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BIOMETHANE USE IN SWEDEN

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Summary

Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. Biogas is one of the cleanest and most versatile renewable fuels available today, answering on challenges of EU sustainable development strategies. Upgraded biogas–biomethane–has the same advantages as natural gas, but additionally is a sustainable fuel that can be manufactured from local waste streams thereby also solving local waste problems. During the last years, the production and use of biomethane has significantly increased in many European countries. Sweden is world leading both in terms of automotive use of biomethane and its non-grid based transportation.

Keywords: biomethane, transport, Sweden

1. Introduction–why biomethane?

Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. Road transport alone contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas. From 1990 to 2013 in EU, all sectors reduced GHG emissions, except the transport sector, where GHG emissions increased by 14 % [6]. This increase is observed despite improved vehicle efficiency because the amount of personal and freight transport has increased.

EU has put a range of policies in place aiming to lower emissions from the transport sector. The main is Renewable Energy Directive 2009/28/EC (RED) which sets for transport sector for 2020 obligation of 10 % quota of fuels from renewable energy sources. Moreover sustainability requirements are defined for liquid biofuels, including minimum greenhouse gas emissions (GHG) reductions and land use issue [5].

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The Renewable Energy Directive is complemented by several other directives:

- The Low Carbon Fuel Standard Directive (2009/30/EC) is an amendment to the Fuel Quality Directive (1998/70/EC) requiring 6-10 % decrease of greenhouse gas intensity of road and inland waterway vessel fuels by 2020 compared to the situation in 2010. This can be achieved by increasing market share of renewable fuels or low carbon fossil fuels.
- The Clean Vehicle Procurement Directive (2009/33/EC) addresses public sector procurement of vehicles and transport services with a purpose to expand sustainable vehicle fleets.
- The Alternative Fuel Infrastructure Directive (2014/94/EU) requires building up filling station networks for methane, hydrogen and electricity, which offer the most sustainable mobility.

On April 28, 2015, the European Parliament's approved the compromise agreement on the reform of the RED, which includes a 7 % cap on conventional biofuels (crop-based), in the EU's renewable energy target for its transport sector for 2020, and included indirect land use change (ILUC) factors but only for reporting purposes. The Council has to confirm the Parliament's vote, which is expected by the end of 2015. If approved, Member States will have to adopt the new legislation by 2017 [10].

Biogas is one of the cleanest and most versatile renewable fuels available today, answering on challenges of EU sustainable development strategies. It might be used to produce heat and electricity, both in small and large-scale applications [1]. It might also be used in various industrial processes or–after upgrading–as vehicle fuel replacing petrol or diesel. Biogas can be produced from almost any organic material through either digestion or gasification. Biogas produced from organic digestible materials also prevents emissions of methane, making it exceptionally good for the climate.

Upgraded biogas–biomethane–has the same advantages as natural gas, but additionally is a sustainable fuel that can be manufactured from local waste streams thereby also solving local waste problems. Several European projects (GasHighway, Biomaster, Baltic Biogas Bus etc.) have shown that biomethane produced and used locally, not only decreases negative environmental impacts of transport sector but, also generates jobs and could increase energy security and long term competitiveness (creation of new market).

The increased interest in natural gas/biomethane as a fuel is picked up by manufacturers, many of whom feature natural gas vehicles in their product line-up. For example the Bus World trade fair in Kortrijk (Belgium) last November manufacturers presented several new models running on natural gas, both for the urban and suburban environment [21].

2. Biomethane in Europe

During the last years, the production and use of biomethane has significantly increased in many European countries. By 2015 biomethane was produced in more than 340 plants in 17 countries. In October 2015 German Energy Agency has organized first European Biomethane

Conference in Berlin. New biomethane markets were discussed and national political frame works as well as the adapted biomethane production concepts were presented [22].

In Table 1 some numbers showing development of biomethane market in chosen EU countries in 2012 are presented [18].

