

Measure title: **Biogas on the net**

City: **Malmö**

Project: **SMILE**

*Measure
number:*

5.2

A Introduction

Prior to SMILE biogas was available and used in a few locations in Sweden as a vehicle fuel. At the end of 2004/beginning of 2005 the majority of vehicles in Malmö ran on petrol only with much smaller numbers using diesel, natural gas or a combination of power sources such as ethanol/petrol, etc. At the time the city buses, a small number of cars in the municipal fleet, some of the taxis and a handful of privately-owned cars could be fuelled with natural gas. Many, but not all, of these vehicles ran only on natural gas. With the exception of the buses, almost no heavy vehicles used natural gas since most lorries used only diesel.

While natural gas is a cleaner fossil fuel than diesel and gasoline, it is not a renewable source of energy for the transport sector. Synthetic fuels or biofuels that are not derived from fossil stocks are possible to make and use in vehicles as a replacement for fossil fuels. Such biofuels have a low or negligible contribution to the greenhouse effect since the emissions of carbon dioxide are offset by other processes that use carbon dioxide to generate the fuel.

It is desirable to introduce biogas in Malmö as well. The sewage water treatment plants in Malmö produce large amounts of biogas which can be upgraded to vehicle fuel or natural gas quality. This would mean that biogas in Malmö could be used in clean vehicles while at the same time reducing the net CO₂ emissions from transport in and around the city. Methane is itself a powerful greenhouse gas leading to additional benefits to the environment depending on the alternative ‘use’ to which it would be put e.g. burning for other benefit or venting to the atmosphere.

The detailed goals of this measure as well as its actual execution changed several times during SMILE. The original objectives are retained with a description of changes. The reason for this is the need for the reader to see how changes in the measure impacted on the technical evaluation. Without this knowledge it might make it more difficult to interpret the results of this measure and understand the execution of the technical evaluation. In particular the “Ystad situation” can be best understood in this context.

In this measure the term “vehicle gas” is introduced and is an important part of the realisation of the measure objectives. Like natural gas, vehicle gas consists primarily, of methane. However, vehicle gas is a mixture of natural gas and upgraded raw biogas. The mixture is often approximately 50% natural gas and 50% biogas but this can vary somewhat based on available supplies of biogas and demand for gas products. While the exact content of vehicles gas will vary, in this evaluation we will assume that about one half of the methane is of fossil origin and about one half is of renewable origin. With regard to CO₂ emissions from vehicle gas these will be set at 50% of natural gas.

A1 Objectives

Based on the original objectives as set out in the original SMILE project plans:

The goal of this measure is to establish a capacity to upgrade and put biogas onto the existing natural gas grid in Malmö, to start and operate two fuelling stations for biogas, and to ensure that an increasing percentage of the biogas made available is sold as biogas and not simply put out onto the net as “natural gas.” To this end, Eon negotiated with the larger of the two city-owned sewage treatment plants “Sjölunda” for the purchase of gas from the swage treatment process.

The establishment of this system enables the municipal fleet of natural gas cars (relating to measure 5.1) and Skånemejerier’s trucks/lorries (relating to measure 5.3) to run on biogas or vehicle gas. Furthermore, Skånetrafiken’s city buses could in theory run on vehicle gas (relating to measure 8.1, among others) but by the end of SMILE supply constraints may not permit all city buses to run on vehicle gas. Additional gas capacity could be absorbed into the natural gas supply grid/network. As demand for fuel gas increased Eon would then divert more and more biogas to the filling stations where possible or be able to sell more amounts of vehicle gas to customers.

The original measure objectives were stated as follows:

- **Objective 1:** Establish a capacity upgrade facility and put biogas onto the existing natural gas grid in Malmö
- **Objective 2:** Operate two fuelling stations for biogas
- **Objective 3:** Enable the municipality to run its fleet of methane-powered cars and Skånetrafiken’s buses on biogas
- **Objective 4:** Increasing percentage of biogas production used to power vehicles
- **Objective 5:** Awareness of production of biogas and its environmental benefits
- **Objective 6:** Acceptance of production of biogas and its environmental benefits
- **Objective 7:** Enable gas fuelling of light and heavy vehicles owned and operated by other organisations and private citizens.

Based on the objectives established *de facto* during the actual implementation of the measure:

- **Objective 1:** Establish a capacity upgrade facility and put biogas onto the market primarily as part of the product “vehicle gas” which is approximately 50% biogas and 50% fossil-based natural gas
- **Objective 2:** Open and operate several fuelling stations for vehicle gas of which one will be dedicated to commercial uses (heavy vehicles) with a slow, overnight, filling process and one which is open to all users with a fast filling capacity
- **Objective 3:** Enable the municipality to run its fleet of methane-powered cars and Skånetrafiken’s buses on biogas or vehicle gas depending on demand and supply
- **Objective 4:** Increasing the percentage of non-fossil methane (biogas) used to power vehicles through a) the marketing and production of vehicle gas and b) through gradually increasing the percentage of biogas making up vehicle gas
- **Objective 5:** Introduce and/or increase awareness of production of biogas and its environmental benefits
- **Objective 6:** Introduce and/or increase acceptance of production of biogas and its environmental benefits
- **Objective 7:** Gas fuelling of light and heavy vehicles owned and operated by other organisations and private citizens.

A2 Description

Based on the original description as set out in original SMILE project plans:

In this measure the biogas used for the production of vehicle fuel is produced in the sewage water treatment plants of Malmö. Biogas can be produced at both the Sjölanda and the Klagshamn treatment plants. The energy content in the available biogas from Sjölanda is 10 GWh/year and the amount of energy from the Klagshamn biogas is 3.3 GWh/year.

