Atrax Energi

# Assessment of bio-ethanol and biogas initiatives for transport in Sweden

## Background information for the EU-project PREMIA

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# Abstract

This report is the result of an assignment on assessment of bio-ethanol and biogas initiatives for transport in Sweden, granted by VTT Processes, Energy and Environment, Engines and Vehicles, Finland to Atrax Energi AB, Sweden.

The report of the assignment is intended to append the literature and other information used in the “PREMIA” project

The work has been carried out by Björn Rehnlund, Atrax Energi AB, Sweden, with support from Martijn van Walwijk, France.

The report describes the development of the production and use of biobio-ethanol and biogas (biomass based methane) as vehicle fuels in Sweden and gives an overview of today’s situation.

Besides data and information about numbers of vehicles and filling stations, the report also gives an overview of:

- Stakeholders
- The legal framework, including standards, specifications, type approval, taxation etc.
- Financial support programs.

Public acceptance, side effects and the effect off the introduction of bio-ethanol and biogas as vehicle fuels on climate gases are to some extent also discussed in this report.

It can be concluded that since the early 1990’s Sweden has had a perhaps slow but steadily increasing use of bio-ethanol and biogas. Today having the EC directive on promotion of bio bio-fuels and other renewable fuels in place the development and introduction of filling stations and vehicles has started to increase rapidly.

From 1994 to 2004 the number of filling stations for bio-ethanol grew from 1 to 100 and during the year 2004 until today to 160 stations. The situation is similar concerning introduction of Flexible Fuel Vehicles (FFVs). Today there are at least 14 000 FFV`s operational in Sweden. Besides that there are also 450 buses running on neat ethanol and almost all gasoline sold in Sweden is blended with 5 % ethanol.

Also the production and use of biogas is increasing fast these days. Until today most of the biogas used for vehicle purposes has been produced as a by-product of treating sewage sludge (anaerobic digestion) for odour control and to reduce the risk of health problems. However, the production of biogas from different kinds of residues has slowly started during the 1990:ties, a production that is focused on just the production of gas and not taking care of a waste problem. A Swedish company is at the moment building a new biogas plant for anaerobic digestion of agricultural residues and also has scheduled to build 5 new plants the coming 6 years for anaerobic digestion of agricultural products. Besides that there are also initiatives to fuel local trains and ferries by biogas

Today there are at least 6000 light- and heavy duty vehicles running on methane (both biogas and natural gas), 65 filling stations for methane (both biogas and natural gas), and 16 000 000 normal $m^3$ natural gas as well as 13 000 000 normal m3 biogas are used for vehicle propulsion.

One important factor, in the long turn, for the development of bio fuels in Sweden seems to be the existence of deeply committed people. One other might bee the belief in a future sustainable production from a national raw material such as cellulose.

The introduction of the EU-directive on the promotion of bio fuels and other renewable fuels as well as the possibility to allow tax exemptions on a national level seems to have been the main catalyst in the latest strong development of the production and use of bio fuels.

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# 1. Background

This report is the result of an assignment on assessment of bio-ethanol and biogas initiatives for transport in Sweden granted by VTT Processes, Energy and Environment, Engine and Vehicles, Finland to Atrax Energi AB, Sweden.

The report of the assignment is intended to append the literature and other information used in the "PREMIA" project (R&D, demonstration and incentive programmes, effectiveness to facilitate and secure market introduction of alternative motor fuels), in its work packages (WPs) regarding international initiatives on alternative motor fuels (WP 2), assessment of short term options in the EU – bio bio-fuels and large scale natural gas (WP 4) and assessment of country specific situations (WP 5).

The work has been carried out by Björn Rehnlund, Atrax Energi AB, Sweden, with support from Martijn van Walwijk, France.

The information in the report is mainly collected from Swedish stakeholders and parties with an interest in bio-fuels, such as inter alia:

SEKAB AB, Örnsköldsvik
BioAlcohols Fuel Foundation, Örnsköldvik
EcoDevelopment AB, Örnsköldsvik
ETEK, Örnsköldsvik
Svenskt Gastekniskt Center, SGC. Malmö
Tekniska Verken/Svensk Biogas AB, Linköping
Stockholm Water Co, Stockholm

And Swedish authorities such as inter alia:

The Swedish Environmental Protection Agency
The Swedish Energy Authority
The Swedish Road Administration
The Ministry of Industry
The Ministry of the Environment
The Ministry of Finance.

# 2. Introduction

Different kinds of alternative fuels have been the subject of discussion as well as research and development in Sweden since the first oil crises in the early 1970's. At first it was only a matter of supply and security issues but later - and in parallel to this discussion - also the positive effects of using alternative fuels on tail pipe emissions - emissions with impact on health and environment - became of interest. During the 1980's - when the supply and security issues did not have the highest priority - the possibility to reduce the impact of transport sector on health and environment was the main reason for further investigations, fleet trails as well as research and development in the area of production distribution and use of alternative fuels.

At that time the interest in alternative fuels included more or less all kinds of fuels that could replace gasoline and diesel oil. Methanol was then considered one of the most promising alternative fuels.

Resulting from developments in engine technology and not at least from the introduction of exhaust gas after treatment equipment together with improved environmental qualities of the conventional fuels, the impact on health and environment caused by tailpipe emissions (predominantly from otto/gasoline engines) was reduced. This reduced the need for new alternative fuels that could contribute to reducing harmful emissions. It was then already possible to see that in the future, when using the best technology, the difference in emissions (both from a quantitative and a qualitative perspective) between engines fuelled with conventional and alternative fuels would be reduced to a level where this difference would be more or less negligible. Together with a stable oil supply situation the interest in alternative fuels was further reduced to a rather low level.

However, during the last years of the 1980's a new issue connected to the emissions from the transport sector merged, the climate change, and that triggered a renewed interest in alternative fuels. Now the alternative fuels had to be non-fossil fuels or rather carbon dioxide neutral fuels or bio-fuels, being fuels with no or at least low net carbon dioxide emissions to the atmosphere.

Some biomass based fuels such as ethanol and rapeseed methyl ester (RME) had already been discussed as possible alternatives to the conventional fuels for a while. Until then one perhaps the most important reasons to consider bio fuels had to do with agricultural and rural issues. Sweden had for example followed the discussions and introduction of ethanol in the USA and Brazil. The knowledge of how to use these fuels was rather good since the technical matters for use of methanol and ethanol are similar. Also the use of RME is rather unproblematic since RME has very similar properties to conventional fossil diesel oil. However, concerning the production of ethanol new raw materials for such production became of interest in Sweden, since the range of accessible agricultural land to produce grain for technical use was restricted because of at first national, and later on EU agricultural policy. One huge national source of raw material was the forest and residues from forest harvesting. In early 1990's the Swedish government presented a "Climate Bill" which - among other measures - included financial support of approximately 4.7 million Euros for research and development on the fermentation of cellulose to ethanol. This initiative was further enlarged when research and development on production from cellulose received an additional governmental support of 23 million Euros in a new Energy Bill, during the second half of the 1990's. The Swedish authority NUTEK first managed these financial means but later, from 1998 onwards, the Swedish Energy Administration manages them

Today the work in the field of ethanol production from cellulose has left the laboratory scale to the pilot scale and is now being done in pilot projects. One year ago a small pilot production plant for research and development in the field of ethanol production from cellulose was started up in Örnsköldvik in mid Sweden. This plant was built with a state support of 16 million Euros from the Swedish Energy Administration. A few months ago the first litres of ethanol was produced in this pilot plant. However, this ethanol will never be used in vehicles or sold on the consumer market. This production is only for R&D purposes and the ethanol produced will be burnt in a stationary heating application in a sulphite mill close to the pilot plant.

Furthermore at the beginning of the 1990’s a couple of hundred Flexible Fuel Vehicle (FFV), Ford Taurus, were imported to Sweden - by a Swedish company manufacturing cars from Ford (Carstedts Motor AB) in Örnsköldsvik - and introduced on the Swedish market. Another initiative at that time was the introduction of neat ethanol (with added ignition improver) for the use as a fuel in buses with diesel engines. Stockholm started with a fleet of 10-32 buses while inter alia Örnsköldvik had 2-3 buses running on neat ethanol. These two initiatives can be considered to be the actual start of the use of ethanol as a vehicle fuel in Sweden. Later the numbers of FFV`s and ethanol busses have grown substantially and at the same time the use of low blending (5 %) of ethanol in gasoline has become common in almost all regions and for all oil companies in Sweden.

In the mid 1990’s and in parallel to the discussion about bio-fuels and ethanol the possibility to use gas (methane) from the treatment of sewage sludge (anaerobic digestion) became an issue of interest. This gas, called biogas, was a result of a necessary treatment of sewage sludge to get rid of bad odours and possible health problems caused by the sludge, when it without treatment is spread on agricultural land. So far the gas usually was flared or at best it was used for heating purposes in district heating plants, like in later years.

Since biogas mainly constituted of methane and carbon dioxide, plus some minor contaminations of sulphur compounds, it was a quite simple technique to clean and shift it to a quality comparable to natural gas (approximately 97 % methane). Natural gas was then already an accepted alternative vehicle fuel with well-known engine technology on the continent, where natural gas had been used for different kinds of purposes for many years and regarded as a well-accepted energy source with a huge international pipeline network.

At that time and still today - Sweden had and a minor natural gas pipeline system (on the West coast). Volvo AB had started the production of so called bi-fuel cars that are able to run on gasoline or methane. At first these cars were meant to run on natural gas, but of course they can also use upgraded biogas.

In the Western part of Sweden (Göteborg, Malmö) a number of buses with diesel engines that were converted to sparkplug operation were at that time already running on natural gas. When biogas became interesting as a biomass based methane fuel, municipalities such as Linköping, Trollhättan and Stockholm started projects to develop biogas use in bus fleets as well as light-duty cars owned by the municipalities, interested companies and also to some extent private persons.

Today the production of biogas has developed from being a by-product from sewage sludge treatment to the production of a vehicle fuel in itself. Even though most biogas comes from sewage sludge treatment, also plants have been built just for the production of biogas using other kinds of feedstock, for example manure. The number of plants and the production capacity is steadily growing. Also the number of buses and light-duty cars has grown substantially, not only for the use of biogas but in the Western part of Sweden also for the use of natural gas.

Although this report focuses on ethanol and biogas, it is important to mention that also RME is a rather big alternative fuel in Sweden both as a neat fuel but also blended with MK 1 diesel oil. The use of RME is also, and similar to ethanol and biogas, growing steadily. Furthermore there are also many research and development activities in the area of alternative fuels produced from gasified biomass, fuels such as methanol, Di-Methyl Ether (DME) and synthetic fuels such as paraffin produced by the Fischer-Tropsch technique/process. One and a half year ago the Swedish Energy Authority started a new research and development program focused on production of alternative fuels from gasified biomass.

# 3. Bio-fuels

## *3.1 Pure bio-fuels*

As mentioned in the previous chapter ethanol has been used in Sweden mainly in neat form 1990.ies as:

- Neat ethanol with added ignition improver and a water content of approximately 5 % (E95)
- Neat, water- free (anhydrous) ethanol, with 15 % added gasoline (to improve engine starting at low temperature) (E85).

E95 is for use in diesel engines (compression ignition engines) while E85 is for use in gasoline (otto/spark-ignition) engines.

Also from the mid 1990's onward, biogas has been used in otto engines. After cleaning and upgrading this gives vehicle quality with approximately 97 % methane content. Biogas is often used in otto engines in small light-duty vehicles fleets owned by municipalities or private companies but to some extent also light-duty vehicles owned by private persons.

lBiogas has also been used in converted diesel (compression ignition) engines, equipped with glow- or spark plugs, making it an otto (spark ignition) engine, mainly in municipal bus fleets.

Besides ethanol and biogas also RME has been used in neat form in diesel engines.

Other alternative fuels as for example methanol, DME, hydrogen and synthetic diesel fuel (paraffin) have also been used for vehicle propulsion but then always in very small test fleets or only in one or two test vehicles.

Certainly methane from natural gas has also been used in vehicles, and then in municipality owned bus fleets, municipality or private company owned vehicle fleets as well as in light-duty vehicles owned by private persons. The use of natural gas is concentrated at the Swedish West coast, because in that part of the country there is a natural gas grid.

## *3.2 Blends of bio-fuels and conventional fuels*

Besides in its pure form ethanol has also been used in blends with gasoline. From the beginning of the year 2001, all gasoline in the Stockholm area as well as in the area South East of Stockholm has been blended with up to 5 % ethanol.

Today all gasoline in Sweden, except the gasoline sold on the island Gotland, is blended with 5 % ethanol.

The reason for not mixing more than 5 % ethanol into gasoline is that this would be against what is stated in EU: s "Fuel directive" as well as what is in line with the European standard on gasoline composition, EN 228. However there are many stakeholders in Sweden that would like to see changes in these two “regulations” to allow blending of up to 10 % ethanol in gasoline.

It is possible to mix more than 5 % ethanol in gasoline but then the fuel cannot be named gasoline anymore. In line with that vehicle manufacturers would probably not, at least initially, accept the use of the fuel in their engines/vehicles.

Concerning blends of other alternative fuels RME has been blended into diesel oil from the mid 1990’s.

Because of the Swedish system with environmental classes of diesel oil and the taxation system connected to this classification system (a similar system exists for gasoline) and the parameters that have to met the requirement for the best environmental class diesel oil (MK 1), it has not been possible to mix more than 2 % RME into a MK 1 diesel oil and still have the mix taxed as a MK 1 diesel oil. Mixing more than 2 % RME into MK 1 diesel oil will make the total mix will, according to the environmental classification parameters, a MK 3 diesel oil with a substantially higher taxation. This has restricted the mixing of RME in diesel oil to a maximum of 2 %.

