CADDET renewable energy

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Ethanol-powered Buses in Skaraborg

Summary

In Sweden, a programme to demonstrate the use of ethanol as a fuel for buses, trucks and cars has been underway since 1991. In total, more than 300 ethanol-powered buses are running in various cities in the country. In Skaraborg county, 15 Scania buses equipped with a third generation of ethanol engines have been running for five years. Tests clearly show that levels of regulated as well as unregulated emissions are well below those for the diesel alternative. The project has demonstrated that ethanol is a viable fuel option, although it cannot yet compete with fossil fuels in today's market conditions.

Highlights

- **A third generation of ethanol-powered buses on the market**
- **No net greenhouse effect as the fuel is renewable**
- **Substantial reduction of nitrogen oxides, particulates and other emissions**

An ethanol-powered bus.

Project Background

Since the first generation of ethanol-powered buses was introduced in Sweden in the beginning of 1980s, there have been tremendous developments. The oldest of the buses have been driven for more than 600,000 km. After demonstrations in a number of cities, a third generation of ethanol-powered engines has enterered the market, and there are now more than 300 buses running.

The use of ethanol as a substitute for diesel results in less emitted greenhouse gases as the fuel is made from biomass. At the same time, other emissions such as nitrogen and particulates are dramatically reduced. The result will be a cleaner and more healthy environment in city centres, as well as a substantial contribution towards controlling the climate change.

The Project

The project in Skaraborg county is one of a number of Swedish demonstrations aiming to show that ethanol-powered buses perform better than those using the best available diesel engines. In Skaraborg, a fleet of 15 buses has been evaluated. The evaluations included the analysis of the results of regular emission tests and measurements of fuel consumption. The buses have been used in city traffic and rural areas.

The aim of the project was to create the basis for a decision regarding the future of large-scale introduction of ethanol buses into public transport. Three goals were set up:

- **the environmental goal**
  ethanol-powered buses must give cleaner exhausts than the best available diesel buses;
- **the reliability goal**
  ethanol-powered buses must have at least the same reliability as diesel-powered buses;

Table 1: Comparison of Exhaust Emissions

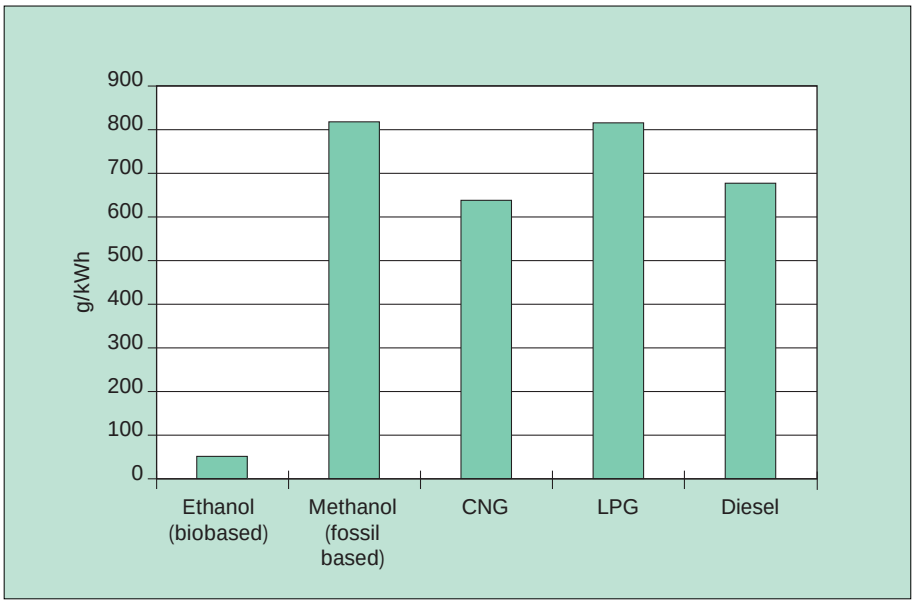
Emissions (g/kWh)	EURO II standard 1996	Diesel Bus Standard 1993	Best available*	Ethanol Bus Skaraborg
Particulates	0.15	0.7	0.05	0.04
Oxides of Nitrogen	7.0	14.0	6.3	3.93
Carbon Monoxide	4.0	5.0	0.1	0.13
Hydrocarbons	1.1	1.5	0.1	0.09
Carbon Dioxide	Yes	Yes	Yes	No

* Swedish solution using catalysts, particulate traps and cleanest available diesel (envirodiesel).

- **the economic goal**
  at the end of the testing period, the costs to own and use ethanol-powered buses must be comparable with the costs for diesel-powered buses when including the value of the reduction of exhaust emissions.

Since the project started in 1993, the 15 buses have in total run for about 3 million km. During this period, data have been collected on fuel consumption and costs for operation and maintenance, as well as on regular performance standards. During the test period detailed emission tests were also carried out.

The project included two types of buses – five new Scania buses designed for ethanol use, and 10 older Scania buses converted for ethanol use. The type of engine used is the same for all buses and is the third generation of its kind. It has a higher compression ratio than the standard diesel engine (24:1) and is equipped with turbo charger and intercooler. The buses have newly-developed oxidation catalysts, resulting in very low levels of regulated and unregulated emissions. Some of the earlier problems with odour from acetic acid in the emissions were also solved. The fuel used is 95% bio-based ethanol from forestry by-products and, for some periods, wine-ethanol. A newly-developed ignition improver (Beraid) and denaturants were added. As new the ignition improver is more effective than the previous material, smaller quantities are needed in the fuel for satisfactory ignition properties.



Results from a life-cycle analysis of CO_2 emissions from bus fuels.

The emission tests show that regulated and unregulated emissions have been reduced to levels lower than today's standard for diesel-powered buses. As the ethanol-powered buses are using renewable fuels, their net emission of carbon dioxide is almost zero. Hence, the use of vehicles like this on a larger scale can make substantial contributions to the reductions in global warming and improve the health and environment in city centres.

Performance

After a five-year test period, it is clear that the ethanol-powered buses generate far lower emissions of nitrous oxides and particulates than diesel-powered buses. There are no net carbon dioxide effects as the raw material is domestic wood – a renewable fuel. The average fuel consumption has been 0.7 litres/km.

The operator, bus drivers and technical staff, as well as customers, are very pleased with the buses. After some initial minor technical problems, not related to the fuel used, the performance has been good. The general conclusion is that the availability is similar to that of standard diesel-powered buses.

Economics

The major factor affecting the economics is the fuel price. Today's fuel prices do not reflect the actual environmental costs to society. Using biofuels involves increased costs for vehicle operators but the environmental benefits are not fully measured. However, using environmental 'shadow-prices', the results are positive. For this project, additional costs for vehicles related to ethanol use were about SEK 100,000/bus (where SEK is the Swedish krona) for the new and converted buses. If the number of ethanol engines and vehicles delivered increases, the production costs will reduce to that of diesel buses.

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SE 98 502 First printed 1998