The upgrading plant was located at the Sjölanda sewage water treatment plant. The capacity of the plant is 10 GWh vehicle fuel per year, which can replace approximately 1.15 million litres of petrol per year. The upgrading plant will remove the CO₂ and other non-methane gases from the biogas produced from the sewage treatment plant and then adjust the resultant gas to natural gas quality by adding approximately 8% propane to the final “product”. This upgraded biogas is then injected into the natural gas grid or used to fill lorry tankers that transport to locations outside the natural gas grid to fuel vehicles directly.

For the filling of vehicles, an existing filling station for natural gas at Spillepeng, as well as a new filling station in Limhamn, were to be used. The project was to be split into two steps. During step one, the upgrading plant for biogas from the Sjölanda sewage water treatment plant was to be erected and put into operation. The fast filling station at Spillepeng was to be reconstructed to operate with upgraded biogas as well as natural gas.

Step one of the project was to last for 18 months. During step two, the fast filling station in Limhamn was to be erected and put into operation as well as the slow filling station for approximately 50 heavy vehicles.

In actual practice the Limhamn facility was replaced by a filling station in Ystad and a slow-fuelling station for lorries, referred to here as “Depå”, was constructed close to Skånemejerier (object of measure 5.3). Pictures of the preparations for the inauguration of the filling station in Ystad appear below. (See section B3 and B4 for greater understanding about the actual implementation of the measure and deviations from the original plans.)

Pictures 1A-1D concern the Ystad filling station



Picture 1A: Arrival of the first container of CNG gas to the Ystad fuelling facility.



Picture 1B: View of interior of fuelling facility container storage of CNG.



Picture 1C: The e.on CNG fuelling “pump” after connections were made with the CNG container storage.



Picture 1D: Inauguration. Eon shares the petrol station with a chain of petrol stations called “tanka”.

All pictures courtesy of Eon.

B Measure implementation

B1 Innovative aspects

- **New conceptual approach, regionally** – Prior to SMILE natural gas was available as fuel for vehicles in Malmö. Upgrading biogas to natural gas quality and integrating it to existing energy systems has a high degree of transferability to other European cities. Making the utilisation of biogas as part of gas fuelling easier and more acceptable for regular car and lorry users.
- **Creation of a new product, locally/regionally/nationally** – During the course of the implementation of the measure Eon and other natural gas suppliers in parts of Sweden agreed to offer a new product “vehicle gas” consisting of approximately 50% biogas and 50% natural gas. The reasons for this decision undoubtedly varied from place to place in Sweden. One reason was concern that demand for pure biogas might outpace supplies. In other places there was a concern that demand for pure biogas might be too weak to recoup investment costs in biogas production. Therefore production and supply of “vehicle gas” would be easier to achieve and be a less risky way to introduce greater amounts of non-fossil methane into the transport sector. The exact mechanics of this innovation lie partly within SMILE and partly outside SMILE and did not originate exclusively from the SMILE application process.
- **Establishment or acceleration of a new market for gas vehicles in south-eastern Skåne, local effect** – By establishing the fuelling station in Ystad, it became possible for people and companies living in or operating in and around Ystad to own and operate gas vehicles. Previously it was necessary to drive 60 km or more to Malmö to fill the cars with CNG. Obviously it would have been possible for people and organisations in Ystad to fuel hybrid gas/petrol vehicles with petrol in Ystad and then when in Malmö fuel these same vehicles with gas. However this would have been very inconvenient and discouraged the purchase and use of gas vehicles.

B2 Situation before CIVITAS

Prior to CIVITAS SMILE natural gas was available as fuel for vehicles in Malmö. No biogas was available for fuelling vehicles and most, if not all, biogas was used at the sewage treatment plants or released into the atmosphere. The vehicles that ran on natural gas prior to SMILE included large parts of the urban bus fleet run by Skånetrafiken, some taxis, some municipal vehicles and a small number of private cars. Biogas produced in Malmö was not upgraded for vehicle use and was instead used exclusively by the sewage treatment plants for internal power generation or burned with no power generation or simply released into the air.

In 2005 Eon sold about 105 GWh worth of natural gas or 10 500 000 N m³ of CNG of fossil origin to vehicular end-uses. Very small amounts of biogas injected into the natural gas grid at points north of Malmö may have, on occasion, reached the local network in Malmö and entered vehicle tanks. These very small amounts have been ignored for the purposes of this evaluation.

B3 Actual implementation of the measure

Actual implementation deviated in a number of ways from the original description and objectives. Please also see Table 1 under section B4 which compares the plans with the actual implementation.

The measure was implemented in the following stages:

Stage 1: Negotiations for gas purchase and contracting for construction of Sjölanda upgrade facility (*February 2005 – Late 2005/early 2006*) – During this stage Eon and the City of Malmö negotiated about the price of the raw biogas, Eon started the building permit etc process. Negotiations stopped and restarted during this period. For an external observer it would have appeared that nothing much happened here.

Stage 2: Ystad fuelling facility (*Late 2006 – May 2007*) – A container with compressor and filling technology was constructed to be used to transport CNG from Malmö to Ystad. A site for fuelling was readied in Ystad.

Stage 3: Operation of Ystad fuelling, step 1 (*May/June 2007-May 2008*) – During this period vehicles were fuelled with CNG in Ystad taken in the container via lorry. This CNG came from the grid in Malmö. See the blue dashed line in Appendix 2.

Stage 4: Operation of Ystad fuelling, step 2 (*May/June 2008 – onwards including post-SMILE period*) – During this period gas was still transported by container on a lorry from Malmö but this compressed gas was vehicle gas, often with a higher than average biogas content. See the blue dashed line with accompanying fuel flow in Appendix 2.

Stage 5: Contract agreement reached, acceleration of the construction of the Sjölanda upgrade facility, permitting and inspection etc -- (*Various dates during 2007- April/May 2008*) – After lengthy delays construction started and was completed very late during the SMILE period.

