Urban waste for biomethane grid injection and transport in urban areas

UrbanBiogas study tour report:

On the Biogas Highway from Stockholm to Gothenburg

WP 2 – Task 2.4, D2.3

May 2012




Fraunhofer IWES

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UrbanBiogas website: www.urbanbiogas.eu

Contents

1. Introduction

Biogas and/or biomethane production from waste has the potential to contribute to the European waste and renewable energy targets. Adjacent upgrading to biomethane quality and grid injection in the natural gas distribution network or to use it as vehicle fuel are opportunities for a renewable energy production and use in urban areas. This approach, Waste-to-Biomethane (WtB), is promoted by the UrbanBiogas project. Core of the project is the implementation of five marketable WtB concepts for European cities: City of Zagreb (Croatia), Municipality of Abrantes (Portugal), City of Graz (Austria), City of Rzeszów (Poland), and City of Valmiera (Latvia).

The elaboration of the WtB concepts for the target cities is supported by the organisation of more than 130 events, including workshops, working group meetings, study tours and city exchange visits. One of these core events was the organisation of a study tour to biogas plants treating the organic fraction of urban and other organic waste in Sweden – the paragon country for waste to biomethane installations. The tour was organised by Fraunhofer IWES, Kassel, Germany, and was conducted on the Biogas Highway from Stockholm to Gothenburg from 29th till 31st May 2012.

The tour started in Stockholm with a visit of Henriksdal (Stockholm) and Västerås biogas plant. The second day included a visit of waste treatment biogas plants in Linköping and Lidköping. At Lidköping a meeting with Flotech, a manufacturer of pressurised water scrubbers, as well as a historical tour through Lidköping´s old town was arranged. The third and last day included a visit of the Borås biogas plant. All together 13 participants from Austria, Belgium, Croatia, Germany, Portugal and Sweden attended the study tour. Two participants caught attention to this tour through the UrbanBiogas website and facebook site.

