 12m Bus, AC 77 person capacity (D2.02 p10)</td>
<td>1st Dec 07 - petrol eng EQ6100-1 on hydrous bioethanol. 2 tanks uses petrol to start with and then bioethanol; 2nd Mar 08 - natural gas eng EQ6103PCN on dehydrated bioethanol - equipped with AC</td>
</tr>
<tr>
<td><strong>Distances Traveled</strong></td>
<td><strong>Bioethanol Used</strong></td>
<td><strong>Pumps Installed / Fuel</strong></td>
<td><strong>Routes Taken</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------</td>
<td>---------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 Low Entrance 3,267,985 km (Spreadsheet)</td>
<td>23 Low Entrance 2,104,976 L (Spreadsheet)</td>
<td>5 fuel stations Capacity 100, 150, 50, 50 and 50 m3 (D2.02 p7)</td>
<td>No. of routes throughout Stockholm.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate 240,000 (D2.02 p9) / 131 Ind 78,787 + 86,119 + 75,982 (D2.02 p10)</td>
<td>Aggregate: 160,000L D2.02 p13 @ €160,000</td>
<td>1 fuel station @ ATC Sarzana depot Jan 07 to Feb 09 8 x 20,000 L (160,000) D2.02 p9</td>
<td>Jan to Sep 07 4 diff routes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate 400,000 (D2.07 p9) Ind 120,092 +142,394 + 197,325 (D2.07 p10)</td>
<td>Aggregate: 237,000L D2.07 p13 @ €237,000</td>
<td>Jan 07 to Mar 09 12 x 20,000L 240,000L D2.07p14 - no problems.</td>
<td>Oct 07 to present same route (D2.02 p7-9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ind 125,872 + 149,172 &amp; 143,334 (Email 7 May)</td>
<td>82,712 L at a cost of €42,182.12 (D2.02 p1)</td>
<td>1 fuel station 15,000 capacity w. Consumption of 1000 L/day</td>
<td>All 5 on one line : Line 75.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Distance</strong> 168,800 Av 33,706 per bus between Apr to Dec 07 (D2.02 p1)</td>
<td>SGM Present’n 07 169,104 km (23,677 hrs) and 08 223,229 km (23,405 hrs)</td>
<td>Tank flow meter not available to measure vehicle consumption (D2.02 p13) Therefore adhoc method p 14</td>
<td>Segregated bus lane 33 km @ Av 20 km/h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10,834 km see table D2.02 p 12.</td>
<td>Dec to Aug 12,244 (Amalgamation of D2.02p11 and D2.07p11 data)</td>
<td>18,050 L (Amalgamation of D2.02p11 and D2.07p11 data)</td>
<td>100 km/d route for Dec 07 to July due to limited fuel availability (intended 300 km/d route.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Distances Travelled</strong></td>
<td><strong>Bioethanol Used</strong></td>
<td><strong>Pumps Installed / Fuel</strong></td>
<td><strong>Routes Taken</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 Low Entrance Articulated 3,541,303 km (Spreadsheet)</td>
<td>26 Low Entrance Articulated 2,982,447 L (Spreadsheet)</td>
<td>1 Pump near bioethanol plant and fuel transported via pipeline to pump (D2.07).</td>
<td>Dongfeng / Nanyang - Same route 15 km round trip for workforce at bioethanol plant. Sometimes guests from airport/ rly stn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate 240,000 (D2.02 p9) / 131 Ind 78,787 + 86,119 + 75,982 (D2.02 p10)</td>
<td>Aggregate: 160,000L D2.02 p13 @ €160,000</td>
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<td></td>
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<tr>
<td><strong>Distances Travelled</strong></td>
<td><strong>Bioethanol Used</strong></td>
<td><strong>Pumps Installed / Fuel</strong></td>
<td><strong>Routes Taken</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 Low Entrance 3,267,985 km (Spreadsheet)</td>
<td>23 Low Entrance 2,104,976 L (Spreadsheet)</td>
<td>5 fuel stations Capacity 100, 150, 50, 50 and 50 m3 (D2.02 p7)</td>
<td>No. of routes throughout Stockholm.</td>
<td></td>
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</tr>
<tr>
<td>Aggregate 240,000 (D2.02 p9) / 131 Ind 78,787 + 86,119 + 75,982 (D2.02 p10)</td>
<td>Aggregate: 160,000L D2.02 p13 @ €160,000</td>
<td>1 fuel station @ ATC Sarzana depot Jan 07 to Feb 09 8 x 20,000 L (160,000) D2.02 p9</td>
<td>Jan to Sep 07 4 diff routes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate 400,000 (D2.07 p9) Ind 120,092 +142,394 + 197,325 (D2.07 p10)</td>
<td>Aggregate: 237,000L D2.07 p13 @ €237,000</td>
<td>Jan 07 to Mar 09 12 x 20,000L 240,000L D2.07p14 - no problems.</td>
<td>Oct 07 to present same route (D2.02 p7-9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ind 125,872 + 149,172 &amp; 143,334 (Email 7 May)</td>
<td>82,712 L at a cost of €42,182.12 (D2.02 p1)</td>
<td>1 fuel station 15,000 capacity w. Consumption of 1000 L/day</td>
<td>All 5 on one line : Line 75.</td>
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</tr>
<tr>
<td><strong>Total Distance</strong> 168,800 Av 33,706 per bus between Apr to Dec 07 (D2.02 p1)</td>
<td>SGM Present’n 07 169,104 km (23,677 hrs) and 08 223,229 km (23,405 hrs)</td>
<td>Tank flow meter not available to measure vehicle consumption (D2.02 p13) Therefore adhoc method p 14</td>
<td>Segregated bus lane 33 km @ Av 20 km/h</td>
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</tr>
<tr>
<td>10,834 km see table D2.02 p 12.</td>
<td>Dec to Aug 12,244 (Amalgamation of D2.02p11 and D2.07p11 data)</td>
<td>18,050 L (Amalgamation of D2.02p11 and D2.07p11 data)</td>
<td>100 km/d route for Dec 07 to July due to limited fuel availability (intended 300 km/d route.</td>
<td></td>
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</tr>
</tbody>
</table>