Because today the European standard for diesel oil EN 590 allows mixing of up to 5 % FAME into diesel oil, the Swedish system for environmental classification and taxation of diesel oil is under investigation by the Swedish Road Administration to see if it would be possible, and then to specify how the system could be changed to also allow mixing of up to 5 % RME or FAME into Swedish MK 1 diesel oil, without increasing the taxation of the mix from a MK 1 level up to a MK 3 level.

# 4. Ethanol stakeholders

## *4.1 Bio Alcohol Fuel Foundation (BAFF)*

In 1983 the Foundation for Swedish Development of Ethanol (SSEU) was founded in Örnsköldsvik, Sweden. The goal of SSEU was to develop the production and use of biomass based ethanol in the transport sector, giving high priority to environmental aspects.

The reason for SSEU´s approach was that they believed that ethanol was the most rational substitute for the conventional fossil vehicle fuels in use with the goal to fulfil environmental goals set up by the government/parliament. According to SSEU other arguments in favour for biomass-based ethanol were:

- Huge national supply of lingo-cellulosic raw material
- Good national knowledge in

    - How to handle forest residues
    - The area of production of bioenergy
    - Process technology in pulp industry and chemical industry

The increasing international interest in bio-ethanol as a vehicle fuel together with an increasing national interest in bio-methanol was the reason behind changing the name of the foundation in 1999 to the Bio Alcohol Fuel Foundation (BAFF).

BAFF is involved in a rapid transition to renewable fuels that they believe:

- Suits the course of nature.
- Ensures Sweden and the Swedish industries to play a leading role in the transition from fossil fuels to bio-alcohols.
- Pave the way to a bright future for Swedish exports

BAFF describes adapting to the use of bio-alcohol as a chain of development, in which all links are equally important for a good result. This chain of development begins with the processing of raw material for production and distribution to vehicles and the different engines. The next link presents the external effects such as emission and marginal values. The last link is the regulation that society imposes in the form of laws taxes and other factors, which help facilitating the transformation.

Today BAFF gives a certain priority to international matters and information dissemination, for example in the European Commission and the European parliament.

From 1983 until today the foundation has been responsible for projects in the area of production, use and information dissemination of bio-alcohols, working with a total budget of approximately 33 million Euros.

BAFF´s clients are:

- Agroethanol AB
- Akzo Nobel AB

- Chematur Engineering AB
- Skellefteå Kraft AB
- Svensk Etanolkemi AB (SEKAB)
- Municipality of Örnsköldsvik

BAFF co-operates very closely co-operation with BioFuel Region and SEKAB, two organisation that are addressed in more detail in the next two sub sections.

## *4.2 Bio Fuel Region (BFR)*

The non-profit organization BioFuel Region (BFR) was established in the year 2003 to be an arena for regional co-operation, with a focus on vehicle bio fuels that are produced from cellulose.

The region constitutes of the two administrative districts/counties:

- Västernorrlands län
- Västerbottens län

The motivations behind BFR are the key problems of climate change and energy supply that the world facing today. To meet for example the voluntary goals in the EU-directive on the promotion of bio -fuels and other renewable fuels,, the volume of bio bio-fuels used has to increase to 10 times today's volume in 6 to 7 years. To achieve that we have to develop systems and technologies that are more sustainable than those existing at present, not to mention establishing supplying facilities that produce 20 billion litres annually.

BFR intends to be a propelling force in that work, where regional co-operation is used to implement the development and introduction of renewable fuels based on biomass from forests, agricultural fields and recycling.

The strategic idea of BFR is to create and lead the development by mobilizing, engaging and activating as many of the forces as possible for developments in the region.

The vision of BFR is to be:

- Self-supporting in transport fuels in 2030.
- A world-leading region in cellulose-based bio-fuels
- In the forefront of the acquisition of knowledge about bio-fuels
- A leader in the development of technology, production and utilization of bio-fuels.

BFR is open for everyone who supports its ideas, goals and its visions. The member fee is 110 Euro annually plus a one-time starting fee of 1100 Euros.

The members of BFR are today:

**Municipalities**

- Härnösand

- Kramfors
- Lycksele
- Norsjö
- Robertsfors
- Skellefteå
- Sorsele
- Storuman
- Sundsvall
- Umeå
- Vilhelmina
- Vindeln
- Vännäs
- Åsele
- Örnsköldvik
- Västerbottens läns landsting

**State/public actors**

- Länsstyrelsen i Västernorrland
- Länsstyrelsen i Västerbotten
- The Swedish Road Administration
- NUTEK

**Universities**

- Umeå University
- Mittuniversity
- The Swedish Agricultural University

**Others**

- Ecodevelopment AB
- Esam AB
- Framtidsbränslen AB
- Norrskog Ekonomiska förening
- ETEK Etanolteknik AB
- Svensk Etanolkemi AB

In the starting phase BFR has tried to engage municipalities and state actors in its work and as members, but in the future BFR will strongly act to engage more members from the private sector

The operational part of BFR today is managed by BFR AB, which is owned by the members. The board of BFR AB constitutes mainly of people from the members municipalities.

The most important part of the operational work is carried out by BFR`s working groups. At the moment BFR has seven active working groups:

- **Public sector**. Development and establishing of new filling stations in the region

- **Industrial development.**

- **Research and development**. Co-operation with universities and promotion of research with interest for BFR.

- **Adult education and commitment.** Production of educational material such as books, pamphlets, seminar material, etc, in the field of climate effects, alternative fuels and ethanol produced from cellulose.

- **School (elementary school and high school).** Production of educational material to be used at courses in elementary school

- **Raw material issues** Co-operation with the Swedish Agricultural University concerning analyse of accessible raw material (cellulose) in the region.

- **Financing**

A central management is to co-ordinating the activities of the working groups.

Today there are approximately 200 people engaged in the working groups and furthermore 40 high school pupils are carrying out their mandatory school project work in BFR projects.

During the first project period, 2003 – 2006, it is calculated that BFR will have a budget of 3 800 000 Euros for process work that aims at preparing the foundation for the future. The plan for the years thereafter until 2010 is to have an annually budget of 765 000 – 1 100 000 Euros.

Each working group will have a base budget of 11 000 Euros for investigations and small project initiatives. For projects that go beyond the working group budgets, a working group has to apply for funding from the co-ordinating management group.

BFR has and will continue to seek funding for its activities from the EU as well as from national organisations and authorities such as NUTEK and the local county administrative boards in the Region. This gives BFR the possibility to participate in and give financial support to project that is initiated by municipalities and private companies.

BFR played a role in establishing today's 9 filling stations in the Örnsköldvik municipality that sell E85 fuel for FFV`s. Another 5 filling stations are currently under construction. These 5 will have a state support (KLIMP) from the Swedish Environmental Protection Agency of 30 % of the total investment cost.

Today BFR together with SEKAB (a local ethanol production company) supports the next 30 erections of ethanol flexible filling pumps (possible to chose the ethanol mixing rate at the pump when filling) in the region with 20m3 bio-ethanol (free of charge). For pumps that will be erected later, as well as for the erection of stationary E 85 pumps, the support from BFR and SEKAB will be 10 $m^3$ bio-ethanol, free of charge.

## 4.3 Svensk Etanolkemi AB (SEKAB)

Svensk Etanolkemi AB (SEKAB) was founded in 1985 and is located in Domsjö near Örnsköldsvik.

The company has around 60 employees and has an annual turnover of approximately 87 million Euros.

Until recently SEKAB`s ownership was equally shared between Akzo Nobel and Domsjö Fabriker. Today SEKAB is owned by a regional consortium including a local insurance company (Länsförsäkringar), a consultant company (Eco development AB) and three energy companies in the northern region of Sweden:

- Örnsköldsvik Energi
- Umeå Energi
- Skellefteå Kraft

SEKAB works primarily in three areas:

- Ethanol
- Ethanol derivates
- Ethanol fuels

SEKAB supplies bio-ethanol for a number of different applications from Sweden's only factory manufacturing ethanol from forestry raw materials. This ethanol is produced in co-operation with Domsjö Farbikers plant for sulphite pulp, situated back to back with SEKAB. SEKAB also buys ethanol produced from the wine surplus in Europe and upgrades it to vehicle fuel quality. Furthermore SEKAB buys sugar cane ethanol from Brazil, also for upgrading to vehicle purposes.

In 2004 SEKAB delivered 18 000 m3 ethanol fuel (ETAMAX D) (ethanol with 5 % water content and added ignition improver) for use in adapted diesel engines/busses and 6 500 m3 ethanol fuel (ETAMAX B) (anhydrous ethanol) for use in Flexible Fuel Vehicles.

## 4.4 Agroetanol AB

Agroetanol AB is owned by the Federation of Swedish Farmers (LRF) and the Swedish Farmer's Supply &Crop Marketing Assoiciation (SLR).

The mission of Agroetanol is to efficiently refine grain to fuel ethanol.

The company's first ethanol plant is situated on the island Händelö, close to Norrköping, and also close to an oil depot and a biomass fired power plant. The plant produces annually 50 000 m3 of ethanol that is intended for gasoline replacement and 45 000 tonnes of protein feed (DDGS).

The ethanol produced in the Händelö plant is used for low blending in gasoline that is distributed in the Stockholm region as well as in the Southeast region of Sweden.

The steam and electrical power needed to operate the plant both originate from renewable sources. The steam, which is primarily used for distillation and drying of feed, is produced in the biomass-fuelled power plant close by.

## *4.5 ETEK Etanolteknik AB*

ETEK Etanolteknik AB is a company owned by:

- Skellefteå Kraft AB
- Örnsköldsvik Energi AB
- Umeå Energi AB
- SEKAB

ETEK: s vision is to:

- Create conditions for bio combines, which can contribute to the supply of ethanol for the transport sector, lignin as a solid fuel and a new industrial export business.
- Be seen as a "Centre of Excellence" for the development of ethanol and lignin from lignocelluloses.

The goals of ETEK are:

- Within given limits operate a research/pilot plant, where the production technology for ethanol and lignin from lignocelluloses can be developed and verified.
- To year 2006 develop a process technology for ethanol and lignin from lignocelluloses that is commercially practicable for a demonstration plant,
- To the year 2008 set thee base for production plants for ethanol and lignin from lignocelluloses with connection to combined heat and power plants, industrial process plants or similar.

A pilot plant for production of ethanol and lignin from lignocelluloses is situated at Domsjö Fabriker in Örnsköldvik and operated by ETEK since 2004.

The pilot plant is a fully furnished factory, but will not produce ethanol for selling commercial purposes. It will have a production capacity of only 200 $m^3$ ethanol per year when operated continuously.

The plant is constructed and operated to produce knowledge. The pilot plant is a research and development centre in co-operation with Lund's University, Chalmers Technical University, Umeå University, Mid Sweden University and others.

# 5. Legal framework

## *5.1 Standards*

Since alternative fuels have been discussed for a rather long period (more than 30 years) in Sweden and a number of fleet tests as well as commercial projects have been carried out during this time, the need for specifications and standards has been highlighted more and more by stakeholders and authorities. During the same time period the role of national standards has been more and more taken over by international standards, primarily European standards (EN-standards) that have been developed by the European Committee for Standardization – CEN. CEN`s Technical Committee number 19 (CEN/TC 19) "Petroleum Products, Lubricants and Related Products" has been taking care of the vehicle fuel related standardization issues.

However, during this period of development and introduction of alternative fuels the Swedish Standardization Group (STG) and later the Swedish Standardisation Institute (SIS), have taken the lead in the production of three Swedish standards on alternative fuels, after initiatives from Swedish stakeholders.

The three alternative fuels for which standards have been established are:

- Fatty Acid Methyl Esters (FAME)
- Alcohols
- Biogas

### 5.1.1 RME

The Swedish standard on FAME, "Automotive fuels – Vegetable fatty acid methyl esters – Requirement and test methods", SS 155436, was decided by STG 1996-11-27, as a reaction on the growing demand for a FAME, or more specificly rapeseed methyl ester (RME), standard. The standard was developed by STG: s Technical Group number 85 (TK 85).

However, 2003-12-05 this Swedish standard was superseded by the European CEN-standard EN 14214 "Automotive fuels – Fatty acid methyl esters (FAME for diesel engines) – Requirement and test methods"

### 5.1.2 Alcohols

1997-06-04 STG decided on a Swedish standard (SS) on Alcohols, "Motor fuels – Fuel alcohol for high-speed diesel engines", SS 155437 in response to a growing demand for a standard on the use of neat ethanol in diesel engines.

The standard was developed by STG: s Technical Group number 85 (TK 85).

Even if the need at that time, and still is, for a standard for ethanol, the standard established was adjusted not only for ethanol, but also for methanol, under the common name “Alcohols”.

A high-speed engine is in the standard defined as an engine with at least 16 revolutions per minute, at maximum performance.

The standard furthermore enumerates demands on alcohols (ethanol and methanol) to be used as vehicle fuel in high-speed diesel engines concerning inter alia:

- Sampling
- Test methods
- Minimum content of alcohol (ethanol or methanol) (%)
- Maximum content of other alcohols (%).
- Density (kg/m$^3$).
- Ash content (%)
- Acidity
- Water content (%)
- Flammability (C)
- Content of aldehydes (%)
- Content of esters (%)
- Content of lead (mg/l)
- Content of phosphor (mg/l)

### 5.1.3 Biogas

999-09-15 STG decided on a Swedish Standard (SS) on biogas, “Motor fuels – Biogas as fuel for high-speed otto engines”, SS 155438, as a reaction on the growing demand on a biogas standard.

The standard was developed by STG: s Technical Group number 85 (TK 85).

As can be seen from the title the standard is for biogas for the use in otto engines, which includes converted diesel engines provided with glows or spark plugs.

A high-speed engine is in the standard defined as an engine with at least 16 revolutions per minute, at maximum performance.

The standard has been adapted in such a way that fuelling and engine equipment developed for natural gas, from a material-technical point of view, may also be used for biogas.