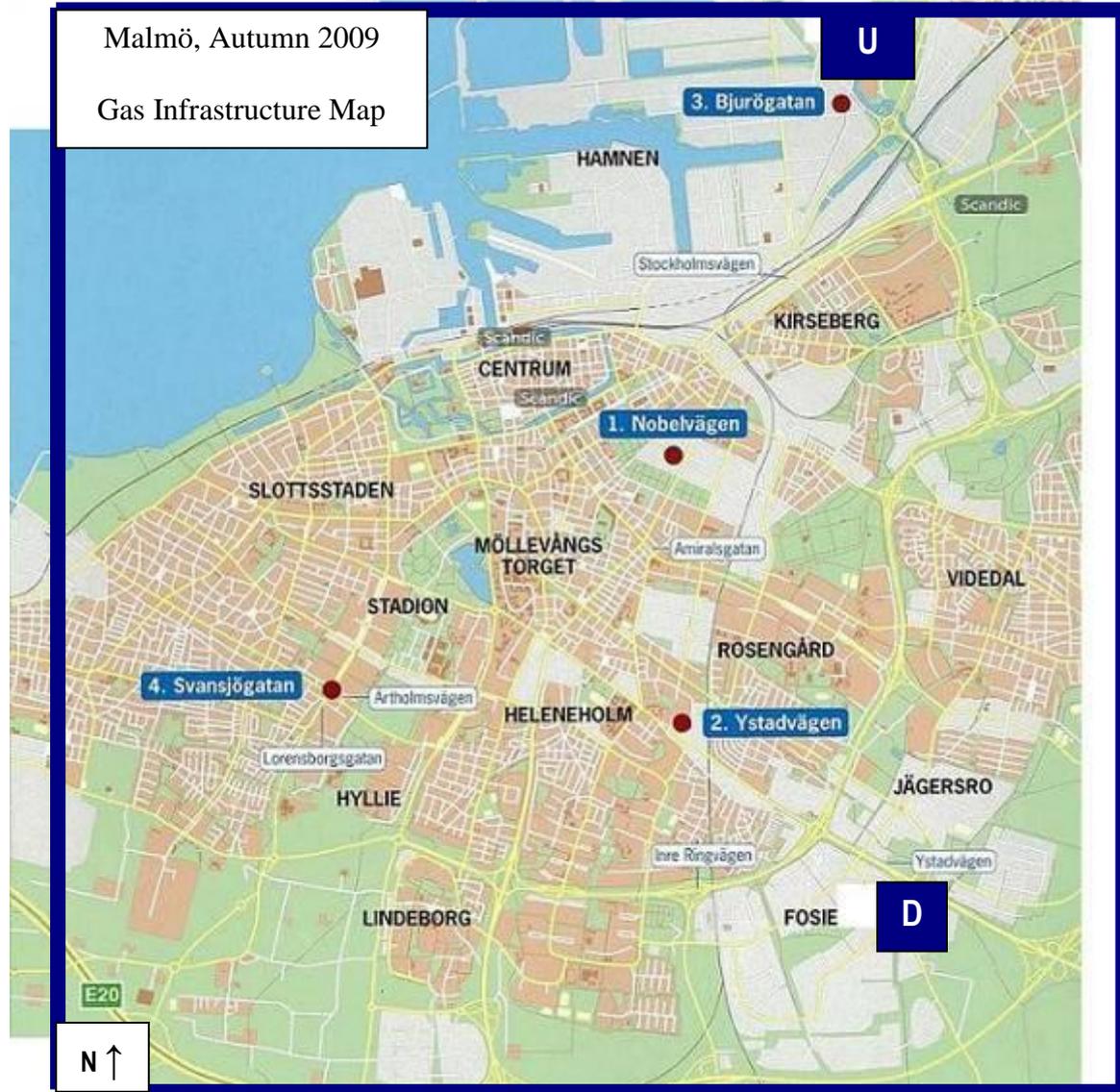
Stage 6: Operation of the Sjölanda upgrade facility and injection of fuel onto the grid (*May/June 2008 – onwards including post-SMILE period*) – During this period the facility came into operation as expected.

Stage 7: Construction of the slow filling station for heavy vehicles called “Depå” (*January 2008-October 2008*) – Construction work commenced and was completed.

Stage 8: Operation of the “Depå” slow filling station – (*November 2008 – onwards including post-SMILE period*) – This facility commenced operations and is operating presently under capacity. The facility is located in an area favourable for companies that operate heavy vehicles besides Skånemejerier.

A map of with the locations of upgrading facility and fuelling facilities in Malmö appears below. This map includes facilities in place during 2005 (red dots), before SMILE measure 5.2 actually started, and in late 2008 when all parts of the measure were in place. A map showing the location of the Ystad fuelling facility in relation to Malmö appears in Appendix 1.

Map 1: Location of EON’s upgrade and fuel facilities in Malmö.



 Red dots are the locations of pre-SMILE fuelling locations for methane as natural gas. During SMILE, as more biogas became available on the grid, the proportion of fossil methane gas at these facilities declined and the biogas content increased. 

U U is the location of the upgrading plant and where city buses can be fuelled with vehicle gas. **D** D is the “depå” location with slow, low pressure, fuelling which is used primarily by Skånemejerier as part of measure 5.3

B4 Deviations from the original plan

The deviations from the original plan can be summarized in Table 1 below. More details concerning deviations can be consulted following Table 1.

Table 1: Overview of deviations

Original project	Actual project	Time
Construction and subsequent operation of upgrade plant at Sjölunda	Construction and subsequent operation of upgrade plant at Sjölunda	Construction: 2007-May 2008 Operation: May 2008-end of SMILE
Construction and subsequent operation of fast fuelling station in Limhamn	Preparation for and subsequent operation of fuelling station in Ystad including container and lorry	Preparation: December 2006- May 2007 Operation: May 2007-end of SMILE
Construction and subsequent operation of slow fuelling station "Depå"	Construction and subsequent operation of slow fuelling station "Depå"	Construction: January 2008-October 2008 Operation: November 2008-end of SMILE

The "original project" column is derived from the SMILE application or the DMP as available.