**Bioethanol Used**

- **23 Low Entrance** 2,104,976 L (Spreadsheet)
- **26 Low Entrance Articulated** 2,982,447 L (Spreadsheet)

**Pumps Installed / Fuel**

- 5 fuel stations
  - Capacity 100, 150, 50, 50 and 50 m3 (D2.02 p7)
- Fuel Purchased from SEKAB

**Routes Taken**

- No. of routes throughout Stockholm.
  - Jan to Sep 07 4 diff routes
  - Oct 07 to present same route (D2.02 p7-9)
### Fuel Efficiency

<table>
<thead>
<tr>
<th>Rates L/100 km</th>
<th>23 Low Entrance 64.41</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26 LE Articulated 84.21</td>
</tr>
<tr>
<td></td>
<td>(Spreadsheet)</td>
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<tr>
<td></td>
<td>71.22 + 70.65 + 67.39 L/100km Av 69.72 (3 closely monitored bioethanol buses to compare w diesel buses) for 4 months - see below D2.02 p9)</td>
</tr>
<tr>
<td></td>
<td>(Aggregate: Av 59.8 (D2.02 p12)</td>
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<tr>
<td></td>
<td>Aggregate: Av 59.8 (D2.07p12) for 2007 and whole period Jan 07-Mar 09 59.1 L/100 km</td>
</tr>
<tr>
<td></td>
<td>Ind: 58.7 + 58.9 + 59.7 Email 7th May.</td>
</tr>
<tr>
<td></td>
<td>61 (D.3 p6)</td>
</tr>
<tr>
<td></td>
<td>49.36 (D2.02 p1)</td>
</tr>
<tr>
<td></td>
<td>SGM Presentat’n 08 100.47 L/100km 07 94.19 L/100km</td>
</tr>
<tr>
<td></td>
<td>Speed 07 9.58 km/h and 08 9.42 km/h</td>
</tr>
<tr>
<td></td>
<td>CONFLICT IN REPORTED DATA</td>
</tr>
<tr>
<td></td>
<td>Dongfeng 45 L / 100 km for both buses (D2.02 p10)</td>
</tr>
<tr>
<td></td>
<td>Scania (Aug to Dec 67.5L/100km (D2.07 p15)</td>
</tr>
</tbody>
</table>

### Cost €/km

<table>
<thead>
<tr>
<th>Price of fuel not known (D2.02)</th>
</tr>
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<tbody>
<tr>
<td>Fuel for ED95 0.99 €/L cf diesel 0.85 €/L (D2.02)</td>
</tr>
<tr>
<td>No incentives for biofuels (D2.07)</td>
</tr>
</tbody>
</table>

| No of maintenance services taken every 10,000 miles (D2.02 p1) |
| No maintenance services taken every 10,000 miles (D2.02 p1) |
| €42,183.12 (SGM Present’n) 07 €69.59 per 100 km 08 €58.66/100 km |
| Diesel €39.05/100km |
| Breakdown frequency 07:1.27 / 1000km 08: 1.31 / 1000km Diesel 1.62 / 1000km |
| No way of calculating maintenance costs but have tables of component failure, failure description & parts replaced/repairs (D2.02 p15-19) |
| Buses checked every week no bioethanol related problems (D2.02 p12) |
| Buses checked everyday, then every week and maintenance every month (D2.07 p12) |
| Scania (2.07) No problems other than routine maintenance |