In the standard is defined that biogas is:

“Gas produced from microbial fermentation of organic material in an anaerobic (oxygen free) environment”.

The standard furthermore enumerates demands on biogas to be used as vehicle fuel in high-speed otto engines concerning inter alia:

- Sampling
- Test methods
- Energy content or amount of methane (Volume %)
- Octane number (MON)
- Maximum carbon dioxide content (Volume %)
- Total [maximum?] sulphur content ($mg/m^3$)
- Total [maximum?]content of nitrogen compounds (exclusive $N_2$) ($mg/m^3$)
- [Maximum contents of?] Other contaminants

The Swedish standards on Fuel Alcohols and Biogas can be ordered from SIS. More information can be found on SIS web page:

www.sis.se

## *5.2 Product norms*

### 5.2.1 SEKAB

Svensk Etanolkemi AB (SEKAB) is a Swedish company located in Örnsköldsvik with interests in production and marketing of ethanol for different purposes as well as other kind of chemicals. SEKAB is the main distributor in Sweden of fuel ethanol for Flexible Fuel Vehicles (FFV) and busses ethanol adapted buses. The ethanol is to some extent produced at a sulphite pulp industry located back to back with SEKAB. However, so far the main volume of ethanol for vehicle purposes comes from upgraded "whine ethanol" which is produced from the wine surplus in the European Union. SEKAB has also started to import sugar cane ethanol from Brazil.

SEKAB markets two different kinds of vehicle fuel ethanol:

- One quality for use in diesel engines, mainly busses.
- One quality for use in Flexible Fuel Vehicles (FFV).

**ETAMAX D**

ETAMAX D is a neat bio-ethanol fuel for adapted diesel engines.

ETAMAX D consists of ethanol with 5 % water content (92.2 % of the total volume), ignition improver, corrosion inhibitor plus to a small extent MTBE and isobutanol.

**ETAMAX B**

ETAMAX B, a mix of gasoline (Swedish environmental class 1, MK 1) and bio-ethanol (86 %) is a fuel for Flexible Fuel Vehicles (FFV). These FFV`s are vehicles with engines adapted to run on gasoline as well as a mix of gasoline and ethanol up to a content of 86 % ethanol.

ETAMAX B consists of anhydrous ethanol (86 % of the total volume), gasoline MTBE and isobutanol.

For more information about SEKAB`s product specification please visit SEKAB`s web site:

**www.sekab.com**

### 5.2.2 Agroetanol

Agroetanol AB owns a production plant for production of vehicle fuel ethanol. The plant is situated in Norrköping, Sweden, and has an annual production capacity of 50, 000 $m^3$ anhydrous ethanol.

The ethanol produced at Agroetanols plant is used for blending with gasoline in the Stockholm region and to some extent the Southeast region in Sweden with up to 5 % ethanol.

The ethanol specification is an agreement between Agroetanol and the oil companies that use the ethanol for blending in gasoline.

For more information about the specification please contact Agroetanol. Information about contacts can be found on Agroetanols website:

**www.agroetanol.se**

## *5.3 On going work on standards and specifications*

During the first five years of the new millennium all over Europe the use of ethanol has grown, not at least after the European Commissions decision on a directive "On the promotion of bio bio-fuels and other renewable fuels" (for vehicle use). In line with these developments, the need for specifications and standards on an international/European level has also grown.

As a consequence the European Commission has inter alia mandated CEN/TC 19 to produce a standard on ethanol for blending with gasoline. The work to produce a proposal for such a standard (however with a maximum blending level of 5 %) has started a while ago in CEN/TC 19. Swedish stakeholders actively participate in that work. In parallel the European standard for gasoline, EN 228, has been adapted to allow a maximum content of 5 % ethanol.

Swedish stakeholders have also taken an active role in a working group (WG) initiated by CEN´s Technical Board (BT), CEN/BT/WG 149 "Liquid and Gaseous Alternative fuels" in December 2002, aiming to initiate a collective European view on the general strategy for improvement of standardization of alternative fuels. One of the recommendations of working group 149, presented in the report "The need for European Standards for liquid and gaseous alternative fuels", 2004-12-08, is that EN 228 should be adapted to allow a maximum content of 10 % ethanol in gasoline and that current work on a standard on ethanol for blending with gasoline should also be adapted to allow a maximum ethanol level of 10 %.

Under the auspice of CEN, a workshop has been established to produce an agreement, a Workshop Agreement, on ethanol for use in Flexible Fuel Vehicles (E85, 85% ethanol and 15 % gasoline).

Swedish stakeholders actively participate in this work and furthermore SIS, on initiative from the Swedish stakeholders, has started work to produce a Swedish standard for E85 based on the Workshop Agreement.

For more information please visit the SIS website:

www.sis.se

### 5.4 Type approval and inspections

FFV and biogas vehicles are covered by the regular type approval system and in line with the EU-regulation on type approval of vehicles. FFV and biogas (bi-fuel) vehicles have to be Whole Vehicle Type Approved (WVTA). The WVTA includes for example limits and performance regulations concerning certain parameters such as maximum allowed engine emissions levels, maximum noise, minimum break braking capacity etc.

However, the emission limits for FFV`s are only verified when the vehicle/engine is fuelled by gasoline.  In the type approval, there are is no specific maximum level defined for using E 85. The engine is only certified for the use of gasoline although the idea behind a FFV is that it able to run on ethanol as well.

Moreover, when it comes to the annual vehicle inspection (inspection maintenance) there is are no possibilities to check the emission levels, even for the use with gasoline, if the owner/driver claims that he or she has ethanol in the vehicle fuel storage tank.

This is clearly a shortage in the system of type approval and annual inspection.

For bi-fuel light-duty vehicles the situation is somewhat different. To get a type approval (WVTA) the manufacturer of the vehicle/engine has to prove that the emission levels/regulations are fulfilled not only when fuelled with gasoline but also with gas (two types of gas). This is different from the situation for FFV: s and certainly a step forward.

However, when it comes to the annual vehicle inspection the situation is similar as for FFVs. There are, according to the regulation, no emission limits for the use of gas that shall be checked at the annual inspections. Once again if the owner/driver claims that he or she only uses gas and that he or she for the moment just has gas in the tank, it is not possible for the inspection staff to check if the maximum allowed emission levels for the use of gasoline are fulfilled.

Today national regulations concerning the gas storage tanks in gas vehicles are in operation. However, at the annual vehicle inspections, these regulations - concerning inter alia pressure-safety and leakage - are currently probably not checked.

For heavy-duty vehicles running on ethanol (buses), there is no emission limits included in the type approval and therefore there are of course no limits to be verified at the vehicle inspection (performed regularly two times per year).

Furthermore, there are no heavy-duty flexible fuel vehicles at all in Sweden. All heavy-duty engines for ethanol use are dedicated ethanol engines. The type approval for heavy-duty engines (Scania bus engines) is so far based on an old exemption, at that time based on the regulation then in force, enacted by the Swedish Environmental Protection Agency. If new types of ethanol engines will be introduced they will need a new type approval.

Heavy-duty vehicles fuelled with gas have to fulfil certain emission levels to get a type approval. Since these vehicles/engines have dedicated gas engines, and not bi-fuel engines, it is also possible to check that all emissions limit are fulfilled during the vehicle inspections (two times per year).

Concerning the annual vehicle inspections, the Swedish National Road Administration is preparing a change in the regulation to allow a better control of the engine emissions and for example also leakage from the gas tanks.

## 5.5 Taxation

Bio-ethanol had already low tax levels before the Swedish membership in the European Union (1995) tax redemption. Ethanol for neat use was excluded from energy tax but not from Value-Added Tax (VAT). Ethanol for all kinds of blending had a very low taxation, about 1 cent per litre plus VAT. The taxation of ethanol was regulated in the Swedish law on Energy Taxation.

During this time biogas (methane from biological anaerobic digestion of biomass) was also not subject to energy taxation.

After Sweden became a member of the European Union the taxation of alternative fuels had to be adapted to the EU directive on energy taxation. According to the rules in that directive, an alternative fuel had to be taxed in the same way as the fuel that it replaced and tax redemption for an alternative fuel could only be accepted when the fuel was used in what could be defined as a pilot project. A pilot project should according to the regulation at that time have the purpose to reduce emissions and the environmental impact from use of the fuel. A so-called pilot project exemption regarding taxation could be issued according to item 8.2d in the directive. This kind of pilot project exemption had to be restricted in time as well as in volume and type of fuels.

During the membership negotiations and also as part of the whole agreement between Sweden and the EU, according to item 8.4 in the directive, Sweden were granted the possibility to exclude biogas from energy taxation.

Until 1997 the only ethanol that was used for vehicle purposes was ethanol used in a couple of hundred FFV`s plus the ethanol used in couple of hundred buses, totalling a consumption of about 10 000 up to 15 000 $m^3$ ethanol, This ethanol was through pilot project exemptions excluded from energy taxation as well as the carbon monoxide taxation, that was introduced at that time. In 1997, added to that volume, Agro Ethanol AB was granted full tax reduction through a pilot project exemption, both for carbon dioxide taxation as well as energy taxation for 50 000 $m^3$ ethanol that was going to be used for low blending in gasoline in the Stockholm area as well as the South-Eastern part of Sweden.

To get grip of the developments and the budgetary issues related to the use of alternative fuels and their reduced taxation, the government in the Financial Bill 2002 introduced a strategy and a budgetary reservation for taxation of alternative fuels. The idea behind the strategy was that all carbon dioxide neutral fuels (mostly bio fuels) should be granted exclusion from carbon dioxide taxation but not from energy taxation. Energy tax exemption should only be granted alternative to fuels used in pilot projects and by pilot project exemption. The budgetary reservation for the strategy was a total of 98 million Euros, being 82 million Euros for the full reduction from carbon dioxide taxation and 10 million for pilot project exemptions. The strategy was notified to and later approved by the EU-Commissions.

However, after the new EC directive on promotion of bio-fuels and other renewable fuels as well as the new Energy directive came into force the Swedish government proposed in the Financial Bill 2004 that all carbon dioxide neutral fuels should be excluded from all kind of taxation except VAT. Also this proposal was notified to the EU-Commission. Sweden has not yet received the Commissions acceptance of this notification, since the Commission is of the opinion that full tax exemption would be “over compensation” and not related to the real situation today. The item is currently under discussion. While discussing this Swedish proposal and waiting for a decision from the EU-Commission, Sweden has decided to use the pilot project instrument to grant all alternative fuel producers and importers of carbon dioxide neutral fuels/bio fuels a full tax reduction until the year 2008, without any restrictions in volume. Today 29 companies are granted this kind of tax exemption mainly concerning ethanol and rapeseed methyl esters (RME) but to some extent also other alcohols and bio oils. The 29 companies are listed in the Appendix of this report.

Because of the restriction in EU´s fuel directive concerning blending of ethanol in gasoline (maximum 5 %) and the Swedish restriction to blend RME/FAME in Swedish diesel oil of the highest environmental classification (MK1) (max 2 %), the loss of tax because of tax revenues for the Swedish government resulting from exemptions on carbon dioxide neutral fuels/bio- fuels could according to information from the Swedish Ministry of Finance be estimated to a maximum of 131 million Euros. The major part of this figure can be related to the replacement of gasoline by ethanol and a minor part to replacement of diesel oil by RME. If it is possible in the future to blend up to 5 % RME in diesel oil without having a higher taxation on the whole blend, this loss of tax revenues will increase to a level of maybe 160 million Euros. If the regulations (EC-directive and EN standard on gasoline) would allow up to 10 % ethanol blended in gasoline, the loss of tax revenues would substantially increase further.

## *5.6 Incentives and other legislation*

### 5.6.1 Authority’s vehicle fleets

In the governmental ordinance, SFS no: 2004:1364 (The Ministry of Industry) “Authorities purchase and leasing of environmentally friendly vehicles” regulations for purchasing and leasing of light-duty vehicles are defined with the purpose to increase the share of environmentally friendly vehicles owned by the government, authorities and similar organizations.

In the ordinance environmentally friendly vehicle are defined as a light-duty vehicles supplied with technology for the use, completely or partially, of electricity, alcohols or gas other than LPG. Furthermore the vehicle should belong to environmental class 2005, environmental class electricity or environmental class hybrid, as defined in Appendix 1 to the law (2001:1080) concerning vehicles exhaust after treatment technologies and vehicle motor fuels.

In the regulation is further declared that:

- At least half of the total amount of light -duty vehicles that authorities purchase or lease during a calendar year shall be environmentally friendly as defined above.
- Some types of vehicles, as for example emergency vehicles, vehicles with special safety arrangements etc do not have to be counted.

It is the responsibility of the Swedish Road Administration to verify and report to the government if the authorities purchase and lease their vehicles in line with the ordinance.

### 5.6.2 Taxation of official company cars used for private purposes

The Swedish authority for taxation issues has, according to a governmental authorization, issued instructions concerning valuation of the benefit of official company car used for private purposes.

According to the regulations a vehicle supplied with technology for the use - partly or completely - of fuels other than gasoline or diesel oil and if the price of the new car is higher than the price of a comparable vehicle without that technology, the value for taxation of the vehicle with the technology shall be adjusted to the value for the vehicle without the technology.

Furthermore the value for taxation for vehicles fuelled by alcohols or gas other than LPG shall bee adjusted to 80 % of the value for taxation of a comparable vehicle. However, the maximum reduction of the value is set to 875 Euros.

In a similar way the value for taxation of an electric vehicle or a hybrid electric vehicle shall be adjusted to 60 % of the value for taxation of a comparable vehicle. In this case the maximum reduction of the value is set to 1750 Euros.

For official company vehicles that can be fuelled with LPG, rapeseed methyl ester (RME) and other types of environmentally adapted fuels, the value for taxation shall be adjusted to the level of a comparable vehicle fuelled by gasoline or diesel oil.