In most countries in Europe, where significant share of the residential and industrial sector have access to the natural gas grid, the biomethane is transported mainly through the gas grid. Such solution is implemented e.g. in Germany, where in 2014 biomethane from 155 upgrading units was injected to the grid (in 2012 it was 118 from 120 as shown in Table 1) [20]. However, in countries such as Sweden where the gas grid coverage is limited and restricted to only a part of the country, have implemented other solutions. In 2012 only 11 of the 53 biogas upgrading plants were injecting biomethane into the national gas grid in Sweden (at the end of 2014 the situation did not changed–from 55 biogas upgrading plants only 10 were injecting biomethane to the grid). The remaining facilities are using alternative solutions to distribute the produced biomethane to the end-users [18].

Table 1. Biomethane development in selected EU countries in 2012 [18]

Country	Biogas plants[1]	Biogas upgrading plants (fed in)	Upgrading capacity[2], Nm^3/h	Gas filling stations	Gas driven vehicles NGV
Austria	421	10 (7)	2 000	203	7 065
Germany	9 066	120 (118)	72 000	904	95 162
Italy	1 264	1 (0)	540	903	746 470
Sweden	187	53 (11)	16 800	190	44 000
The Netherlands	211	16 (16)	6 540	150	5 201

[1] not included landfill plant
[2] referring to biomethane
[3] total (public and private)

2.1. Technical standards

Biomethane from organic matter offers an extension and gradually increasing substitution for fossil natural gas. It can be mixed at any ratio with natural gas when used in natural gas vehicles. Development of technical standards can significantly support implementation of advanced biofuels, in that biomethane. Standards for biomethane need to meet both, requirements of the natural gas grid and requirements of automotive use. The Swedish standard SS 155438 "Motor fuels – Biogas as fuel for high-speed Otto engines" developed in 1999 was for long time the only standard regulating direct use of biomethane as an automotive fuel [1, 17].

On February 2015 Technical Committee CEN/TC 408 "Natural gas and biomethane for use in transport and biomethane for injection in the natural gas grid", has published document

Table 2. Requirements, limit values and related test methods for natural gas and biomethane as automotive fuels with normal MN grade (methane number as in EN 16726) [9]

Parameter	Unit	Limit values[a]		Test method
		min	max	
Total volatile silicon (as Si)	mgSi/m^3		0,1 or 0,5[b]	SP test method
Hydrogen	% mol/mol		2	EN ISO 6974-3 EN ISO 6974-6 EN ISO 6975
Hydrocarbon dew point temperature (from 0,1 to 7 MPa absolute pressure)	^{o}C		-2 (as in EN 16726)	ISO 23874 ISO/TR 11150 ISO/TR 12148
Oxygen	% mol/mol		1	EN ISO 6974 series EN ISO 6975
Hydrogen sulfide +Carbonyl sulfide (as sulfur)	mg/m^3		5 (as in EN 16726)	EN ISO 6326-1 EN ISO 6326-3 EN ISO 19739
S total	mgS/m^3		[c]	EN ISO 6326-5 EN ISO 19739
Methane number	Index	65[d] (as in EN 16726)		Annex A of EN 16726
Compressor oil			[e]	ISO 8573-2
Dust impurities			[f]	ISO 8573-4
Amine			10[g]	VDI 2467 Blatt 2:1991-08
Water dew point	See 4.4			

Comments

[a] Limit values are absolute, the number of the decimal places shall not imply the accuracy of the test method.

[b] A silicon content of ⟨0,1 or 0,5 mg/m^3 is considered as a safe level. Further research is needed for a decision whether a higher limit value is acceptable.

[c] Currently, there is a difference between the automotive industry needs for sulfur content (10 mgS/m^3 including odorisation) and the values the gas industry can provide (30 mg/m^3 including odorisation). See Annex B. It is possible to cover this parameter in a national foreword.

[d] The methane number depends on the composition of the distributed natural gas. It should be noted that only a small fraction of the distributed natural gas has a methane number below (MWM) of 70.

[e] The fuel shall be free from impurities other than „de minimis" levels of compressor oil and dust impurities. In the context of this European Standard, „de minimis" means an amount that does not render the fuel unacceptable for use in end user applications.

[f] Fueling stations providing LNG should include a filter with maximum size of 5 µm nominal and 10 µm absolute with 90 % efficiency and giving maximum particle contamination of 10 mg/L of LNG to protect the vehicle system from debris.

[g] When the absence of liquid water can be demonstrated, it is necessary to monitor these parameters.