### Maintenance Costs

| Articulated buses have more problems compared to non-articulated buses despite same engine type. |
| Problems with starting in very warm and cold temperatures and loss of power (D2.02 p7) |
| NK - Commercially Sensitive Data |

### Notes on Maintenance Data

| NK |
| Data not directly comparable statistics for breakdown. |

### Direct Comparison

| ED95 |
| Yes on same route and model |
| Tank flow meter not available to measure vehicle consumption (D2.02 p13) Therefore adhoc method p14 |

| Diesel |
| 38.37 + 31.72 + 38.39 L/100 km (Av 36.47) D2.02 p 12 no direct comparison available except for 6 buses of |
| Ye on same route and model - slight difference in cylinders and size |
Routes taken not disclosed but stated that all buses in comparison ‘from same area’

<table>
<thead>
<tr>
<th>similar characteristics and route. 43.4 L/100 km (36% Var)</th>
<th>(6 cylinders and 9.11 L). 70.27 L/100 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>(D2.3 p6) 47.6 L/100 km again not direct comparison.</td>
<td>See also D2.6p12</td>
</tr>
<tr>
<td>D2.07 p12 43.4 L/100 km</td>
<td></td>
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</tbody>
</table>

Notes:

1. **La Spezia Function problems (D2.02 p10):**

   Within 2007, out of a total of 353 days of service from the day of their registration, the buses were not available:
   - the 2001 bus: 106 days, of which 105 for bodywork problems following an accident, 1 for programmed maintenance;
   - the 2002 bus: 16 days, of which 7 for motor problems (lost of motor oil), 5 for problems with the disability service, 4 for programmed maintenance;
   - the 2003 bus: 24 days, of which 13 for bodywork problems following an accident, 11 for motor problems (lost of motor oil). (The programmed maintenance did not prohibit the vehicle from its schedule).

   In the first months of 2008 (1 January – 31 May), out of 152 days of service, the buses were not available:
   - the 2001 bus: 1 day for programmed maintenance;
   - the 2002 bus: 2 days for programmed maintenance, 1 for a problem with the disability service;
   - the 2003 bus: 1 day for programmed maintenance and 29 days for bodywork problems.

   List of interventions D2.02 p 11

   **From D2.07 report p10 :**

   Within 2008, out of 365 days of service, the buses were not available:
   - the 2001 bus: 29 days, of which 27 for engine problems, 2 days for programmed maintenance;
   - the 2002 bus: 2 days for programmed maintenance, 2 for a problem with the disability service;
   - the 2003 bus: 3 days for programmed maintenance and 29 days for bodywork problems.

   List of interventions D2.07 p11
Annex 4 Recommendations for handling of ED95

Recommendations from the Swedish Petroleum Institute for the safe handling of E85 fuel at petrol stations (the same is applicable for ED95)

More and more cars are now using bioethanol (E85) fuel. There are now several new installations at petrol stations around the country to meet the demand for E85 from the growing number of customers. And the number of E85 installations in petrol stations is expected to increase dramatically in the next few years.

The aim of these recommendations is to provide instructions on the specific measures that need to be taken, from a safety perspective, at petrol stations now selling E85. The basis for the recommendations is the risk assessment that was carried out on a comparison between the properties of E85 and petrol.

The recommendations have been compiled by the Swedish Petroleum Institute in consultation with the Swedish Rescue Services Agency, and are intended for use by the petrochemical branch and the municipalities in their role as authorising and supervisory authorities.

The Swedish Rescue Services Agency is of the opinion that if these recommendations are adhered to the handling of E85 will be safe and therefore meet the requirements of flammables and explosives legislation. If other technical solutions are opted for then the site owner must, by means of a specific risk assessment for the site, prove that the selected solutions will result in safe handling – from a fire and explosion perspective. As regards the establishment of new sites the recommendations can be followed straightaway.

Existing sites must as soon as possible be refitted in accordance with these recommendations, with regard to flame arresters, vapour recovery and depth gauging. The alterations needed at these sites to the materials and surface treatments used in order to follow the recommendations could from a risk perspective take some time.

Legal requirements

Authorisation is required for the handling of flammables at petrol stations. Authorisation granted for the handling of petrol does not automatically also apply to the handling of E85. A petrol station that sells petrol must, when wanting to also sell E85, also obtain authorisation for the handling of E85.

The basis for an application for authorization should always be a satisfactory assessment of the risks of fire and explosion and the likely injuries and damage that could occur. Sites intended for the handling of E85 must not be put into commercial use before they have been officially inspected and deemed to meet the technical requirements for safe handling. This of course also applies to the establishment of new sites that either handle just E85 or that handle both E85 and petrol.