### 5.6.3 Parking fees

Several municipalities in Sweden have decided to allow environmentally friendly vehicles to use parking lots free of charge, for which one normally has to pay a parking fee.

The number of municipalities is changing over time but it is steadily growing.

The definition of environmental friendly vehicles differs between the municipalities, but vehicles fuelled by neat alcohol (E85) and biogas are probably always included in the different definitions.

## *5.7 A national strategy*

July 3, 2003, the Swedish government decided to appoint a special investigator with the mission to propose national goals and strategies for a continued introduction of renewable vehicle fuels. The strategy should be adapted to the goals in the EC directive on the promotion of bio fuels and other renewable fuels.

Furthermore the investigator should look at the possibility to make it mandatory with at least one fuel pump for renewable fuels at every gasoline and diesel oil filling station and should also investigate the possibility to use any kind of so called “Green Certificates” to promote the introduction of renewable fuels.

In a report early spring 2004 the investigator presented a proposal concerning the idea to make it mandatory to have at least one fuel pump for renewable fuels at every gasoline and diesel oil filling station.

Based on the investigator’s proposal the government is currently preparing a bill concerning a new law that will enforce all gasoline and diesel oil filling stations, except for the smallest ones, to set up at least one pump for a renewable fuel such as ethanol, RME or biogas.

According to the latest information about this proposal such alternative fuel pumps should be installed at the latest by the end of 2006.

December 2004 the investigator presented his second and final report and his proposals in that report can be summarized as follows:

- The Swedish goal for the replacement of gasoline and diesel oil with a renewable fuel until 2010 shall be 5.75 %. This goal can easiest be reach by low blending of ethanol into gasoline and RME into diesel oil.
- The limit for ethanol low blending in gasoline should be increased to 10 % and for RME into diesel oil it should be increased to 5 %.
- The tax exemption for renewable fuels should cease in 2008 and should be replaced by a system based on “Green Certificates”.

# 6. Support programs

## 6.1 Local investment programs

Between 1998 and 2002 it has been possible for municipalities to apply for financial support to so called local investment programs (LIP) comprising investments and information measures in the field of environmental improvements. Initially the programmes were handled by the Ministry of the Environment. On January 1$^{st}$, 2002, the responsibility for the program was transferred to the Environmental Protection Agency.

A rather large number of Swedish municipalities have - together with companies, organizations and the inhabitants of the municipalities - under the local investment program “umbrella”, ,planned, proposed and carried out different kinds of environmental initiatives and /projects. The purpose of the programmes including the financial support for the programmes by the state has been to accelerate the realization of all those small steps forward and environmental improvements that are necessary in the municipalities, in order to reach the Swedish government’s overreaching environmental goals.

In December 2002, 211 programs in 161 municipalities had been granted financial support from the state with an average of 30 % of the total investment cost. In total 700 million Euros have been granted to local investment programs. Approximately 10 % of these total funds have been reserved for measures in the transport sector, including all kind of environmental improvements and approximately a quarter of this 10 % has been reserved for investments in environmentally friendly vehicles including investment in refuelling stations for alternative fuels. Together with funding supplied by the municipalities, companies, organisations etc, the total investment in environmentally friendly vehicles and refuelling stations for alternative fuels can be calculated to be approximately 80.5 million Euros.

The investments in the field of environmentally friendly vehicles and alternative fuel filling stations mainly focused on the introduction of vehicles fuelled with biogas, but also other alternative fuels such as ethanol (neat or blended with gasoline) and DME have occurred.

The LIP-projects on alternative fuels and their results have been evaluated and an analysed on behalf of the Swedish Environmental Protection Agency by Atrax Energi AB in cCo-operation with TFK – Transport Research Institute, AVL MTC AB and Miljökonsult B Goldstein result.

The result can be summarized as follows:

- In total, financial support has been granted to 87 measures in 41 programs in 32 separate municipalities.
- In total almost 1500 vehicles have been procured with financial state support from the local investment programs.

| | Biogas | Ethanol | Others |
|---|---|---|---|
| LD vehicles | 906 | 224 | 114 |
| LD Trucks | 22 | | 20 |
| HD Trucks | 66 | | 7 |
| Busses | 1122 | | 4 |

.

- In total 18 refuelling stations have been erected with financial support from de local investment programs.
- Especially for biogas, the LIP-support has had a clear positive effect on the procurement of vehicles and the erection of biogas refuelling stations.

| | Total in Sweden 2003 | Numbers with LIP financial support | Share of total with LIP-support |
|---|---|---|---|
| LD vehicles | 12487 | 1286 | 10 % |
| HD vehicles | 1100 | 194 | 18 % |
| Refuelling stations biogas | 34 | 18 | 47 % |
| Refuelling stations ethanol | 92 | 2 | 2,2 % |

- For future LIP-projects of the type being studied it is considered important to use more stringent demands/requirements in the procedure to decide if a project should be supported. Requirements should be prescribed for emission tests for production and distribution of the fuels, as well as production of standard models/patterns tests concerning emissions from vehicles (including emission factors). Using audit certificates is considered important for the economical follow-up of the projects.
- Two important elements for a successful project that have been identified while analyzing the responses to the inquiry are that environmental issues have a high priority in the municipalities and that there are dedicated people working in the project management, people that strongly believe in the project as well as in the future potential of the technologies that have been tested.
- Two important barriers that have been identified are unrealistic project budgets and lack of municipality financing of the projects, supplementary to the support from the LIP-program.
- The evaluation indicates that when the technology used in the project is already mature enough for a market introduction, mainly lessons about practical problems can be learned from the type of projects studied here. In line with that, this type of projects produces rather little information concerning the need for further research and development.
- Information about knowledge and experiences generated by the projects should preferably not only be disseminated within the own project group/municipality (receiving support from the LIP-program) but also to external parties, for example other municipalities and stakeholders interested in alternative automotive fuels. For most of the investigated projects this has not been done. External dissemination of

knowledge and experiences obtained during a project might be used as a criterion to grant future support from the LIP-program.

- It is proposed to start a thorough discussion concerning inter alia the specific goals of investing in environmentally friendly vehicles. Such a discussion should be based on knowledge about market conditions and political strategies. It should for example focus on the purpose of the procurement of the vehicles, how to give the right signals to the market and if procurements should be technically driven or not.
- The evaluation has shown that the reported figures on environmental impact have been obtained in many different ways. Since the criteria for obtaining LIP-support do not specify the model to be used for calculation of the environmental impact, the municipalities have used different models, often without any resemblance among them. Therefore, it has not been possible to come up with a relevant summary of the reported impact on the environment.

  Because of the lack of consistent data, new impact calculations have been carried out, based on basic data concerning production volumes, type and size of vehicle fleets, etc. An overarching calculation has been carried out concerning the environmental impact that will result of using the approximately 1500 vehicles emanating from the projects with LIP-support.

**Calculated emission reduction (kg per year) from the total amount of environmentally friendly vehicles with financial LIP-support (compared to the use of conventional fuel gasoline for LD-vehicles and diesel oil for HD-vehicles)**

| Fossil $CO_2$ | SOx | NOx | NMVOC | $CH^4$ | CO | Part |
|---|---|---|---|---|---|---|
| 5 936 000 | 515 | 26 920 | 800 | -2 030 | 5 610 | 520 |

**Calculated emission reduction (kg per year) from the total amount of environmentally friendly vehicles with financial LIP-support (including production and distribution of the fuel (biogas or ethanol)) (compared to the use of conventional fuel gasoline for LD-vehicles and diesel oil for HD-vehicles)**

| Fossil $CO_2$ | SOx | NOx | NMVOC | $CH_4$ | CO | Part |
|---|---|---|---|---|---|---|
| 5 915 700 | 1 130 | 26 235 | 4 145 | -46 000 | 5 540 | 400 |

- The municipalities have not included in their calculations the effect on the climate that is associated with the methane emissions from production, cleaning and upgrading of biogas. The range of the methane emissions is, however, of crucial importance to determine if the production, distribution and use of biogas in vehicles will give rise to an increased or decreased environmental or /climate impact. The other categories of greenhouse gas emissions arising from production and distribution of biogas are insignificant compared to the emissions from the use in vehicles. As a result, it can be assumed that the reduction of emissions of greenhouse gases calculated by the municipalities, and because of that also the reduced impact on the climate, might be overestimated. The magnitude of the environmental impact from production and use of biogas is strongly dependant on how the biological material otherwise would have been treated and is also dependant on the system boundaries that have been used for the calculation. It is also important to note that there is a relatively high potential for reducing methane emissions by further developments in biogas production, cleaning and upgrading technologies, compared to the situation today.

- It has not been possible to fully relate the environmental effects from the vehicles in the projects with support from the LIP-program to the estimated additional costs of these vehicles. It has not been possible to evaluate all observed effects. It has for example been difficult to get a clear grip on the extra maintenance costs for the light-duty vehicles. However, it can be concluded that the measures that have been studied turn out to give a positive net present value ratio, when the environmental investments are related to the environmental effects.

**Valuation of the emission reduction, compared to the use of conventional fuel gasoline for LD-vehicles and diesel oil for HD-vehicles (Calculated in Euros) from the total amount of environmentally friendly vehicles with financial LIP-support**

| Effects | Fossil $CO_2$ | SOx | NOx | NMVOC | $CH_4$ | PM |
|---|---|---|---|---|---|---|
| Local | | 3 235 | 20 273 | 1 005 | | 111 213 |
| Regional | | 1 180 | 182 404 | 2 710 | | |
| Global | 973 115 | | | | -6 984 | |
| Total | 973 115 | 4 415 | 202 677 | 3 715 | -6 984 | 111 213 |
| Total valuation | 121 288 151 Euro | | | | | |

**Valuation of the emission reduction, compared to the use of conventional fuel gasoline for LD-vehicles and diesel oil for HD-vehicles (Calculated in Euros) from the total amount of environmentally friendly vehicles with financial LIP-support (including production and upgrading of the fuel)**

| Effects | Fossil $CO_2$ | SOx | NOx | NMVOC | $CH_4$ | PM |
|---|---|---|---|---|---|---|
| Local | | 7 093 | 19 760 | 5 202 | | 85 541 |
| Regional | | 2 590 | 368 940 | 14 044 | | |
| Global | 969 792 | | | | -158 361 | |
| Total | 969 792 | 9 683 | 388 700 | 19 246 | -158 361 | 85 541 |
| Total valuation | 1 314 601 Euro | | | | | |

- The environmental benefits, per Euro invested by the state, emanating from the projects has been calculated and also appeared to be positive.

  **0.13 – 0.70 Euro, per Euro invested**

- The initial governmental investments have also to a great extent resulted in further municipal as well as private investments. This can be interpreted as a sign that the stakeholders see a good future potential in the measures taken.
- The majority of the municipalities have the opinion that the LIP-support is an efficient instrument to increase the use of alternative vehicle fuels. According to them, the support from the LIP-program also has pushed through investment decisions as well as accelerated the development in the area of alternative fuels. However, many have the opinion that the most important measure to significantly increase the use of alternative fuels is to adjust the fuel taxes with the purpose to reduce these taxes for the alternative fuels in comparison with today's conventional fuels.
- The LIP-support for distribution and use of alternative fuels has not in any obvious way stimulated technical developments in this area. It has neither contributed to the introduction and use of technologies that are not yet sufficiently mature for a market introduction.
- A large share of the respondents to the inquiry- that was a part of the evaluation - has declared that they would like to pursue their work and they think that introduction of alternative fuels is the right way for the future. From the motivations they have supplied it is, however, possible to assume that this opinion could be a result of their own will to adjust /confirm to already taken political decisions instead of their opinion being a result of the project as such.
- Based on the material that has been made available and the analysis of this material, it can be concluded that the LIP-projects have contributed significantly to the development of biogas production and the use of biogas vehicles in Sweden. The analysis also shows that the use of biogas as a vehicle fuel is environmentally advantageous, but that issues concerning other alternative use of the biogas and the leakage of methane strongly affect the result. The size of the projects that have been analyzed is not big enough to drive technical developments. Furthermore, these projects neither do not initiate an increasing interest in the automotive industry to produce alternative-fuelled vehicles.

The financial support to local investment programs ended in year 2002.

However, in year 2002 a new program was initiated with the purpose to give financial support to investment programs focused on reduction of the emissions of climate gases, the climate investment programs (KLIMP).

In a first stage a total of 92 million Euros was reserved for investments during 2002 – 2004.

## 6.2 Other support programs

As mentioned in Chapter 2 there has been a financial support programs on research, development and demonstration of production of ethanol from cellulose (lingo-cellulosic raw material??), which is handled by the Energy Authority. The program that ran between 1998 and 2003 had a total budget of 23 million Euros. The result of the program is inter alia a pilot plant for R&D that is constructed in Örnsköldvik and operated by ETEK Etanolteknik AB. Se section 4.5 for further information about ETEK.

Today also other alternative fuel production research is being performed on fuels such as methanol, DME and synthetic diesel produced from gasified biomass (Fischer-Tropsch Technique). The Swedish Energy Authority handles these projects. The financial support for R.D&D during the time period 2003-01-01 until 2006-12-31, the FALT – program, has been set to approximately 6 million Euros.

Besides the FALT program there are also different kinds of financial support from the Energy Authority for R&D demonstration plants concerning gasification of biomass (Värnamo) and black liquor (Piteå).

There is also a financial research and development support program running concerning research and development in the field of engine technology. Either the Energy Authority or the authority NUTEK handle these programs

# 7. Bio-ethanol

## *7.1 Buses*

Between 1990 and 1993 a fleet test with a total 32 ethanol- fuelled Scania buses was carried out in Stockholm by AB Storstockholms Public Traffic Company (SL).

The project was carried out in two phases. The first phase ran in 1990 – 1992 and the second phase in 1992 – 1993. The project was carried out in close co-operation with Scaniabussar AB, Katrineholm, Saab-Scania AB, Scaniadivissionen, Södertälje and Svensk Etanolkemi AB (SEKAB), Örnsköldsvik.