FprEN 16723-2:2015 prepared under a mandate given to CEN by the European Commission and the European Free Trade Association. If the working group's proposal is accepted, then the standard will be published in 2016 [9].

Mentioned document consists of two parts:

- FprEN 16723-1:2014, Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network – Part 1: Specifications for biomethane for injection in the natural gas network,
- FprEN 16723-2:2014, Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network – Part 2: Automotive fuel specifications.

Part 2 specifies the requirements and test methods for natural gas (group L and H), biomethane and blends of both at the point of use as automotive fuels and applies to these fuels irrespective of the storage state (compressed or liquefied).

3. Biomethane in Sweden

Sweden is world leading both in terms of automotive use of biomethane and its non-grid based transportation. The development of biogas as vehicle fuel in Sweden is a result of a combination of a surplus of gas from biogas plants, primarily at the sewage treatment plants, and a low electricity price that forces the biogas into markets other than electricity production [14, 17]. In Sweden natural gas and biomethane are complementary fuels [16]. In 2014 more than 50 % of the produced biogas was used as transport fuel (biomethane) in Sweden and represents over 70 % of the total sold CNG (Fig. 1).

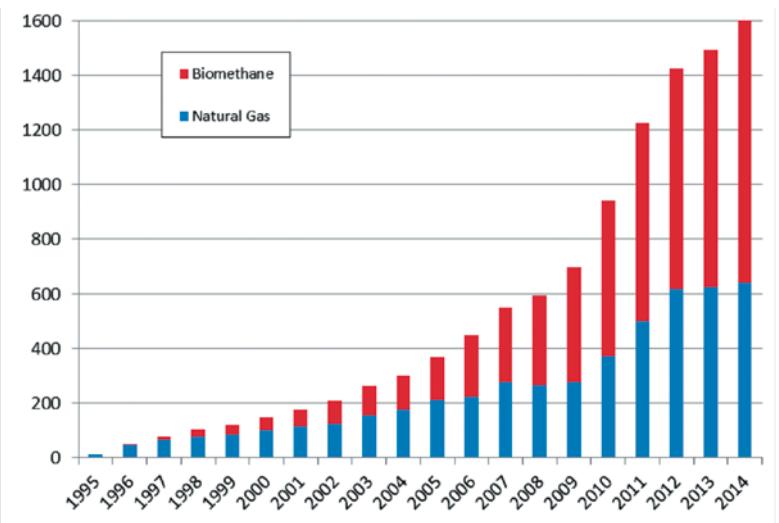

Fig. 1. Volumes of CNG/biomethane used in Sweden, GWh [16]

In the last 15 years, the Swedish market for natural gas fuel has grown steadily. At the end of 2014 Sweden had a well-balanced fleet with 46 975 light duty vehicles, 2 315 buses (17 % of national market) and 750 HD trucks (Fig. 2).

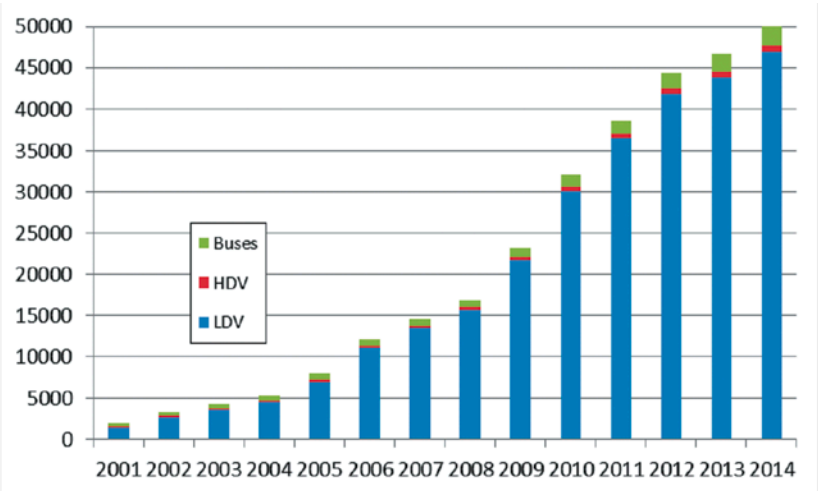

Fig. 2. Number of NGVs in Sweden, end of 2014 [16]

In 2014 there were 59 biogas upgrading plants in the operation: 41 water scrubbers, 6 PSA and 12 amine scrubbers. In 2015 two new membrane units and 1 cryogenic one started operation [16].