- Deviation 1: Contractual Delays** – The measure suffered from a major delay (approximately. month 40 instead of month 22) when the upgrading plant was built and the biogas was made available for distribution in the natural gas grid. Also the construction of one of the two filling stations was delayed in relation to Annex IB (month 28 instead of 22). When a filling station commences operations prior to the completion of the upgrading plant, the gas in the filling stations will be biogas according to the same principle as green electricity is delivered: the removal of gas from the grid at the filling station of natural gas was compensated by input of biogas in another part of the network. This is already the case at the existing filling stations in Malmö. The construction of the upgrading plant was delayed because of troubles getting the Malmö Water and Waste Works and the P3 EON to agree on the price and volume of raw biogas to be purchased. Without this contract signed it was impossible for EON to proceed with the plant construction.
- Deviation 2: Alternative fuel station established** – Construction of a fuelling facility in the town of Ystad. During SMILE a fuel station was established in Ystad, located some 60 km from central Malmö. Biogas produced in Malmö was compressed and shipped by tank lorry to Ystad for distribution and sales from that point. This replaced the planned location in Malmö.
- Deviation 3: Delay in establishment of slow fuelling station** – This facility was built and came into operation later than anticipated in the original planning. Had the facility been built earlier fuelling would have been 100% CNG with no biogas component. This means that the delay has not reduced the amount of biogas placed in vehicles.

B5 Inter-relationships with other measures

5.2 involves the production and sale of biogas, often as a principal component of vehicle gas.

Table 2: Overview of inter-relationships with other measures.

Number	(Approximate) Measure name	Relationship	Comments
5.1	Clean municipal fleet	Vehicles procured and taken into use as part of this measure that run on natural gas can be fuelled with the vehicle gas generated or otherwise made available by activities undertaken within 5.2	The degree of the relationship depends on the % of new vehicles procured that actually can run on natural gas and how frequently their tanks are filled with gas instead of petrol.
5.3	Skånemejerier's new vehicles and eco-driving	During SMILE Skånemejerier (Scania Dairy Company) purchased 10 new delivery vehicles that run on natural gas. These vehicles began running on vehicle gas during the latter half of 2008 when the slow-filling station "Depå" was completed in proximity to Skånemejerier.	These new vehicles, together with a small number of existing vehicles in the fleet can run on the gas made available as part of 5.2. Not all of the existing vehicles operate in and around Malmö.
Several	Skånetrafiken has or is heavily involved in ~5 measures in SMILE.	The overwhelming majority of Skånetrafiken's buses in Malmö run on natural gas and the intention has been to make sure that all urban buses in Malmö would use gas from Eon. However by the end of SMILE there will be insufficient raw biogas production for all buses to run on vehicle gas.	Skånetrafiken has a longer-term goal of ensuring that all inter-urban bus services that run to/from Malmö, as well as other similar inter-urban or regional buses in Skåne be fuelled with gas.
9.1	Car-sharing: Sunfleet	Some of Sunfleet's vehicles are petrol/gas hybrids.	The degree of the relationship depends on the % of new vehicles taken into service that actually can run on natural gas and how frequently their tanks are filled with gas instead of petrol.
11.8	UMAS	The procurement of new vehicles by the hospital in Malmö is part of SMILE. Those vehicles that run on natural gas can be fuelled as part of the success of 5.2	The degree of the relationship depends on the % of new vehicles procured that actually can run on natural gas and how frequently their tanks are filled with gas instead of petrol.

C Evaluation – methodology and results

C1 Measurement methodology

C1.1 Impacts and Indicators

Table of Indicators. *Insert own table where available, use landscape layout as necessary*

Nr.	Relates to GUARD Nr.	INDICATOR Name	Possible DESCRIPTION	DATA /UNITS
8		CO ₂ emissions	CO ₂ per vkm or per MJ energy supplied	
13		Awareness level	Degree to which the general public's awareness has changed	Survey
14		Acceptance level	Survey of opinions on part of general public	Survey
MSE-27	4	% of biogas produced that is used by vehicles	% of biogas produced that is used by vehicles	%
MSE-25	1	Revenues per sale of gas	Revenues obtained from the sale of biogas	Euros per volume sold biogas
MSE-26	2	Costs for production of gas per sale	Costs for the construction of facilities, marketing etc.	Euros per volume sold biogas

Detailed description of the indicator methodologies:

- **Indicator 8** (*CO₂ emissions*) – This is based on the assumed model emission level of CO₂ from light vehicles using petrol and the assumed model emission level of CO₂ from light vehicles using vehicle gas. The assumption is that since there is more power available from CNG than petrol and that 50% of the content of vehicle gas is non-fossil that CO₂ emissions fall by ~60%/vkm when switching to vehicle gas.
- **Indicators 13 and 14** (*Awareness and acceptance*) – Figures are provided based on the survey of the general public undertaken during the spring of 2008.
- **Indicator MSE-27** (*Biogas produced used by vehicles*) – This is an indication of how successful the measure has been in getting production of biogas supported by actors in the transportation sector.
- **Indicator MSE-25** (*Revenues per sale of gas, relates to GUARD revenues/PT km...*) These figures are based on data and estimates provided by Eon.
- **Indicator MSE-26** (*Cost for production of gas per sale, relates to GUARD costs/PT km...*) – These figures are based on data and estimates provided by Eon.

C1.2 Establishing a baseline

The baseline is a description of the situation with regard to measure 5.2 prior to the start of SMILE. The most important part of the baseline is the fuelling of vehicles that would come to use biogas in the future or vehicles that did not use gas at all prior to SMILE but which were replaced with new vehicles that could use biogas, natural gas or vehicle gas.