The goal of the project was to study the possibility to improve the emission values (quantitative and qualitative) from the busses by using ethanol instead of diesel fuel in ethanol adapted buses/engines.

FurtherOther goals of the project were inter alia:

- To study how to best mix the ethanol and ignition improver
- How to distribute the ethanol mix and how to fuel the busses.
- To build a station for mixing and loading [for ethanol fuel?]out in Örnsköldvik
- To build up specialized services and maintenance capacity at the bus depot in Stockholm.
- To carry out an information program for politicians, people living in Stockholm and market stakeholders.

The buses were equipped with oxidizing catalysts. The purpose of the exhaust catalysts was catalytic burning of the exhaust emissions of acetic aldehydes resulting from ethanol combustion.

The Iignition improver was added (2 %) to increase the cetane number of ethanol which otherwise is too low for the use of ethanol as a fuel for a compression ignition/diesel engine. In order to To reduce the need of ignition improver, as far as possible the compression ratio of the engines was increased.

A program for characterization of the exhaust emissions from ethanol use was carried out and showed a substantially reduction of the emission levels of NOx, CO and HC compared to the use of diesel oil.

The running costs for the ethanol buses were higher than for buses running on diesel oil. This was mainly caused by:

- A higher price for the ethanol fuel compared to diesel oil (40 % higher)
- A higher fuel consumption because of the lower energy content in ethanol compared to diesel oil.
- Higher service and maintenance costs because of a higher frequency in services intervals (380 Euros per bus and per year).

The costs for the project were calculated to be 5200 Euros [M/k € ????] for phase one and 5800 Euros [k € ???] for phase two. The project was financed by:

- Stockholm Public Traffic Company (Municipality owned) AB Storstockholms Lokaltrafik (SL) (2500 Euros) [k € ???]
- The government through different authorities (8500 Euros). [k € ???]

The results of the project was were so promising that the public traffic transport company in Stockholm, (SL), decided to continue running the busses on ethanol and to increase the number of ethanol fuelled buses to such an extent that all inner- city buses (approximately 200 - 300) would be running on ethanol.

One problem with the first ethanol fuelled buses was a slight smell coming from the emissions of unburned ethanol, basicly from acetic acid and acetic aldehyde. From early 2000 onwards this problem is more or less solved by the introduction of new and more effective catalytic converter technology.

In parallel to SL': s increasing use of ethanol buses, other municipalities and public transportation companies decided to - at least to some extent - change from diesel- buses to ethanol buses.

According to figures from SEKAB, there are 398 ethanol buses running in Sweden today.

**Number of ethanol fuelled buses in Sweden, May 2005**

| Municipality | |
|---|---|
| Stockholm | 250 |
| Umeå | 32 |
| Borås | 18 |
| Helsingborg | 16 |
| Falun | 15 |
| Örnsköldvik | 14 |
| Skövde | 12 |
| Halmstad | 11 |
| Sundsvall | 10 |
| Norrköping | 9 |
| Luleå | 8 |
| Mariestad | |
| Total | 398 |

During 2004 SEKAB delivered approximately 18, 000 $m^3$ ethanol fuel (ETAMAX D) for adapted diesel engines to bus companies in Sweden.

In 2003, Scania announced that they would stop cease the production of ethanol heavy-duty engines. Scania gave as the reason behind this decision that the demand for ethanol buses was too low to motivate a production line for this type of engines. As a result of that the municipality of Stockholm and the local public traffic company decided to start planning for a shift from ethanol fuelled busses to biogas-fuelled busses.

Today, 21 of the buses operating on inner-city lines are fuelled by biogas and the remaining buses by ethanol. However, after discussions and requests from public transportation companies inter alia, Scania has decided to continue the production of heavy-duty engines adapted for ethanol. The public transportation company in Stockholm has ordered 90 new ,furthermore,ethanol buses. Furthermore, there are discussions going on to set up a consortium of different interests in ethanol- fuelled heavy-duty engines, by municipalities and transportation companies etc. The goal of the consortium will be to come up with a joint order for ethanol-fuelled, buses for Scania. The order should have such a size that it makes it economically feasible for Scania to continue the production of ethanol engines also in a longer perspective.

Even though today it is again possible to buy ethanol-fuelled buses from Scania, the public transportation company in Stockholm has decided to continue the shift from ethanol fuelled buses to biogas buses for the inner city of Stockholm. However, the number of busses today by ,ethanol busses in , operated ethanol buses and new ordered ethanol busses that will be put in service shall in parallel to the introduction of biogas busses, be operating in the suburbs of Stockholm.

It is difficult to get information about the price of ethanol fuel for adapted diesel engines. Probably ethanol fuel is bit slightly higher more expensive than for diesel oil, and in addition to that comes the fact that the ethanol fuel has a lower energy content compared to diesel oil.

## *7.2 Flexible Fuel Vehicles (FFV)*

In early 1990's a Ford manufacturer [importer/dealer??] in Örnsköldsvik (Carstedts Motor AB) started to import Flexible Fuel Vehicles (Ford Taurus), adapted to run on gasoline as well as on an ethanol fuel containing 15 % gasoline (E85). The gasoline is added to enable to start the engine even when the temperature is far below  °C, as to enhance fale visiblity.

In 1994, the first Swedish filling station for E85 was opened in Örnsköldsvik.

People and companies etc, that were interested in the FFV Ford Taurus, could lease a car from the Ford manufacturer/importer. Because of legal problems, it was not possible however, for private persons in Sweden to buy one of these cars.

The number of Ford Taurus cars increased over the years and simultaneously the number of filling station that could offer E85 increased. The introduction of FFV and E85 was supported by BAFF (SSEU at that time) and SEKAB, and the Oil Company OK promised to set up a filling station in every municipality with at least 5 FFVs.

One problem for an increased use of FFV: s was that the available number of Ford Taurus cars was limited and that these cars only could be leased. Another problem was that the car was hey often were considered as being to be too big, to be used for example by service companies, municipalities etc.

### 7.2.1 Technical procurement

In 1997, the Environmental Technology Delegation and the municipality of Stockholm initiated a discussion. In 1998 this resulted in the establishment of a technical procurement consortium, the Swedish FFV Buyers Consortium (SFFVBC). The aim of the Consortium was to ensure that a new and smaller type of FFV should be marketed in Sweden for a reasonable price.

Initially a project group carried out the operative work of the consortium as with representatives from:

- The municipality of Stockholm
- Auto Emission Consultant KEE AB
- OK (petroleum company)
- The Swedish Road Administration
- KFB
- The Environmental Technology Delegation

The tasks for the project group were to:

- Analyse the prerequisites for a joint procurement of FFV: s
- First contacts with possible buyers and marketing companies.
- Preliminary decision on type of vehicle
- Preliminary decision on procurement form
- Proposal for a product specification including energy efficiency/fuel consumption, emissions etc.
- Proposal for a consortium agreement.

An inquiry concerning the interest among possible buyers that was carried out between May and June, 1998, and had as result those 200 organizations declared to be interested to buy altogether approximately 3200 vehicles of FFV-type.

In August 1998 the consortium and an executive committee were established. After dinga tender had been distributed and negotiations, had followed the Ford Motor Company finally offered to deliver a FFV that fulfilled the product specification, namely FFV Ford Focus with 1.6 litres engine, with the condition that the members of the consortium would purchase at least 4000 vehicles during a two-2 year period.

In May 2000, the number of interested clients had reached a number of 3000 and Ford decided that this was sufficient to start the production of the Ford Focus FFV for delivery between September 2001 and June 2003. The price that Ford finally asked for the FFV Ford Focus was approximately 500 Euros below the price of an equivalent gasoline Ford Focus vehicle.

The FFV procurement project was financially supported by the government, through the LIP-program. From a cost effectiveness perspective it can be concluded that a financial support of 100 Euros per delivered FFV Ford Focus has resulted in a product with a price that is 500 Euro below the price for a gasoline Ford Focus.

Since this procurement was finalized, the number of FFV Ford Focus in Sweden has continued to grow, and today FFV Ford Focus in Sweden counts approximately 14 000 vehicles.

Until 2005 the Ford Focus and those Ford Taurus cars still running were the only FFV models available in Sweden. However, spring in 2005 SAAB Motor Company has introduced a FFV version of its model SAAB 9.5. Volvo has also announced that it will in the autumn of 2005 introduce FFV versions of the Volvo S40 and Volvo V50.

An estimation made by BAFF concerning the number of FFV: s in the future predicts that in 2009 Sweden will have about 300 000 FFV: s (7 % of the total light-duty fleet in Sweden) and 450 000 FFV: s 2011 (10 % of the total light-duty fleet in Sweden).

## 7.3 Production potential

If all agriculture land that is available for growing crops for technical purposes, like vehicle fuels, would be used to grow grain, approximately 300 000 $m^3$ ethanol could be produced annually from that grain. That would allow blending of 5 % ethanol in all gasoline that is used annually in Sweden.

Today almost all gasoline in Sweden is already blended with 5 % ethanol. However, the ethanol predominantly comes from importing European surplus wine ethanol and Brazilian sugar cane ethanol. Only 50 000 $m^3$ of the total volume of 300 000 $m^3$ is produced in Sweden and steams from grain cultivated in Sweden.

The agricultural land that is available for growing biomass for technical purposes might in the future also be used to grow for example rapeseed to produce RME or it might be used for energy forests or other energy crops for the production of biogas.

However, the figures on the amount of land that is available for energy production are among others depending on agricultural policies on a European level and may change when these policies change.

When the technology for ethanol production from cellulose, as for example forest residuals or straw, is mature and ready for a market introduction the supply of raw material will increase substantially and with that the possibility to use domestic produced bio-ethanol. However it is not sure that the production costs of domestic bio-ethanol produced from grain, or in the distant future cellulose, will be competitive with Brazilian bio-ethanol or for example bio ethanol from East Asia.

## *7.3 E85 filling station infrastructure*

As mentioned earlier the first filling station for E85 was opened in 1994 in Örnsköldsvik. Since then the number of filling station has grow during the years and in 2004 station number 100 was erected.

Furthermore, from 2004 until today the number of filling stations has grown from 100 to166, and it is still increasing. There seems to bee a “snowball” effect and now the ball is not just rolling, but even strongly accelerating.

The filling stations for FFV fuel are more or less spread out over the whole country. For more information, see the FFV filling station appendix.

As mentioned earlier in the beginning the oil company OK supported the introduction of E 85 by erecting filling stations in each municipality with a minimum number of FFV: s. Today BioFuel Region and SEKAB, also mentioned before, support the erection of new filling stations and especially flexible once that offer the client a possibility to choose the mix between gasoline and ethanol.

When installing a pump for FFV fuel there may be some extra costs. If the FFV fuel pump is installed when an old gasoline pump had to be replaced anyway (approximately every 5:th year at larger fuel stations) the additional costs are marginal, if the new pump is a stationary E85 pump without the possibility to change the mix of gasoline and ethanol. If the new pump is a flexible one, the extra cost will be in the range of 3300 to 5500 Euros. If the storage tank is not resistant to ethanol and has to be replaced, that will result in further extra cost between 16 400 to 33 000 Euros.

During 2004 SEKAB delivered approximately 6500 m3 ETAMAX B (E85 fuel) to filling stations in Sweden.

The price of E85 follows the price of gasoline and is slightly different between different filling stations. In May 2005 the price for one litre of E85 was 0.87 Euro, while the price for 1 litre of gasoline with an octane rating of 95 was 1.17 Euros. The lower price compensates for the lower energy content in ethanol compared to gasoline, but as already mentioned the lower energy content is already to some extent compensated by the higher octane number of ethanol compared to gasoline. With the price level as it was in May in Sweden, it would probably be somewhat cheaper to use E85 instead of gasoline.

# 8. Biogas

The composition of biogas for vehicle use is more or less the same as natural gas for vehicle use. The “raw” biogas as it comes from the production unit (anaerobic digestion) has methane content of about 60 %, the rest is mainly carbon dioxide plus different contaminations, often sulphuric compounds. After upgrading/cleaning of the “raw” gas, the biogas/bio based vehicle gas has a methane content of about 97 %. However, the energy content is still somewhat lower than for natural gas since the biogas does not have components with higher energy content such as butane that occurs in natural gas.

The use of methane for vehicle purposes was introduced in Sweden in the late 1980-ties and early 1990-ties. The technology for use in light-duty vehicles with spark ignition engines (gasoline engines) was already well known and so called bi-fuel cars that could use both gasoline and methane were on the market. Although primarily adapted for natural gas, these cars could easily be optimised for biogas.

However, for the use of methane in heavy-duty vehicles with compression ignition engines (diesel engines) these engines had to be more or less reconstructed into spark ignition engines with spark- or glow plugs.

## *8.1 Biogas as vehicle fuel*

At first the use of biogas started with some small test fleets, often a couple of buses in a municipality owned public transportation company fleet.

One of the first actors at that time was the Municipality of Linköping acting through its own company Tekniska Verken Linköping and Linköping Biogas AB. At first, the gas was upgraded gas from the municipality owned sewage treatment plant. In 1992, 5 buses were running on biogas and the biogas filling station was situated at the sewage treatment plant. After a while the number of buses increased and a pipeline was built to transport the upgraded gas to the bus terminal a couple of kilometres away from the sewage treatment plant.

A plant for production of biogas from agricultural, slaughterhouse and food industry residues was opened in 1997. Until then biogas had mainly been produced as a rest product from the treatment of sewage sludge. Now the raw material was not sewage sludge anymore although the plant still could be said to bee mainly built for residual treatment rather than biogas production. At that time also a public filling station was also constructed and some of the municipality owned light-duty vehicles plus some private owned light-duty vehicles were running on biogas.