It is worth to underline that Sweden, without access to a natural gas pipeline system (except a 300 km stretch along the southwest coast), has managed to build up a good refueling network in the southern half of the country, and now is expanding it into the northern part. At the end of year 2014 there were over 155 public filling stations and 63 non-public ones [16]. This was possible via building of local plants for the production of biomethane. There are more than a dozen cities where the bus fleets completely rely on biomethane. The positive development when it comes to bus fleets has resulted from municipal and regional support for biomethane.

The support system in Sweden in biogas sector is mainly focused on increasing the usage of biomethane as vehicle fuel.

The existing support systems include [4, 16, 17]:

- no carbon dioxide or energy tax on biogas until the end of 2015 (extension 2020 pending EU approval),
- 40 % reduction of income tax for use of company NGVs until end of 2019,
- investment grants for marketing of new technologies and new solutions for biogas during 2010-2016. Maximum 45 % or 25 MSEK (~3M€) of investment cost,

- climate investment grant for municipalities: total budget 1,925 MSEK (~200 M€) until the end of 2018,
- 0,2 SEK/kWh (~€ 0,02/kWh) for manure based biogas production to reduce methane emissions from manure. Total budget 355 MSEK (10 years).

In last days the Swedish Government has presented its plan for a taxation policy of biofuels in relation to the EU regulation. In a special application to the European Commission (EC) the government have asked for a continued tax exemption for biogas as a fuel until the end of 2020 [19]. Positive answer will form basis for stable development of the sector in next years.

3.1. National strategies

In Sweden government 2020 goals for renewables (50 % of the total energy utilization and 10 % goal in transports) are already reached.

Sweden has published a governmental vision to have a fossil free transportation sector by 2030 and a sustainable and resource efficient energy system without net emissions of greenhouse gases to the atmosphere by 2050 [4].

In the same time the gas industry has announced their biomethane vision with 100 % target in NGV market by 2030, and 100 % in the national grid by 2050. It is planned that national strategy will be launched in December 2015 [16].

4. Case studies

In Sweden tens of municipalities have shown that local policies played key roles in market creation. Municipal policies have enabled their citizens and companies to make transition to sustainable transport based in 100 % on renewable energy, being ahead the national goal for 2030.

Biogas is the most obvious example of municipal opportunities, since municipalities control both the source of biogas, biowastes, and large amount of transport. Therefore, they can create both supply and demand locally. Municipalities are responsible for biowaste management and they can decide it to be used for transport fuel production. They can also decide that their own vehicles, municipal buses and waste trucks will use the local fuel. It means that municipalities can create local isolated markets independently, even without involvement of private companies and even if those fuels are not used elsewhere.

Successful market creation has been implemented politically and technologically diverse ways. Main instruments have been ownership policy of municipal companies and purchasing policies. Municipalities have not only utilized their existing companies, but also established new companies for this sector, e.g. distribution companies Svensk Biogas and Fordonsgas. Public purchasing policy legislature has been effectively implemented

for vehicle and their energy purchases as well as for transportation service procurements (e.g. city buses and waste trucks) for all municipal organizations. Moreover new area of expertise for local companies has arise–production of upgrading equipment (e.g. Malmberg, Purac), gas vehicles (e.g. Scania, Volvo).

The regions of Västra Götaland and Skåne in western and southern Sweden are responsible for a significant part of the development of biogas. Unique interaction between research, political decisions, trade and industry has been significant for the development of the biogas field in these regions [3, 12].

4.1. Västra Götaland

Göteborg and West Sweden are forerunners in biogas production for vehicle use, where a third of Sweden's methane gas fueling stations are located. By the end of 2009, there were around 7,500 gas-driven vehicles consuming 100 GWh biogas and 100 GWh natural gas [3].