The establishment of the Ystad fuelling facility as part of SMILE compared with the facility originally intended in Malmö is problematic for the technical evaluation. The reason for this is that, as can be seen in Appendix 1, Ystad is located some 60 km away from Malmö. Vehicles using vehicle gas in Ystad will not primarily be driven in Malmö. This means that the advantages for local air quality in Malmö will be so small as to be pointless to attempt to ascertain. On the other hand, the establishment of the Ystad fuelling facility means that the network of fuelling locations in southern Sweden is enhanced and, in effect, the SMILE measure in Ystad means that a new market opportunity of gas powered vehicles presents itself there – a local innovation that would not have occurred during SMILE without SMILE funding.

Yet the original intention for SMILE measures in Malmö was for the measures to be located in Malmö and have their primary benefit in Malmö and the very immediate vicinity. Ystad is located too far from Malmö and the effects (environmental benefits, acceleration of the market for gas vehicles) are overwhelmingly located in and around Ystad.

For this reason, Ystad is a “problem” for the technical evaluation. The solution has been to treat “Ystad” as a separate but linked project in this measure. In each location in this evaluation where figures related to Ystad are mentioned they appear last. It is then up to the reader to decide whether to include the Ystad statistics in a grand total or not. It is the opinion of the technical evaluator that the Ystad numbers should be kept outside of the technical evaluation report, even if the Ystad sub-project has been approved as a part of this SMILE measure.

In 2005 Eon sold about 105 GWh worth of natural gas or 10 500 000 N m³ of CNG of fossil origin to vehicular end-uses in Malmö. In 2005 there were no locations in or around Ystad to purchase CNG for vehicle purposes.

C1.3 Building the business-as-usual scenario

Business as usual would be that Eon or other organisations/actors in the energy sector did not sell biogas or vehicle gas in or immediately adjacent to Malmö as part of SMILE. In this case the municipal energy company in Lund – Lunds energi – would have been the closest place vehicles could have been fuelled with vehicle gas or biogas at the two fuel stations in Lund. However, Lund is 15 km away from the centre of Malmö. It is very unlikely that residents and organisations whose operations are centred in Malmö would drive 30+ km to Lund (round trip) for filling their vehicles with vehicle gas. We can perhaps assume that there would be some effects in Malmö from some organisations and residents in Lund using biogas or vehicle gas. However for this evaluation, we will build the business as usual scenario based on simply removing SMILE measure 5.2 and furthermore assuming that the four pre-existing stations for gas in Malmö would have physically dispensed vehicle gas with initially a very low biogas content which would have increased during 2006-2008. This biogas would have been injected into the grid at other locations in Skåne. The total amount of biogas produced and injected into the grid in the entire region of Skåne would have been lower without SMILE.

The business as usual scenario is based on what fuels and vehicles most likely would have been used in Malmö to achieve the same functions that the present vehicles using vehicle gas or biogas replaced. This requires several assumptions:

1. Procurement of gas vehicles within or outside the SMILE framework would have been identical but the vehicles would have physically run on gas with more natural gas content instead.
2. Pre-existing vehicles using natural gas would have continued to operate in 2008 just the same as in 2005.
3. The uses of biogas generated as part of the by-products of the sewage treatment plants in 2005 would have been the same in 2008: i.e. an unknown proportion of the gas would have been used internally at Sjölanda and the rest would have been simply released into the atmosphere.
4. Alternative sources of biogas, produced at some distance from Malmö, would not have been commercially available on the market as pure biogas for vehicles in Malmö. The composition of gas on Eon’s natural gas grid in Malmö would be similar to the composition during 2005, prior to SMILE. The market for vehicle gas in Malmö and Skåne would have developed slower without SMILE. Eon would have sold 115 GWh of gas for vehicle use of which 35 GWh would have been biogas imported from other locations in Skåne and 80 GWh would have been CNG.

C2 Measure Results

C2.1 Economy

Absolute measure costs:

Estimated total costs for entire SMILE period: 27.4 million SEK. The original budget was 23.2 million SEK. The sub-projects “Sjölunda upgrade station” and “Ystad” proved more expensive. In the latter case, this is because transport of gas by road in containers with a mobile compressor would have not been included in the original plans for an additional filling station in Malmö itself. The slow-fuelling station in Malmö turned out to be less expensive since it was built with a smaller capacity (15 vehicles overnight versus 50 vehicles overnight) than was originally planned.

Absolute measure revenues:

These revenues come from the sale of gas. The revenues are estimated for one entire year for 2008. This is because while gas sales started in Ystad during the first half of 2007, the remaining sub-projects in 5.2 did not start until 2008 and rather late during the year. Hence while there were some small revenues in 2007, these have been placed in 2008. In this way there were no revenues for 2005-2007 inclusive. These figures are obtained from the CEA documents for all three sub-projects. In 2008 revenues were approximately 9 million SEK.

Economic indicators:

- Costs per gas sale:

27.4 million SEK/14 GWh] ie ~2million SEK/GWh *assuming all costs borne by sales during 2008.*

OR *if only operating costs involved* 7.44 million SEK/14 GWh or ~0.53 million SEK/GWh

- Revenues per gas sale:

~1million SEK/GWh

Please note that these are approximate figures are based on 2008 as if all parts of the measure had been operating the entire year. The costs per gas sale will vary considerably depending on how set-up/investment costs are recouped or whether just operating costs are included, as can be seen above. Furthermore, each part of the measure - Depå, Sjölunda, Ystad - has different cost and revenue profiles. The gas sold is based on a mixture of biogas (some of which is produced locally thanks to the 5.2 measure) and natural gas. Finally, the figure of 14 GWh as a fictive measure of gas sales during 2008 is based on certain assumptions concerning the development of the market. The actual figures for the first entire 12 month period of operation of all parts of the measure may be lower than 14 GWh.