From 1997 onwards the production of biogas in the Linköping plant has steadily increased and today the production is around 4.5 million normal $m^3$ upgraded vehicle gas per year. This biogas plus some biogas from the sewage treatment plant are used as fuel for all of the 65 city buses in Linköping. The biogas from the sewage treatment plant is more or less used as compensation to meet the demand on days with a high consumption of biogas.

The number of public filling station has grown from one to eight and in the near future two more will be built. Since most of the filling stations are rather far from the production plant the distribution of gas is carried out by trucks

Initially the biogas production plant was owned by the municipality of Linköping together with the Swedish Farmers association and the Swedish slaughter companies association but today the plant is owned solely by the municipality of Linköping through its company Svensk Biogas AB.

An upcoming project concerning biogas and with interests from the municipality of Linköping involved are:

- The erection of a new production for biogas in Norrköping, a town not far away from Linköping
- The fuelling of local trains going from Linköping to Västervik with biogas.

The plant in Norrköping is scheduled to use raw material coming from dedicated agricultural production sector and the slop from production of ethanol from wheat. The slop is otherwise used for production of animal fodder. No residues from slaughterhouses etc will be used. As a consequence, there will be no need of hygienezation/sterilization of the sludge to avoid the risk of health impacts etc.

Therefore this “new” kind of biogas will be named “Green Gas”, to make clear that the raw material is from the agricultural sector and that the plant is built to produce gas from a fresh (or dedicated?) raw material and not for the purpose taking care of residues. In line with this it will also be possible to use the by-products from the biogas production, the anaerobic digested sludge, as a fertilizer for agriculture land. Because of contamination of for example heavy metals, this is not possible with anaerobic treated sludge from sewage treatment plants. The plant in Norrköping will have a production capacity of 2 million normal $m^3$ upgraded vehicle gas. The investment cost is estimated at 3.8 million Euros. The same type of plant but including sludge hygienezation/sterilization can be estimated to have approximately 20 % higher investment cost. Furthermore the running costs for a plant including hygienezation/sterilization will be substantially higher than without this process step since the hygienezation/sterilization step demands heat/steam in significant quantities.

Svensk Biogas AB is also planning to build five more Green Gas plants during the coming 6 years. These plants will be situated close to the existing natural gas pipeline on the Swedish West coast. The idea behind this is to use the natural gas pipeline for the distribution of biogas. The volume of biogas pumped into the natural gas pipeline will then be used in refuelling stations along the pipeline. Of course the gas that will refill the cars will not be exactly the same gas that is pumped in, but this does not matter since both types of gas in the pipeline are more or less neat methane. The only thing that matters are that not more gas should be used for vehicle purposes than the biogas that has been pumped in to the system. As soon as more gas is used this amount of gas has to be regarded as natural gas and not biogas. The same system is used in Sweden for distributing and using so called “green electricity” produced from other sources than oil and coal.

The use of biogas as a vehicle fuel has grown steadily over the years and today biogas for vehicle purposes is produced and used in about 20 Swedish municipalities while about five municipalities have introduced biogas as a fuel for public transportation (buses) on a large scale

Besides Linköping biogas is today produced from different kind of residues in Helsingborg, Eslöv, Kalmar, Uppsala, Kristianstad, Skövde and Västerås.

All other biogas production in Sweden, including biogas for vehicle use, comes from treatment of sewage sludge.

### 8.1.1 Vehicles, filling stations, produced volume

Below is presented figures from the Swedish Gas association concerning the numbers of gas vehicles, gas filling stations and sold gas volume for the years 2001 – 2004.

These figures include vehicles running on and filling station for natural gas as well as volume sold methane for vehicle purposes.

**Number of vehicles**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|
| LD-Vehicle. | 20 | 35 | 395 | 759 | 1008 | 1292 |
| HD-Vehicle | 0 | 18 | 35 | 55 | 84 | 103 |
| Busses | 24 | 151 | 227 | 265 | 282 | 330 |
| Total | 44 | 204 | 657 | 1079 | 1374 | 1725 |

**Number of filling stations**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|
| Public | 1 | 3 | 7 | 12 | 15 | 18 |
| Buss | 1 | 5 | 7 | 7 | 7 | 8 |
| Total | 2 | 8 | 14 | 19 | 22 | 26 |

**Sold volume gas (kNm$^3$)**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|
| Natural gas | 986 | 4213 | 6017 | 7086 | 7552 | 9010 |
| Biogas | 0 | 95 | 1120 | 2776 | 3783 | 4940 |
| Total | 986 | 4308 | 7137 | 9862 | 11335 | 13950 |

**Number of vehicles, filling stations and sold volume gas per year (kMm3) for each involved municipality, 2001-12-31**

| | VEHICLES | | | | Filling stations | | | Sold Volume | |
|---|---|---|---|---|---|---|---|---|---|
| Municipality | LD-vehicles | HD-trucks | Busses | Total | Public | Bus | Total | Natural Gas | Biogas |
| Eslöv | | | | 0 | | | 0 | | |
| Falkenberg | | | | 0 | | | 0 | | |
| Gislaved | | | | 0 | | | 0 | | |
| Gnosjö | | | | 0 | | | 0 | | |
| Göteborg | 649 | 48 | 67 | 764 | 4 | 2 | 6 | 3 183 | 931 |
| Halmstad | | | | 0 | | | 0 | | |
| Helsing borg | 61 | 10 | | 71 | 1 | | 1 | 138 | 55 |
| Jönköping | 27 | 1 | | 28 | 1 | | 1 | | 44 |
| Kalmar | 35 | 3 | | 38 | 1 | 1 | 2 | | 80 |
| Kristianstad | | | | 0 | | | 0 | | |
| Laholm | | | | 0 | | | 0 | | |
| Lerum | 3 | | | 3 | | | 0 | | |
| Lilla Edet | | | | 0 | | | 0 | | |
| Linköping | 67 | 6 | 60 | 133 | 2 | 1 | 3 | | 3332 |
| Lund | | | | 0 | | | 0 | | |
| Malmö | 146 | 41 | 217 | 404 | 6 | 4 | 10 | 7048 | 398 |
| Mölndal | 5 | | | 5 | 1 | | 1 | | |
| Partille | 4 | | | 4 | | | 0 | | |
| Skövde | | | | 0 | | | 0 | | |
| Stockholm | 400 | 7 | | 407 | 4 | | 4 | | 306 |
| Uppsala | 12 | 0 | 46 | 58 | | 1 | 1 | | 740 |
| Trollhättan | 70 | 5 | 10 | 85 | 1 | 1 | 2 | | 423 |
| Total | 1479 | 121 | 400 | 2000 | 21 | 10 | 31 | 10369 | 6309 |

**Number of vehicles, filling stations and sold volume gas per year (kMm3) for each involved municipality, 2002-12-31**

| | VEHICLES | | | | Filling stations | | | Sold Volume | |
|---|---|---|---|---|---|---|---|---|---|
| Municipality | LD-vehicles | HD-trucks | Buses | Total | Public | Bus | Total | Natural Gas | Biogas |
| Eslöv | | | | 0 | | | 0 | | |
| Falkenberg | | | | 0 | | | 0 | | |
| Gislaved | | | | 0 | | | 0 | | |
| Gnosjö | | | | 0 | | | 0 | | |
| Göteborg | 1338 | 63 | 70 | 1471 | 5 | 2 | 7 | 3 292 | 2 193 |
| Halmstad | | | | 0 | | | 0 | | |
| Helsing borg | 76 | 11 | | 87 | 2 | | 2 | 98 | 160 |
| Jönköping | 51 | 1 | | 52 | 1 | | 1 | | 99 |
| Kalmar | 35 | 3 | | 38 | 1 | 1 | 2 | | 66 |
| Kristianstad | | | | 0 | | | 0 | | |
| Laholm | | | | 0 | | | 0 | | |
| Lerum | 5 | | | 5 | 1 | | 1 | | |
| Lilla Edet | 15 | | | 15 | 1 | | 1 | | |
| Linköping | 128 | 12 | 64 | 204 | 2 | 1 | 3 | | 3 598 |
| Lund | | | | 0 | 2 | | 2 | 49 | |
| Malmö | 471 | 70 | 229 | 770 | 8 | 4 | 12 | 7 861 | 597 |
| Mölndal | 9 | | | 9 | 1 | | 1 | | |
| Partille | 6 | | | 6 | | | 0 | | |
| Skövde | 13 | | | 13 | | | 0 | | |
| Stockholm | 450 | 10 | | 460 | 4 | | 4 | | 361 |
| Uppsala | 23 | 1 | 46 | 70 | | 1 | 1 | | 1200 |
| Trollhättan | 92 | 7 | 10 | 109 | 1 | 1 | 2 | | 551 |
| Total | 2712 | 178 | 419 | 3309 | 29 | 10 | 39 | 11 300 | 8 825 |

**Number of vehicles, filling stations and sold volume gas per year (kMm3) for each involved municipality, 2003-12-31**

| | VEHICLES | | | Filling stations | | Sold Volume | | | |
|---|---|---|---|---|---|---|---|---|---|
| Municipality | LD-vehicles | HD-trucks | Buses | Total | Public | Bus | Total | Natural Gas | Biogas |
| Borås | 40 | 9 | | 49 | 1 | | 1 | 0 | 88 |
| Eskilstuna | | | 10 | 10 | | 1 | 1 | | 262 |
| Eslöv | | | | 0 | | | 0 | | |
| Falkenberg | | | | 0 | | | 0 | | |
| Gislaved | | | | 0 | | | 0 | | |
| Gnosjö | | | | 0 | | | 0 | | |
| Göteborg | 1787 | 61 | 93 | 1941 | 6 | 2 | 8 | 3 760 | 3 195 |
| Halmstad | | | | 0 | | | 0 | | |
| Helsing borg | 77 | 14 | | 91 | 2 | | 2 | 83 | 236 |
| Jönköping | 98 | 2 | | 100 | 1 | | 1 | | 135 |
| Kalmar | 30 | 3 | | 33 | 1 | 1 | 2 | | 50 |
| Katrineholm | 6 | | | 6 | 1 | | 1 | | 4 |
| Kristianstad | 74 | 4 | 22 | 100 | 1 | 2 | 3 | | 978 |
| Laholm | | | | 0 | | | 0 | | |
| Lerum | | | | 0 | 1 | | 1 | 105 | |
| Lilla Edet | 20 | | | 20 | 1 | | 1 | | |
| Linköping | 250 | 12 | 64 | 326 | 2 | 1 | 3 | | 3 948 |
| Lund | 15 | 15 | 24 | 54 | 2 | 1 | 3 | 1355 | |
| Malmö | 563 | 41 | 210 | 814 | 8 | 3 | 11 | 8 473 | 218 |
| Mölndal | | | | 0 | 1 | | 1 | 225 | |
| Partille | 0 | | | 0 | 1 | | 1 | 86 | |
| Skövde | 30 | | | 30 | 1 | | 1 | | 26 |
| Stockholm | 450 | 22 | 1 | 473 | 4 | | 4 | | 527 |
| Ulricehamn | 10 | | | 10 | | | 0 | | |
| Uppsala | 25 | | 46 | 71 | | 1 | 1 | | 1014 |
| Trollhättan | 100 | 8 | 12 | 120 | 1 | 1 | 2 | | 666 |
| Total | 3 575 | 191 | 482 | 4248 | 35 | 13 | 48 | 14 087 | 11 347 |

**Number of vehicles, filling stations and sold volume gas per year (kMm3) for each involved municipality, 2004-12-31**

| | VEHICLES | | | Filling stations | | Sold Volume | | | |
|---|---|---|---|---|---|---|---|---|---|
| Municipality | LD-vehicles | HD-trucks | Buses | Total | Public | Bus | Total | Natural Gas | Biogas |
| Borås | 60 | 7 | 13 | 80 | 1 | 1 | 2 | 0 | 303 |
| Eskilstuna | 5 | 1 | 10 | 16 | 1 | 1 | 2 | | 388 |
| Eslöv | 61 | 2 | 4 | 67 | 1 | 1 | 2 | | 287 |
| Falkenberg | 5 | | | 5 | 1 | | 1 | 24 | |
| Gislaved | 14 | | | 14 | 1 | | 1 | 31 | |
| Gnosjö | 6 | | | 6 | 1 | | 1 | 7 | |
| Göteborg | 2611 | 66 | 95 | 2 772 | 6 | 2 | 8 | 5 219 | 2 119 |
| Halmstad | 28 | 3 | | 31 | 1 | | 1 | 88 | |
| Helsing borg | 102 | 18 | | 120 | 2 | | 2 | 92 | 330 |
| Jönköping | 130 | 2 | 0 | 132 | 1 | | 1 | | 200 |
| Kalmar | 30 | 2 | | 32 | 1 | 1 | 2 | | 58 |
| Katrineholm | 34 | 3 | 0 | 37 | 1 | 0 | 1 | | 72 |
| Kristianstad | 128 | 5 | 25 | 158 | 2 | 1 | 3 | | 1094 |
| Laholm | 10 | | | 10 | 1 | | 1 | 44 | |
| Lerum | | | | 0 | 1 | | 1 | 135 | |
| Lilla Edet | 20 | | | 20 | 1 | | 1 | | |
| Linköping | 469 | 14 | 64 | 547 | 4 | 1 | 5 | | 4 352 |
| Lund | 25 | 20 | 24 | 69 | 2 | 1 | 3 | 1418 | |
| Malmö | 653 | 49 | 196 | 898 | 4 | 3 | 7 | 8 430 | 218 |
| Mölndal | | | | 0 | 1 | | 1 | 272 | |
| Norrköping | 40 | 2 | 18 | 60 | 2 | 1 | 3 | | 513 |
| Nyköping | 3 | | | 3 | 1 | | 1 | | 1 |
| Partille | 0 | | | 0 | 1 | | 1 | 174 | |
| Skövde | 0 | | | 0 | 1 | | 1 | | 67 |
| Stockholm | 555 | 24 | 21 | 600 | 4 | 2 | 6 | | 1 096 |
| Ulricehamn | 10 | | | 10 | | | 0 | | 10 |
| Uppsala | 25 | | 46 | 71 | | 1 | 1 | | 1 130 |
| Trollhättan | 120 | 11 | 17 | 148 | 1 | 1 | 2 | | 842 |
| Västerås | 10 | | 16 | 26 | 1 | 1 | 2 | | 67 |
| Ängelholm | 10 | 9 | | 19 | 1 | | 1 | 2 | |
| Åstorp | 8 | | | 8 | 1 | | 1 | 7 | |
| Total | 5172 | 238 | 548 | 5958 | 47 | 18 | 65 | 15 943 | 12 929 |

The municipality of Stockholm has since the middle of the 1990's in different ways supported the use of biogas for vehicle purposes, mainly for use in LD-vehicles in for example the municipality owned LD-vehicle fleet.