Göteborg and West Sweden have a long history of using methane gas in vehicles. City of Göteborg is a pioneer in many types of biogas technology. Municipal waste water company began biomethane production and opened the first private biomethane filling station in 1992 at municipal sewage treatment plant. Since then Göteborg has been one the largest biomethane producers in Sweden, mostly based on municipal sewage.

Volvo built their first methane gas-driven bus at the end of the 1980s. In 1994, the first fueling station for compressed biogas was built at Gryaab wastewater treatment plant where converted Volvo bi-fuel cars were refueled.

Since 1996, the city-buses in the City of Trollhattan have been fueled by locally produced biogas, placing the city amongst the first in Sweden in biomethane use. Two years later the company Fordonsgas was founded, now one of Sweden's leading gas-fueling stations operators. These developments lead to the formation of the Biogas West project.

Launched in 2001, Biogas West is a regional cooperation project in Western Sweden to implement biogas as a vehicle fuel. Led by Business Region Göteborg, the project involves more than 25 stakeholders representing companies, municipalities in the western region, organizations and authorities. The purpose of Biogas West was to develop a new environmentally-sound industry that stimulates market development for the production, distribution and use of biogas as a vehicle fuel [3, 11].

The increased use of biomethane and the development of the western Sweden cluster contribute to substantial reduction of greenhouse gasses emissions. In addition, it solves waste problems and stimulates the production of organic fertilizers.

In Göteborg and Western Sweden, biogas is used on a large scale and replaces 20 % of the fossil fuels used in the transport sector. Biogas is used in cars, buses, trucks and ships. Biogas is produced from household and industrial waste, as well as agricultural and forest residues, and Göteborg is the leading centre for thermal gasification, producing large amounts of biomethane from forest residues.

Thanks to the well-developed natural gas grid, regional biogas grids and liquefied biogas, Western Sweden is a leading centre for the production, distribution and use of liquefied biogas. The region is a world-leading cluster for developing biogas engines and vehicles. Methane-diesel engines for heavy duty trucks, buses, construction vehicles and ships are being developed, as well as vehicles with gas-electric hybrid power trains.

4.2. Skåne Region

Skåne aims to have 100 % renewable public land transport system by 2015 in the whole province based on locally produced wind power and biowastes [6, 7].

By 2020 the 100 % renewable requirement is extended to all transport, which is directly controlled by provincial and municipal governments: own/leased vehicles, waste trucks, ferries and water buses. Renewable electricity is the main technology for rail transport, biomethane for road transport and liquefied biomethane LBG for water transport. Main source of renewable electricity for transport is wind power, which originates from offshore wind farms, onshore wind farms, individual onshore turbines and building integrated wind turbines.

Currently locally produced biogas is used as biomethane in road transport and agricultural tractors. In addition, LBG is available for trucks. Local LBG production is planned and it will be used in water transport also. There are now 7 upgrading plants, over 40 biomethane filling stations and 2 LBG stations in Skåne.

Fig. 3. Biomethane filling station for buses in Kristianstad in Skåne

Provincial target for biogas production in 2020 is 3 TWh, of which 95 % originates from waste feedstocks. At least 85 % will go to vehicle use. Half of the production would come from biogas plants and half from one central gasification plant. The gasification plant project is run by E.ON, the most important private partner in the region. The plant will be located either in Malmö or Landskrona. Public-private partnerships are essential for reaching the goals.

City of Malmö was slowly starting with biogas use in transport sector, but it became the first Swedish municipality to operate natural gas (CNG) city buses in 1987; by 2000 all city buses were running on CNG. Other types of vehicles started using CNG in 1996, when the first public filling station was opened. Biomethane use started in 2008, when upgrading plant was opened at a municipal sewage treatment plant. Since then the share of biomethane use has been increasing and it is the goal of municipal government to stop using natural gas in city buses and municipal vehicles in 2015. By the end of 2015 at least 75 % of municipal vehicles should be biomethane powered, and the rest by other renewable fuels (including electricity from wind and PV).

Malmö has also co-funded private efforts. An excellent example is biogas powered milk transport: milk trucks and the first slow filling station at a dairy depot in 2009. It was a new application for slow filling stations [7].