E85 like petrol is a class 1 flammable liquid and is governed in Sweden by the regulations in SÄIFS 1997:9 and SRVFS 2004:7. The rules for classification of hazardous areas plans that must be drawn up for all petrol stations and which govern the choice of fittings are the same for stations that only handle E85 as they are for those that handle E85 and petrol.

During application of the regulations consideration should be given to the specific differences in the properties of E85 when compared to petrol; therefore it is recommended that certain extra precautionary measures are taken for E85 installations.

- E85 has different corrosion properties compared to petrol, which must be taken into consideration when selecting materials for the various parts of an installation. Unsuitable materials for use with E85 are, for example, aluminium, zinc and brass. E85 has a different affect to petrol on certain plastics and rubberized materials.

- Bioethanol and petrol have different explosive limits. This means that an explosive gas atmosphere in an E85 storage tank will exist across a wider temperature range than in a petrol storage tank. There are varying details about the temperature range but the SAE Technical
Papers Series, 950401, “Flammability Tests of Alcohol/Petrol Vapours” gives the temperature range at which a gas atmosphere in a closed container is explosive as being from -41°C till -10°C for petrol and from -33°C to +11°C for E85. Exactly what the temperature range is does not influence the shape of the practical extra precautionary measures that are recommended here.

Design of petrol stations handling E85

Selection of materials
The corrosion properties of E85 must be taken into consideration when selecting materials for the various parts of an installation. The petrol companies require that the suppliers concerned state in writing that the materials used in various parts of the system are suitable for use with E85. A suitable way of doing this is via certificates or other written documentation.

- Storage tanks should be manufactured from suitable materials or have a surface treatment that is approved for use with E85. Petrol storage tanks often only have rust protection on one third of the inside tank bottom. That is not sufficient for E85. The entire container must be manufactured from materials that are approved for use with E85.
- The filling pipe should be of a suitable plastic material or hot-dip galvanized steel. Hot-dip galvanized steel is acceptable in those cases in which the filling pipe is usually empty.
- Distribution pipes should be of a suitable plastic material.
- Gaskets and other materials in the dispenser unit should be made of materials that are suitable for use with E85.
- Hoses and filling nozzles should be made of materials that are suitable for use with E85.
- The overflow protector on an E85 installation should be specifically adapted for use with E85. The same type of overflow protector that is used for petrol will not work.

Increased risk of ignition
The following measures are recommended to prevent an ignition from spreading to the system, because the gas atmosphere in an E85 system will have a compound within the explosion range more often than is the case with petrol.

There should be flame arresters on the storage tank ventilation system in accordance with SÄIFS 1997:9 marginal 4.2.6. As this applies to new installations, the new regulations based on the ATEX directive also apply and state that flame arresters should be designed in accordance with current EU standards. Flame arresters in accordance with class IIB1 are recommended.

Some form of flame arrester should also be in use during the filling up of petrol station underground storage tanks. This can either be a flame arrester, a well-functioning interlocking shut-off valve or a liquid type flame arrester.

It is rare but it has occurred that static electricity has caused small fires or small flames that have quickly gone out during the filling up of vehicles. To eliminate this risk as far as possible, the filling nozzles on E85 pumps should not be fitted with any latched fuel dispenses, i.e. driver operated snagging devices.
Recovery system for gases

The Swedish Environmental Protection Agency’s regulations SNFS 1991:1 contain requirements for the recovery of vapours from vehicle petrol. E85 is not covered by these requirements. Accordingly there are no requirements for the recovery of vapours from and recycling of E85.

Vapour recovery systems are usually divided into two stages. Stage I is for the recovery of vapours from storage tanks and then on to the depot for recycling; and stage II is for the recovery of vapours during the filling up of vehicles and in to the storage tank. If vapour recovery systems are connected to an E85 installation consideration should be given to the safety risks involved.

Until this issue has been studied further it is recommended that stage II not be connected to vapour recovery systems. If E85 is connected to stage I the person responsible for the site should ensure with the supplier of the vapour recovery system at the relevant depot that this does not entail any safety risks. This should be documented in a suitable manner.

Depth gauging

During manual depth gauging (level measuring) the increased risk of ignition should be observed. As an extra precautionary measure a wooden stick should be used and there should be written instructions on how to carry out this task in a safe way. There are alternatives to level measuring with a measuring stick, for example, automatic tank measuring, which is preferable from a safety perspective.

Extinguishing agents

In the assessment of the fire service consideration should also be given to the need for dedicated alcohol resistant extinguishing foam for use on E85, because detergent foam does not have sufficient extinguishing capacity for E85.

(http://www.srv.se/templates/SRV_Page____17990.aspx)

See also BEST Deliverable 4.2 A Storing and dispensing E85 and ED95.