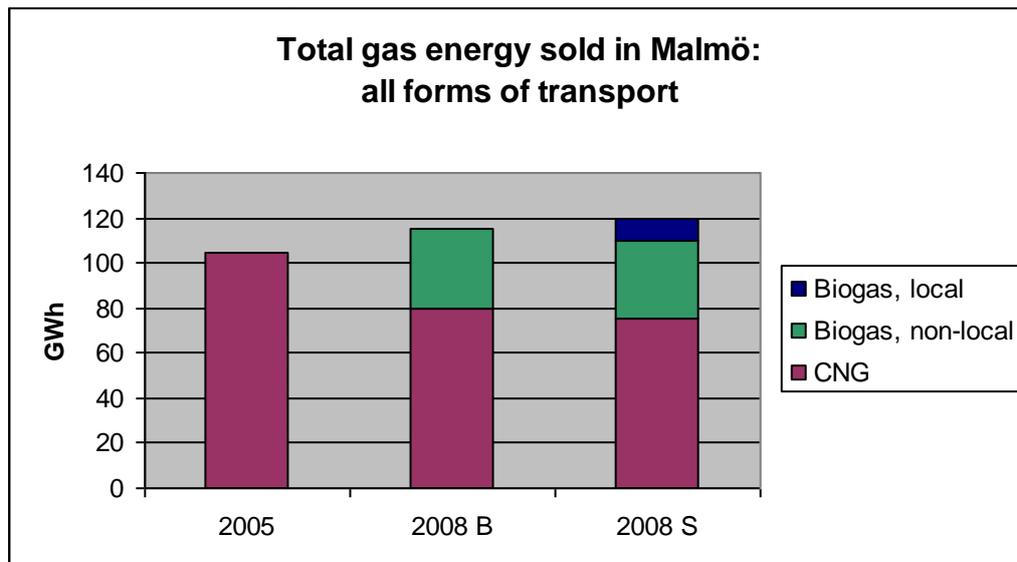
C2.2 Energy

Eon sold gas in 2008¹ according to the following:

Buses bought 65 GWh natural gas and 35 GWh biogas (which included import of biogas from other locations in the grid) while at various public stations and the commercial, slow-fill “Depå” station 20 GWh of gas was sold (of which half or 10 GWh was from local biogas and half was from fossil sources). “Ystad” is counted as part of the various public stations.

¹ This is actually a twelve month period straddling 2008 and 2009, based on an extrapolation of the situation in the fall of 2008 when all of 5.2 measure components were in place.

Diagram 1. Gas production and sales in Malmö.



2008B stands for “business-as-usual” scenario in Malmö while 2008S stands for “SMILE”.

For all practical purposes 100% of raw biogas purchased from the Sjölunda Sewage Treatment plant and then upgraded and sold by Eon has gone to transportation. However, the majority of this gas has been sold as vehicle gas. Obviously much of the raw biogas has not actually been used in vehicles but *production* of biogas has been purchased by vehicle owners and vehicle users at a different location to the production.

C2.3 Environment

While the release of CO₂ differs quite a bit compared with the baseline, because of the assumption that biogas produced elsewhere would otherwise have made up 30% of all gas fuel used by transport vehicles in Malmö (versus 37% in SMILE), the reduction of CO₂ as the result of this measure is not as great as perhaps originally hoped for. The difference between NO_x and PM₁₀ releases is negligible given the business as usual scenario. Had instead diesel and petrol been the only fuels present in the business-as-usual scenario then there would have been a measurable difference.

Ystad as a methodological problem.

While the fuelling station in Ystad has dramatically accelerated the infrastructure for vehicle gas in Malmö, thus supported the purchase and use of gas/petrol light vehicles, the environmental effects of this measure are not concentrated to Malmö which is where the SMILE measure is supposed to be implemented. Sales of vehicle gas in Ystad were only 0.5% of Eon’s gas sales in the entire combined Malmö and Ystad area in 2007 and 3% during 2008. Eon does not anticipate the percentage of sales to increase so that Ystad sales increase faster than those in Malmö: rather the opposite is most likely. Because of the very small effect here and that the environmental benefits are not primarily in the SMILE city of Malmö, the environmental benefits are calculated solely on the assumptions made in the first paragraph in this section. This means that any environmental effects from Ystad are kept out of the evaluation.

7% of the total GWh sold - which will have 60% reduction of emissions - is 8.4GWh or 840 000 Nm³. While it is not entirely clear, and according to Eon is unknown, which vehicles fuelled in Malmö actually will be using this fuel in their tanks we will assume in this evaluation that these 8.4 GWh will be used by light vehicles and not used by buses.

Here we assume that a light vehicle requires 0.074 Nm^3 vehicle gas per km or that 13.5 km can be driven on 1 Nm^3 vehicle gas. With 0.114 kg CO_2 released per km with vehicle gas this means that $1\,292\,760 \text{ kg CO}_2$ were emitted using this 7% difference because of the measure instead of $1\,723\,680 \text{ kg CO}_2$ emitted if this 7% had been natural gas (at $0.152 \text{ kg CO}_2/\text{km}$). In total this leads to a difference of $430\,920 \text{ kg}$.

C2.4 Transport

In Ystad, prior to SMILE, it was not possible to fuel vehicles with CNG, biogas or vehicle gas. In a business-as-usual scenario the situation in 2008 would be the same as the situation in 2005, provided that some other actor did not establish a fuelling station.