5. Future trends of development in Sweden

5.1. Substrate – potential and limitations

In the past, environmental issues and waste management requirements drove the success of the current biogas production system in Sweden. In Sweden, many municipalities have installed co-digestion plants in order to fuel their public transportation fleet as a local solution to climate change and air pollution [13]. Nonetheless, the number of municipalities with biogas fuelled fleets is still relatively low and more municipalities could use biofuels in their public transportation systems from local substrates.

The Swedish Waste Management and Recycling Association has noted an increase of 21 % in organic waste for biogas production from 2013-2014 [2]. There is growing number of municipalities collecting separated organic waste (190 from 290), the report identified an additional 70 which will install new organic waste handling facilities in the coming years [2]. This offers opportunities to increase the substrate base and develop biogas plants throughout Sweden. As owners of the waste, municipalities can drive the production and development of biogas. In several studies [3,10] public-private partnerships have been indicated as one of elements supporting the development of biogas.

However for biogas production several obstacles are noticed such as substrate competition, suggestion of new very tough regulations on digestate as fertilizer (limits on content of heavy metals), uncertainties concerning ILUC etc. [15].

With future scenarios of biomethane development pathways also other sources of raw material for biomethane production are taken into account. Sweden is pioneering in the large scale production of biomethane produced from forest industry waste within Europe.

The first large-scale gasification plant, GoBiGas, set to produce biogas from wood materials, is presently starting up in Göteborg. The GoBiGas plant will be directly connected to the natural gas grid running along the west coast of Sweden [16].

5.2. Research topics

Sweden is world leading both in terms of automotive use of biomethane and its non-grid based transportation. Today the biomethane is mainly transported in its compressed state in mobile storage units, but other solutions such as transport of its liquefied state and by way of local gas grids are under development [12].

Local gas grids are an option that gains more and more attention in Sweden as a means of transporting biomethane and natural gas outside the existing national natural gas grid. In larger volume markets, their economics are competitive with road transport, in spite of the much larger investment cost. Rather large-scale local or even regional grids are being projected, aiming to interconnect larger industries, cities, biomethane production plants and LNG terminals at the coast (3 LNG import terminals in 2015).

The market for liquefied biomethane (LBG) and natural gas in Sweden is growing especially by possibility of substituting diesel in heavy duty vehicles (Volvo and Scania) and substituting oil in ships [12].

The availability of liquefied gas will also support the use of L-CNG filling stations servicing both conventional CNG vehicles and hopefully also long haulage 44 ton trucks using LNG. There are currently two L-CNG filling stations operating in Göteborg & Södertalje and an LNG station, which is situated in the city of Malmö. The first production plant for liquefied biomethane (LBG) is located in Linköping in the VästraGötaland County and is in operation since 2012 [7].

During the last couple of years Volvo Trucks have developed diesel-methane trucks, for both CNG and LNG filling, which are now on the market.

BiMe-Trucks, a project financed by the Swedish Energy Agency, has been an important part of the Swedish LBG development, coordinating refueling stations construction and vehicle introduction. The aim of the project was to erect LNG refueling stations and to develop, offer and deliver to market LNG/LBG powered road haulage trucks equipped with energy-efficient methane diesel engines. Within the project three refueling stations (Fig. 4) were constructed and 48 vehicles were delivered to customers [22].

Fig. 4. Volvo LNG/biomethane truck at filling station, Göteborg

Another innovation is the future overland transportation of LNG/biomethane using tank trailers to supply filling stations without close access to biogas plants or the NG grid [12, 15].

6. Conclusions

The prospects for biomethane are highly promising, especially when taking into account passenger cars, heavy goods and air traffic and when looking at the bigger picture of the international markets.

Biomethane is an attractive fuel to support the transition from the fossil fuels and to response to emission reduction challenges. The use of biomethane will imply very low GHG emissions if produced e.g. through gasification of biomass (comparable to advanced biofuels) or even negative GHG emissions when produced from feedstock which otherwise would emit methane during its decomposition process such as organic municipal wastes or manure.

In Sweden biomethane is already pushed forward so it can be a good example for analyzing pluses and minuses of such solution. Swedish-Polish Sustainable Energy Platform [23] is promoting good practices from Sweden by organizing study tours, seminars and conferences as well as establishing contacts between researchers, local authorities and enterprises interested in the Swedish model of biomethane use in transport.

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