However, Stockholm does not use any residues for biogas production. The gas used comes solely from the treatment of sewage sludge in the Henriksdal and the Åkeshov sewage treatment plants. Today Åkeshov delivers approximately 900 000 $Nm^3$ upgraded biogas for vehicle purposes while Henriksdal delivers 600 000 $Nm^3$ upgraded biogas. It is planned that in the near future Åkeshov will deliver 2 million $Nm^3$ to the public biogas stations in

Stockholm and Henriksdal will deliver approximately 6 million $Nm^3$, for use in the public transportation bus fleet.

Stockholm has since the mid 1990's prioritised ethanol as a fuel for the city buses. However, today the plans are to introduce biogas as a fuel for the inner city busses while ethanol will be used in buses serving the Stockholm suburbs.

Today 21 buses are running on biogas, but when the biogas capacity has reached 6 million $Nm^3$ per year, altogether 120 buses will be running on biogas.

Gas-fueled (methane) vehicles are generally more expensive to produce than vehicles running on gasoline or diesel. Buying a light-duty vehicle is approximately 3300 Euros more expensive than the same model running on gasoline. This figure for buses is approximately 34 000 Euros. The extra costs are mainly related to the gas storage tanks. These extra costs are compensated today by a lower energy price, calculated per unit of energy. Biogas is available on the market today for a price that is slightly lower, calculated on an energy basis, than the price of gasoline. The idea is that at least the extra costs for purchasing a light-duty vehicle after fully compensated after 3 to 5 years of normal use. This is also the case for natural gas.

Concerning service and maintenance the costs for light-duty vehicles, those are the same for vehicles running on methane as for vehicles running on neat gasoline. However, for heavy-duty engines/buses the service and maintenance costs are higher for buses running on methane compared to buses running on diesel oil. This comes in first hand from the need of shorter intervals for replacement of spark plugs and engine oil.

The cost to build a gas filling station can be estimated to be about 330 000 Euros including compressing station, methane storage (2000 – 3500 $Nm^3$) and dispenser. There will be additional costs for installation and inspection of approximately 55 000 Euros. In case that gas has to be transported to filling stations by truck, this will add to selling price of gas. In the future, along with the erection of growing numbers of gas filling stations, the cost of a gas station will probably come down substantially.

### 8.1.2 Production potential

The potential supply of raw material for the production of biogas, for a competitive price, has been discussed for a long time. This issue is of course depending on the fact if the biogas is produced from residues as a part of a necessary process to take care of these residues so it can be regarded as a residue itself, or if the biogas shall be regarded as a high quality fuel produced from raw material only with the purpose to produce the fuel. In the first case one might even take into account that the producer of the biogas might get paid for taking care of the residuals. In the other case a producer of biogas will be forced to pay the market price for the raw material. Depending on the future policy on biogas all options in between these two situations have to be considered.

Concerning the supply of raw material, the opinions among experts and researcher are diverse. Different ways of taking the possibilities to take care of the residues of different sectors into account will produce different results. For example up to which distance can residues bee transported while still being made available at a competitive price? Or how to estimate [valuate?] the risk of competition with other applications, for example using garbage as a raw material for heating purposes?

In a study from Jordbrukstekniska Institutet (JTI) in 1997-1998, the total Swedish biogas potential was estimated to be 17.4 TWh annually. The agricultural sector counted for the major part of the feedstock potential.

In order to estimate future biogas potentials a new estimate for different substrate categories has been made by BioMil AB and Svesnkt Gastekniskt Center (SGC). The results are compared with the JTI report in the table below.

**Biogas potential estimated by JTI and BioMillAB/SGC**

| **Substrate** | **Biogas potential within 10 years (GWh/year) JTI** | **Adjusted biogas potential (GWh/year) BioMill/SGC** | **Comments** |
|---|---|---|---|
| Specially grown crops | 3250 | 7190 | 10 % of agricultural land, mix of crops |
| Manure | 2940 | 2560 | Reduced live stock |
| Straw | 7140 | 0 | |
| Tops and potato refuse | 920 | 920 | |
| Chaff | 60 | 60 | |
| Organic household waste | 600 | 940 | |
| Garden waste | 230 | 230 | |
| Organic waste from restaurants and food industry | 60 | 0 | Now included in the household waste |
| Park waste | 240 | 240 | |
| Municipal sewage sludge | 970 | 970 | |
| Private sludge | 30 | 30 | |
| Paper and paper pulp industry | 110 | 90 | Two plants have been converted to aerobic treatment process |
| Other industry | 820 | 820 | |
| **Total** | **17 370** | **14050** | |

The main difference between the estimates concerning the biogas potential is that straw has been excluded and that the acreage with specially grown crops has been increased from 6 to 10 %. Furthermore the yield from crops has been increased as a result of the inclusion of sugar beet and corn in the mix of crops grown.

The total estimate made by BioMil AB and SGC is now 14 TWh.

However, is it important to mention that the JTI estimate has been criticized by other experts several times and of course also by stakeholders with interest in alternative fuels, residues and the oil industry. In the most pessimistic estimates concerning the potential for production of biogas a figure of 1.5 up to 2.5 TWh has been mentioned.

# 9. Public acceptance

Concerning Flexible Fuel Vehicles (FFV) in Sweden there has more or less never been any problems concerning public acceptance. There seems to always have been a clear interest among private persons, municipalities and companies concerning these kinds of vehicles. Since it has been possible to purchase these vehicles for the same or even a lower price as a similar vehicle felled by gasoline, purchasing a FFV has probably been a very easy way to contribute to the reduction of the emissions of greenhouse gases as well as giving your company a "green profile".

The only real problem for FFV`s in Sweden has been that only one vehicle was available:
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- At first the Ford Taurus was too big for some people and some purposes.
- Later the Ford Focus might have been too small, at least if one prefers fast and fancy car. This problem is probably solved today because soon one can buy also the SAAB 9.5, Volvo S40 and Volvo V50 in FFV-versions.

Another problem might have been that for a long time the lack of ethanol filling stations made people that had bought a FFV more or less only use gasoline to avoid large detours for filling up. With the increasing number of ethanol stations today this problem is diminishing.

Concerning biogas-fuelled vehicles the problem with the lack of different models has probably been the same. In this case the lack of filling station has probably been more obvious, since there were very few filling stations for a long and because they were often located at industrial sites, bus depot etc.

Another problem has been that people with environmental concerns did not want to use gasoline and perhaps therefore regarded the bi-fuel vehicles as mostly fuelled by gasoline instead of biogas.

On the West coast where a natural gas grid exists, the produced biogas often has been fed in to the natural gas system and the biogas filling stations have used gas from this natural gas grid. As long as the amount of gas used to fuel vehicles is not above the amount of produced biogas, it is correct so say that you drive your car on biogas. However, when the amount of gas used for vehicle propulsion exceeds the amount of produced biogas, you have to admit that you are driving on natural gas. This system is flexible and practical and it is quite similar to the system used for "green electricity" but perhaps it is confusing for some people

# 10. Effect on emissions of greenhouse gases

Ethanol produced with a minimum use of oil and conventional fuels - for example using energy/steam produced from the combustion of biomass or garbage - will contribute substantially to reducing the net emissions of carbon dioxide. For example a Life Cycle Assessment (LCA) carried out by Agroetanol AB shows that the net emissions of carbon dioxide when replacing gasoline by low blending of ethanol into gasoline is reduced by approximately 80 %. .

When using ethanol from upgraded European wine surplus ethanol the figures are somewhat lower because of a higher use of industrial fertilizers and fossil energy, but still the reduction might be as high as 50-60 %. Concerning the wine ethanol the result is also depending on definitions and alternative use. If the surplus wine is regarded as a waste than the figures concerning $CO_2$ reduction are more favourable.

Concerning sugar cane ethanol from Brazil, it has for a long time been claimed that the methods used for cultivation and harvesting were of such character that the reduction of carbon dioxide emissions would be non-existing or very low. However, today it seems that experts on these issues more and more agree that this is not correct and that the use of bio-ethanol from a global perspective contributes substantially to the reduction of the net carbon dioxide emissions.

Biogas has always been regarded as a fuel with no or extremely low emissions of carbon dioxide. In most cases this is correct. However, concerning biogas it might be necessary to include the emissions (leakage) of methane in the LCA since the climate change potential of methane is much higher than for carbon dioxide (approximately 23 times).

For example when upgrading biogas to vehicle quality, today there is a leakage of approximately 2% methane when using common technology. This leakage will substantially reduce the overall positive climate effect when using biogas instead of a conventional fuel. However, it is important to note that already today there are new modern technologies available that reduce this leakage to a very low level. Now it is important to start using this technology, at least when building new production plants.

During the production of biogas the leakage of methane might be much higher than from the upgrading. However, for this situation it is important to take into account the alternative use of the raw material that has been used for the production as well as the alternative use of the biogas itself. As long as the biogas is produced from some kind of waste or rest product, the release of methane might have occurred anyway and from that point of view it is much better to use it in a sensible and productie way as much as possible instead of doing nothing. Besides that, when flaring biogas or natural gas as much as 10 % of the gas might still escape unburned.

# 11. Additional effects

There may be a number of additional side effects when using ethanol and biogas. Most of these effects are probably positive. However, this early in the development and use of ethanol and biogas it might be difficult to give any firm conclusions on many of the probable effects. But in some cases the positive effect it is already quite clear now.

- The use of biomass such as forest residues, agricultural products and agricultural residues will have a positive rural effect in the sense that people that otherwise might have had to leave their homestead still can earn a living out in the countryside by producing the raw material for the production of bio fuels.
- The erection of plants for production of ethanol and biogas will create new job opportunities for construction people and later also for people operating the plants. A 50 000 $m^3$ ethanol plant (wheat as raw material) will need about 50 people for management and operation.
- Transportation of raw material for the fuel production will also create new job opportunities.
- Development of new technology, as for example fermentation of ethanol from cellulose or anaerobic digestion of agricultural residues may give the companies involved an advantage compared to companies that are not involved. This also may have positive effects on the country as a whole, when the companies can market their knowledge etc. on the international market. New job opportunities could be one of the positive effects.

# 12. Conclusions

The introduction of alternative fuels in Sweden has, as in most countries, been a slow process. Even if there have been certain moments during this time, when the development has accelerated in an obvious way, there seems to be no doubt that the most effective catalyst was the EU-directive on the promotion of biofuels together with the possibility to introduce country-specific tax exemptions for biofuels or other renewable fuels.

Involved stakeholders and other actors have always asked the government and EU for clear signals, signals to make the future as predictable as possible. When these kinds of signals finally come, the introduction and use of biofuels will really start to accelerate.

The perhaps most important signal from the government has been that biofuels will get full tax exemption, even if not being used in a pilot project. Even if other kinds of tax exemptions on vehicles etc are important, there are no doubt that the tax exemption on the fuel is the most important one.

One important reason that ethanol and biogas both are so well developed in Sweden and that they have continued to develop, even if slowly, from the beginning of the 1990's until now is that there have all the time been people deeply committed in the development, production and use of these fuels. People with a belief in the risk of climate change and he possibility for the biofuels to reduce the emission of greenhouse gases. The building up of organizations and companies such as BAFF, BioFuel Region, ETEK and Svensk Biogas AB together with activities in a number of municipalities has certainly improved the possibilities for the ethanol and biogas to exist.

Another important factor has probably been the belief in a future sustainable production from national raw materials, such as for example cellulose.