This means that a switch from light vehicles using petrol to light vehicles using gas and petrol was accelerated in Ystad, thanks to SMILE, because of the expansion of vehicle gas fuelling capacity from essentially 0 GWh/year in 2005 to 0.6 GWh/year during latter half of 2007 to 4.0 GWh/year during 2008. In theory, assuming that all vehicles using gas in Malmö are light vehicles, this could mean that 57 cars were bought and used in Ystad during the last 12 months in SMILE than otherwise would have run on petrol. This is based on the assumption that these vehicles would have been driven $100\,000 \text{ km}$ during this 12 month period and used vehicle gas exclusively at $0.07 \text{ Nm}^3/\text{km}$ during this period. In practice the figure for the total number of cars bought in Ystad and in the very immediate vicinity would be higher than 57 during the entire SMILE period when the Ystad station was in operation (18 months since the station came into operation instead of 12 months, gas vehicles would not exclusively use gas only during this period but instead use gas most often, etc.) so that *perhaps* as many as 90 gas/petrol vehicles will have been purchased in the Ystad area because of SMILE.

In Malmö there is essentially no effect on transport since decisions to buy and use gas powered vehicles would have been made regardless of the availability of vehicle gas with a biogas content. Without SMILE CNG would have been available as well as supplies of non-local biogas added to the natural gas grid.

C2.5 Society

The awareness of the measure on the part of the general public in and around Malmö has been indirectly measured during April and May of 2008 as part of the General Public Survey undertaken as part of the evaluation. Approximately 3.1% of the general public associated Eon with biogas.

In Sweden, Eon is generally not associated with biogas, natural gas or sources of energy other than electricity and district heating. Eon in Sweden did not start with gas until the 1980s and gas (natural gas or biogas) is a very small part of the entire Swedish energy system. The natural gas pipeline in Sweden enters Denmark from Malmö and proceeds along the western coast towards Göteborg with some shorter branch lines.

The level of awareness found can therefore be seen as a level that could be expected given the relatively small general awareness about gas in Sweden.

In the General Public Survey where members of the general public were asked about what activities they associated with various SMILE partners, it was rare if more than 2% of the public responded with a correct association. That Eon and biogas had a 50% higher rate of association than average suggests that Eon achieved a relatively good level of awareness in Malmö during SMILE.

C3 Achievement of quantifiable targets

The reader should refer back to page two in the template to see that not all seven objectives, either in the original form or in the revised de facto objectives that arose during the course of the measure, had quantifiable targets.

No.	Target (Objectives from page 2)	Rating
1	Establish a capacity upgrade facility and put biogas onto the market primarily as part of the product “vehicle gas” which is approximately 50% biogas and 50% fossil-based natural gas	**
2	Open and operate several fuelling stations for vehicle gas of which one will be dedicated to commercial uses (heavy vehicles) with a slow, overnight, filling process and one which is open to all users with a fast filling capacity	**
3	Enable the municipality to run its fleet of methane-powered cars and Skånetrafiken’s buses on biogas or vehicle gas depending on demand and supply	*/ **
4	Increasing the percentage of non-fossil methane (biogas) used to power vehicles through a) the marketing and production of vehicle gas and b) through gradually increasing the percentage of biogas making up vehicle gas	*/ **
5	Introduce and/or increase awareness of production of biogas and its environmental benefits	0
6	Introduce and/or increase acceptance of production of biogas and its environmental benefits	0
7	Gas fuelling of light and heavy vehicles owned and operated by other organisations and private citizens.	*/ **
NA = Not Assessed 0 = Not achieved * = Substantially achieved (> 50%) ** = Achieved in full *** = Exceeded		
Notes: Most objectives had no numerical targets to compare with, ie goals were expressed in ways that made the goals easy to achieve. 3. Demand may be higher than supply at present. 35% of the gas in the urban buses run by Skånetrafiken in Malmö is biogas but Skånetrafiken would have liked this to have been a higher percentage. 4. This has increased and some marketing and increase in production has occurred. But since there are no numerical goals associated here it is difficult to assess with one symbol. 5 and 6. It is difficult to see that Eon, through its efforts alone, has introduced or increased awareness and acceptance. Eon has surely contributed to a general increase in awareness and acceptance but has not had a major activity on its own oriented towards awareness and acceptance during SMILE. 7. Again, since there are no numerical goals associated here it is difficult to assess with one symbol.		

C4 Up-scaling of results

Up-scaling can be achieved in several ways.

- First, more biogas could be produced and added to vehicles directly or via the grid. This could be locally produced gas if we confine up-scaling to Malmö, depending on the degree of raw material available, both from sewage processing and other possible sources.
- Second, other locations could start to supply additional biogas that would be transported in the grid and sold in Malmö (and other locations) as vehicle gas.
- Third, additional fuelling stations could be established in Malmö. Presently there are only five locations. An additional “depå” with overnight filling could be established in the harbour areas or in an area where a number of local companies might be on the verge of switching towards gas vehicles. The number of “public” stations (for private motorists) probably does not need to increase during the immediate years unless there is a great acceleration in the use of gas

powered light vehicles, particularly as demand from heavy duty vehicles currently outstrips supply.

- Fourth, other locations could be equipped with filling stations thus making it easier for potential gas car owners in Malmö to see that they could use the cars in many more locations without the risk of running out of fuel. The establishment of the fuelling facility, supplied by lorry, in Ystad is an example of this strategy. However the effects in Malmö would be at least initially very very small.
- Fifth, Eon is considering establishing an LNG facility using biogas produced from and upgraded at the smaller Klagshamn sewage treatment plant. The Klagshamn sewage treatment plant has a sewage treatment capacity about 33% of Sjölanda. Eon's actions will be based on signals provided by key freight actors in the Malmö area. Presumably the LNG facility, where the LNG contains much more energy per volume compared with CNG, would be in place to meet demands for long-haul lorries that are, at present, being fuelled with diesel.
- Sixth, Eon is considering establishing a very large biogas production facility in the harbour area in Malmö (to the north, off the map, of Map 1 on page 5). This facility would rely on surplus food or crops grown for biogas production. Eon intends that this facility would increase by ~10 times the amount of biogas available compared with today (2008/2009). A decision about such a facility lies several years in the future and will depend on the development of demand for biogas. The development of the debate about using food to produce fuel, thus reducing carbon dioxide emissions from the transport section, can come to impact on decisions about such a facility.

C5 Appraisal of evaluation approach

A drawback is the lack of a prior study of awareness and acceptance to be included in a baseline. The Ystad sub-project differs from the rest of the measure and therefore, in theory, should have been dealt with separately. However, the volume of sold gas there is about 3% of the total in Malmö and Ystad taken together and therefore in hindsight it has turned out that it was wise to not devote precious evaluation resources on such a small volume of gas sales. It would have also proved difficult to establish a baseline for Ystad since neither the measure leader nor the then site manager informed the technical evaluation staff about the establishment of the fuelling station in Ystad until such time that it was not possible to organise data collection in time.

C6 Summary of evaluation results

The key results are as follows:

- **Key result 1** – Eon has established a local biogas injection to the grid through purchase of raw biogas from Sjölanda and the establishment of an upgrade facility. This has led to the introduction of 10 GWh biogas to the local transportation system that otherwise would have been met in part by biogas produced elsewhere or by natural gas.
- **Key result 2** – Eon has established a vehicle gas fuelling facility in Ystad, some 60 km away from Malmö where no vehicles could be fuelled with natural gas or vehicle gas before. This has provided a much needed infrastructure for the expansion of use of gas powered-vehicles in this area. However, the effects on Malmö as the result of this part of the measure are negligible.
- **Key result 3** – Eon has established a slow-filling fuel gas facility for heavy vehicles to be fuelled overnight. This was a much needed improvement in fuelling infrastructure in Malmö. However this facility as finally built was not as large as original planned.
- **Key result 4** – This measure has led to a reduction of 430 920 kg in CO₂ being emitted by vehicles in Malmö and the surrounding areas during 2008. That this reduction was not higher is because of allocation of some of the CO₂ reduction to other measures in Malmö where the biogas was used in vehicles and that production of biogas elsewhere in Sweden added so much biogas in the business as usual scenario.

D Lessons learned

D1 Barriers and drivers

D1.1 Barriers

- **Barrier 1** – a fuelling facility was originally intended to be in Malmo but was established in Ystad which is 60km away from Malmo. This may be problematic for technical evaluation and assessing the benefits the measure has in Malmo since the effects are apparent where the filling station is.
- **Barrier 2** – lack of prior studies in awareness and acceptance makes it difficult to properly measure this characteristic as a success factor for this measure.
- **Barrier 3** – availability of raw materials and processing facilities that can yield biogas / vehicle gas.
- **Barrier 4** – relatively low awareness of gas (whether natural gas or biogas) as a fuel in Sweden.

D1.2 Drivers

- **Driver 1** – availability of and limited other use for biogas from sewage water treatment plants in Malmo which can be upgraded to vehicle fuel or natural gas quality.
- **Driver 2** – clean vehicles can use biogas which reduces the emissions of CO₂ generated by transport in Malmo.
- **Driver 3** – ability of the municipal fleet of clean vehicles (measure 5.1), Skånemejerier's trucks/lorries (measure 5.3) and Skånetrafiken's city buses to run on biogas or vehicle gas, so exploiting the synergies offered by SMILE.
- **Driver 4** – ability to upgrade biogas to natural gas quality for usage in clean vehicles and to use the existing natural gas grid to carry upgraded biogas to fuelling stations.
- **Driver 5** – desire to expand a bio fuel infrastructure by introducing new fuelling stations and bringing them closer to public and organisation for increase in use.
- **Driver 6** – opportunity to use the existing filling station for natural gas at Spillepeng.

D2 Participation of stakeholders

- **Stakeholder 1** – EON Gas private company, has a leading role of project management
- **Stakeholder 2** – Regional public transport company as a transport operator offers strong support to the measure
- **Stakeholder 3** – Car drivers are seen to be in strong support of the measure
- **Stakeholder 4** – Local dairy company has a strong support for the measure
- **Stakeholder 5** – Regional bus operator
- **Stakeholder 6** – Companies and owners of gas fuel vehicles in Malmo
- **Stakeholder 7** – City of Malmo as a project facilitator and also as the producer and commercial provider of the raw biogas

D3 Recommendations

- **Recommendation 1** – it is recommended to establish more fuelling stations in Malmo and perhaps a further overnight slow filling station in the harbour areas or close to companies which may switch to gas vehicles.
- **Recommendation 2** – to increase availability more gas can be produced for distribution in Malmo.
- **Recommendation 3** – to enable existing filling stations in Malmo to supply biogas to potential clean vehicle owners thus increasing biogas availability in more locations.
- **Recommendation 4** – marketing campaigns to promote availability of vehicle gas and switching to clean vehicles at strategic locations such as filling stations, vehicle suppliers and relevant professional magazines.

D4 Future activities relating to the measure

The measure template does not specifically mention any future activities for this measure. Future activities could be seen as recommendations.

At some point in the future, demand for vehicle gas may come to grow much faster than incremental increases in production from existing facilities in Malmö and other places in Skåne.

Eon is considering constructing an upgrade facility at the Klagshamn sewage treatment facility and using this and fossil natural gas in combination to produce LNG vehicle gas. Eon is also considering the construction of a much larger biogas production facility in the harbour area. The source for the fuel production would be crops grown for this purpose. As such this represents a departure from Eon's previous strategies for sourcing biogas: agricultural waste and sewage gas. These are considerations that Eon has at this moment and depend on growth in demand for vehicle gas and LNG as well as cost developments. Decisions to actually construct these facilities may be several years in the future.

Refer to the end of section C4 on page 14 for more information about *potential* future activities.