# Appendix

### Companies with alternative fuels tax exemption

| Company | Fuel | Date |
|---|---|---|
| AB Svenska Shell | E, F | 031211, 041209 |
| Ageratec AB | F | 050414 |
| Agroetanol AB | E | 031211 |
| Agrofuel AB | heavy alcohols | 031211 |
| Alco Sweden AB | E | 031211 |
| Carry on HB | F | 031211 |
| Domsjö Fabriker AB | E | 031211 |
| ELAB Utveckling AB | E, F | 031211 |
| Energilotsen i Sverige | E, F | 031211 |
| Excellensen Källesjö AB | F | 041209 |
| Fortum Oil OY | E, ETBE, nexbtl | 041209 |
| Fred Holmberg & CO AB | E, F | 031211 |
| Halmstads Etanolproduction AB | E | 031211 |
| Hampekraft HB | biooljebas | 050414 |
| Jonsson Bengt | raps oil | 040624 |
| LEFAB Legofyllnad AB | E, F | 040311 |
| Kemetyl AB | E | 031211 |
| Malmström Per | rapsolja | 050414 |
| Norups Gård AB | F | 031211 |
| OK Q8 | E | 031211 |
| Preem Petroleum AB | E, F | 031211 |
| Scanbio ASA | veg/animal etsters | 031211 |
| Svenska Ecobränslen AB | F | 031211 |
| Svensk Etanolkemi AB (SEKAB) | E | 031211 |
| Roma Etanolproduktion AB | E | 031211 |
| Stockholm Stad | hydrogen | 031211 |
| Swedegrain  AB | E | 031211 |
| Svenska Statoil AB | E, F | 031211 |
| TallOil AB | E, F, FAEE | 031211, 041209 |

E = ethanol, F = Fatty Acid Methyl Esters

**Filling stations May 2005 for ethanol fuel Etamax B (E85), Flexi Fuel Vehicles**

| | City/Town | STATION | ADRESS |
|---|---|---|---|
| 1 | Alvesta | Oljeshejkerna Johnsson | Videgatan 2 |
| 2 | Aneby | Preem Petroleum | Kapellgatan |
| 3 | Arboga | Ej allmänt tankställe | |
| 4 | Arjeplog | OK-Q8 | Lappvallsvägen 17 |
| 5 | Arvika | OK-Q8 | Blästervägen 2 |
| 6 | Boden | OK-Q8 | Brogatan 32 |
| 7 | Bollnäs | Statoil | Framnäsvägen 1 |
| 8 | Borlänge | OK-Q8 | Bygatan 33 |
| 9 | Borlänge | Statoil | Bygatan 30 |
| 10 | Borås | OK-Q8 | Hultagatan 9 |
| 11 | Borås (Viareds ind. område) | Bilisten | Viaredsvägen 4 |
| 12 | Edsbyn | Edsbyns Bensin & Närbutik (Statoil) | Verkstadsgatan 3 |
| 13 | Eksjö | OK-Q8 | Stallbergavägen 2 |
| 14 | Emmaboda | Runes Bensin & Oljeimport AB | Stenvägen 1 |
| 15 | Enköping | OK-Q8 | Gesällgatan 1 |
| 16 | Enköping | Q Star | Stockholmsvägen 16 |
| 17 | Eskilstuna | OK-Q8 | Västergatan 13 |
| 18 | Eskilstuna | Q Star | Mått Johanssons väg 16 |
| 19 | Eskilstuna | Q Star | Strängnäsvägen 66 |
| 20 | Falköping | Station 1 | Nordmannagatan 2 |
| 21 | Falun (Ingarvet) | OK-Q8 | Ingarvsvägen 1 |
| 22 | Finspång | Q Star | Skäggebyvägen 50 |
| 23 | Gislaved | Ambjörnsons Bil | Hagagatan 6 |
| 24 | Gävle | OK-Q8 | Skogmursvägen 37 |
| 25 | Göteborg | Statoil Gårda | Fabriksgatan 2 |
| 26 | Göteborg (Angered) | Statoil Hjällbo | Hjällbovägen 1 |
| 27 | Göteborg (Hisings backa) | OK-Q8 | Litteraturgatan |
| 28 | Göteborg (Mölndal) | OK-Q8 | Göteborgsvägen 83 |
| 29 | Göteborg (Västra Frölunda) | Statoil | Radiovägen 4 |
| 30 | Götene | Station 1 | Lundängsgatan 9 |
| 31 | Halmstad (Sannarp) | OK-Q8 | Frennapsvägen 2 |
| 32 | Hedemora | OK-Q8 | Gussarvsgatan 27 |
| 33 | Helsingborg | OK-Q8 | Välavägen, Österleden |
| 34 | Helsingborg | Preem Petroleum | Ängelholmsvägen 38 |
| 35 | Hudiksvall | Statoil | Kungsgatan 50 |
| 36 | Hudiksvall | OK-Q8 | Södravägen 20 |
| 37 | Härnösand | OK-Q8 | Kaptensgatan 4 |
| 38 | Jämjö | OK-Q8 | Riksvägen 2 |
| 39 | Jönköping | Statoil | Ryhovsvägen 3 |

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|---|---|---|---|
| 40 | Jönköping | Station 1 | Jordbrovägen 8-10 |
| 41 | Jönköping | OK-Q8 | Jordbrovägen 10 |
| 42 | Kalix | Lundströms Gas och Svets | Hangarvägen 6 |
| 43 | Kalix | OK-Q8 | Parallellgatan |
| 44 | Kalmar | Preem Petroleum | Törnebyvägen 2 |
| 45 | Karlshamn | Station 1 | Jannebergsvägen 6 |
| 46 | Karlshamn (Asarum) | L.J. Oljeledningar | Smidesvägen 5 |
| 47 | Karlskoga | OK-Q8 | Viaduktsgatan 4 |
| 48 | Karlskrona (Lyckeby) | OK-Q8 | Stationsvägen |
| 49 | Karlstad | OK-Q8 | Hagalundsvägen 27 |
| 50 | Katrineholm | OK-Q8 | Vasaväg 34 |
| 51 | Kinna | OK-Q8 | Lyddevägen 1 |
| 52 | Kristianstad | Statoil | Kanalgatan 66 |
| 53 | Kristinehamn | OK-Q8 | Västerlånggatan 4 |
| 54 | Kungsbacka | Statoil | Varbergsvägen |
| 55 | Kungälv | Statoil | Teknikergatan 1 |
| 56 | Köping | OK-Q8 | Hultgrensgatan 12 |
| 57 | Köping | Station 1 | Nybblesbacken 2 |
| 58 | Lidköping | Lidbil AB (OK-Q8) | Mellbygatan 48 |
| 59 | Lidköping | OK-Q8 | Tallskogsväg 3 |
| 60 | Lidköping | Station 1 | Rörstrandsgatan 4 |
| 61 | Lindesberg | OK-Q8 | Kristinavägen 8-10 |
| 62 | Linghem | Q Star | Gamla E4, Rycklösa |
| 63 | Linköping | Tage Rejmes Bil | Vigfastgatan 1 |
| 64 | Linköping | Station 1 | Torvingegatan 1 |
| 65 | Ljusdal | Statoil ICA Express | Gamla Kyrkogatan 8 |
| 66 | Ludvika | Samuelssons Bil & Bensin (OK-Q8) | Tunnelgatan 2 |
| 67 | Luleå | OK-Q8 | Robertviksgatan 3 |
| 68 | Lycksele | OK-Q8 | Villarydsvägen 2 |
| 69 | Lycksele | Statoil | Ume väg 3 |
| 70 | Löddeköpinge | OK-Q8 | Transportvägen 22 |
| 71 | Malmö | OK-Q8 | Vattenverksvägen 60 |
| 72 | Malmö (Almgården) | Statoil | Derbyväg 2 |
| 73 | Malmö | Ej allmänt tankställe | |
| 74 | Mariestad | Station 1 | Björnbärsvägen 1 |
| 75 | Markaryd | Preem Petroleum | Ulvarydsvägen 1 |
| 76 | Mjölby | Q Star | E4, infart mot Mjölby Västra |
| 77 | Motala | Skobes Bil i Motala (OK-Q8) | Vintergatan 9 |
| 78 | Norrköping | OK-Q8 | Moa Martinssons gata 6 |
| 79 | Norrköping | Q Star | Risängens industiområde |
| 80 | Norrköping (Klinga rastplats) | OK-Q8 | Skärblackavägen 4 |
| 81 | Norrköping | Q Star | Spårgatan 5 |
| 82 | Norrköping | Station 1 | Koppargatan 11 |
| 83 | Norrtälje | OK-Q8 | Stockholmsvägen 51 |
| 84 | Nyköping | OK-Q8 | Gustavsbergstigen 2 |

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|---|---|---|---|
| 85 | Nässjö | OK-Q8 | Brogatan/Gjutaregatan |
| 86 | Nödinge | OK-Q8 | Nödingevägen 2 |
| 87 | Olofström | Station 1 | Östra ringvägen 294 |
| 88 | Piteå | OK-Q8 | Oktanvägen 4 |
| 89 | Rimbo | OK-Q8 | Roslagsvägen 6 |
| 90 | Robertsfors | OK-Q8 | Storgatan 25 |
| 91 | Ronneby | Station 1 | Västervägen 1-3, Kallinge |
| 92 | Rättvik | OK-Q8 | Riksvägen 26 |
| 93 | Sala | OK-Q8 | Gymnasiegatan 2 |
| 94 | Sandviken | OK-Q8 | Linggatan 30 |
| 95 | Skara | Statoil | Skaraborgsgatan 39 |
| 96 | Skellefteå (Erikslid) | OK-Q8 | Upplagevägen |
| 97 | Skellefteå (Sörböle) | OK-Q8 | Mackvägen 5 |
| 98 | Stockholm | Statoil Frescati | Roslagsv./Fiskartorpsv. |
| 99 | Stockholm (Bergshamra) | OK-Q8 | Kungshamravägen 1 |
| 100 | Stockholm (Brommaplan) | OK-Q8 | Brommaplan 408 |
| 101 | Stockholm (Farsta) | OK-Q8 | Forshagagatan 1-3 |
| 102 | Stockholm (Gustavsberg) | OK-Q8 | Blekingsv 1 |
| 103 | Stockholm (Gustavsberg) | Uno X | Afrodites väg, Mölnvik |
| 104 | Stockholm (Hammarby) | Statoil | Fabriksväg 51 |
| 105 | Stockholm (Haninge) | ICA Maxi Haninge (Statoil) | Söderbyleden |
| 106 | Stockholm (Kista) | Shell | Danmarksgatan 54 |
| 107 | Stockholm (Kungens Kurva) | Statoil | Ekgårdsvägen 4 |
| 108 | Stockholm (Märsta) | OK-Q8 | Arlanda stad |
| 109 | Stockholm (Sköndal) | Statoil | Nynäsvägen/ Bogårdsvägen |
| 110 | Stockholm (Solna) | Preem Petroleum | Johan Enbergs väg 2 |
| 111 | Stockholm (Täby) | OK-Q8 | Saluvägen 3, Arninge C |
| 112 | Stockholm (Upplands Väsby) | Statoil ICA Express | Kapellvägen 1 |
| 113 | Stockholm (Upplands Väsby) | OK-Q8 | Glädjens trafikplats |
| 114 | Stockholm (Västberga) | OK-Q8 | Kontrollvägen 2 |
| 115 | Stockholm (Åkersberga) | OK-Q8 | Rallarvägen 2 |
| 116 | Stockholm (Årsta) | OK-Q8 | Partihandlarvägen 20 |
| 117 | Strängnäs | Statoil | E20, Riksväg 55 |
| 118 | Sundsvall (Skönsberg) | OK-Q8 | Gillebergsgatan 1 |
| 119 | Sundsvall | Statoil | Norrmalmsgatan 1 |
| 120 | Sunne | OK-Q8 | Sörgårdsgatan 3 |
| 121 | Svedala | OK-Q8 | Norra Tvärgatan 24 |
| 122 | Sveg | OK-Q8 | Vallarvägen 5 |

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|---|---|---|---|
| 123 | Säffle | OK-Q8 | Sommarovägen 2 |
| 124 | Söderhamn | Preem Petroleum | Norralagatan 19 |
| 125 | Södertälje | Statoil | Verkstadsvägen 7 |
| 126 | Södertälje | OK-Q8 | Järnagatan 19 / Bangatan 8 |
| 127 | Södertälje, Pershagen | Q Star | Avfart E4 Södertälje Syd |
| 128 | Södertälje | Ej allmänt tankställe | |
| 129 | Tanumshede | Br. Brandts personbilar (OK-Q8) | Industrivägen 2 |
| 130 | Torsby | OK-Q8 | Kyrkogatan 16 |
| 131 | Tranås | Skobes Bil i Tranås (OK-Q8) | Ågatan 36 |
| 132 | Trelleborg | OK-Q8 | Kontinentplan |
| 133 | Trelleborg | Ej allmänt tankställe | |
| 134 | Trollhättan | OK-Q8 | Tunhemsvägen 4 |
| 135 | Uddevalla | OK-Q8 | Strömstadsväg 50 |
| 136 | Umeå | OK-Q8 | Odlarvägen 2 |
| 137 | Umeå (Ersboda) | Statoil Greenzone | Överstevägen 5 |
| 138 | Uppsala | OK-Q8 | Årstagatan 5-7 |
| 139 | Vara | Statoil | Kungsgatan 35 |
| 140 | Vedevåg | Q Star | Länsväg 249, ICA Kvarnhallen |
| 141 | Vessigebro | Statoil | Brogatan 33 |
| 142 | Vetlanda | Shell | Nygatan 14 |
| 143 | Vimmerby | Station 1 | Södra Industrigatan 10 |
| 144 | Vårgårda | Station 1 | Wallentinvägen |
| 145 | Västervik | OK-Q8 | Allén 76 |
| 146 | Västerås (Nordanby) | Statoil | Bergslagsvägen 2 |
| 147 | Västerås | OK-Q8 | Djuphamsvägen 3-5 |
| 148 | Västerås | Ej allmänt tankställe | |
| 149 | Växjö | Statoil | Hejaregatan 17 |
| 150 | Växjö | OK-Q8 | Arabygatan 53 |
| 151 | Växjö | OK-Q8 | Sambandsvägen 2 |
| 152 | Växjö | Ej allmänt tankställe | |
| 153 | Åmål | Preem Petroleum | Karlstadsvägen |
| 154 | Älmhult | OK-Q8 | Skolgatan 6 |
| 155 | Älmhult | Station 1 | Danska vägen 120 |
| 156 | Ängelholm | Pump (OK-Q8) | Nordalagatan 2 A |
| 157 | Ödeshög | OK-Q8 | E4, Östgötaporten |
| 158 | Öjebyn | OK-Q8 | Gammelstadsvägen 21 |
| 159 | Örebro | OK-Q8 | Västhagagatan 7 |
| 160 | Örebro | OK-Q8 | Södermalmsplan 3 |
| 161 | Örnsköldsvik | OK-Q8 | Härnösandsvägen 4 |
| 162 | Örnsköldsvik (Domsjö) | OK-Q8 | Hörnettsvägen |
| 163 | Örnsköldsvik | Statoil | Vikingagatan 3 |
| 164 | Östersund | OK-Q8 | Körfältsvägen 2 |
| 165 | Östersund | Statoil | Krondikesvägen 97 |
| 166 | Övertorneå | OK-Q8 | Sockenvägen 2 |