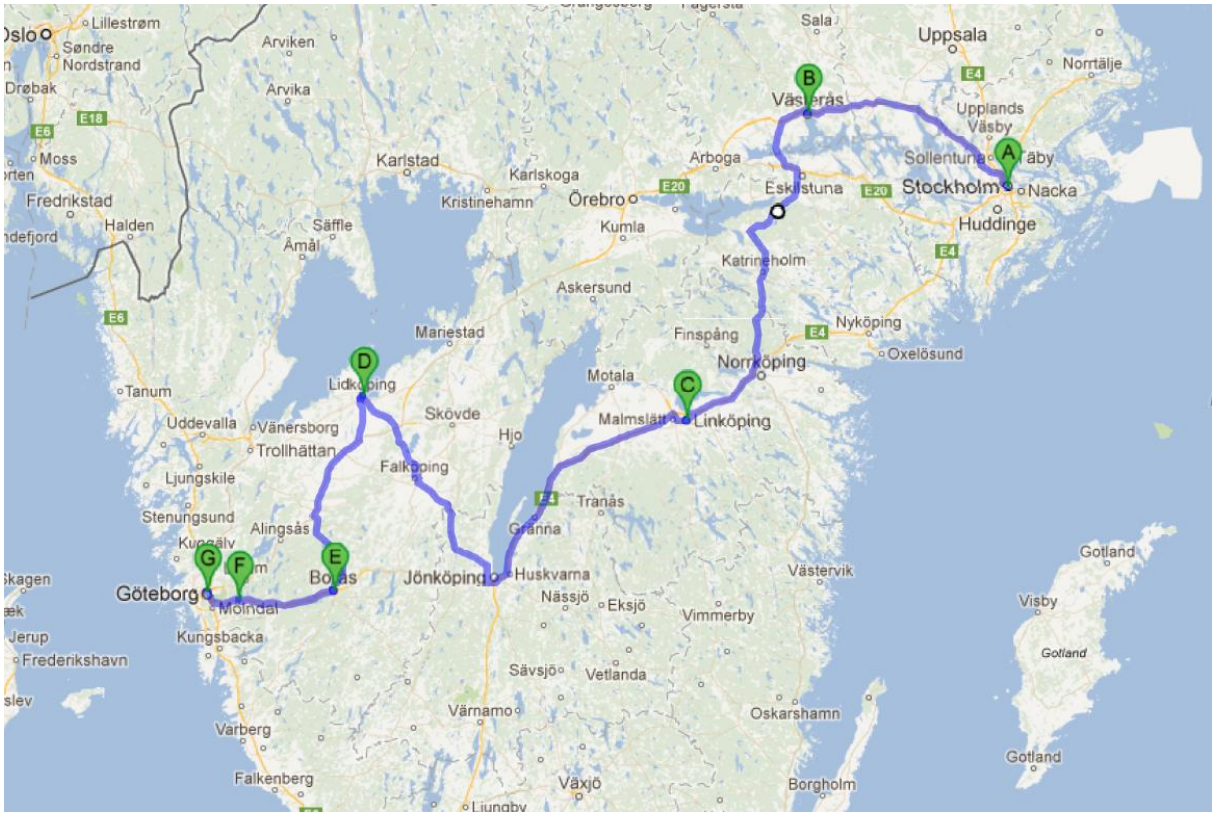
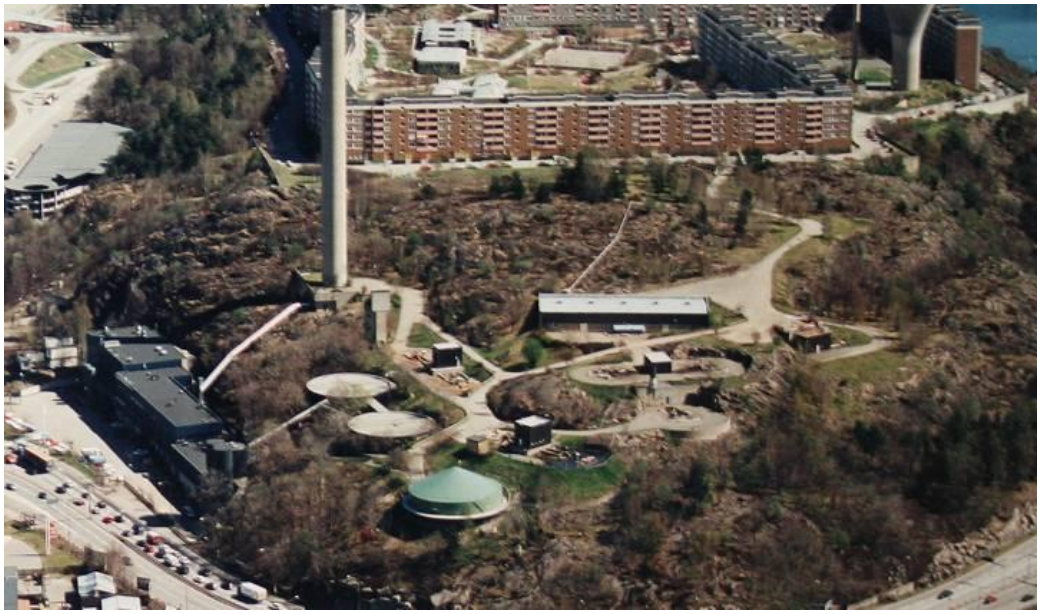


Figure 1: Stations of the UrbanBiogas study tour on the Biogas Highway from Stockholm to Gothenburg (source: google maps)

Legend: A: Henriksdal biogas plant; B: Västeras biogas plant; C: Linköping biogas plant; D: Lidköping biogas plant; E: Boras biogas plant; F: Landvetter Airport; G: Gothenburg city centre

Picture 1: Group photo in front of the digesters of Linköping biogas plant

2. Henriksdal biogas plant of Stockholm Vatten



Picture 2: The Henriksdal biogas plant [Stockholm Vatten 2008]

The first stop was at the Henriksdal waste water treatment plant (WWTP). Mrs Lena Jonsson, a research and development engineer from Stockholm Vatten, presented the biogas plant concept and handed out an informativ guide about the biogas plant. Henriksdal is the largest WWTP in Sweden. It is operated by Stockholm Vatten, a municipal water company. The main parts of the biogas plant as well as the WWTP are built underground in rocks. Thus, the plant is also called “world`s largest underground plant”. Wastewater from about 800,000 person equivalents is treated at the plant. The biogas plant has 7 digesters with a total volume of ca. 39,000 m^3. Figure 2 provides an overview of the biogas production process.

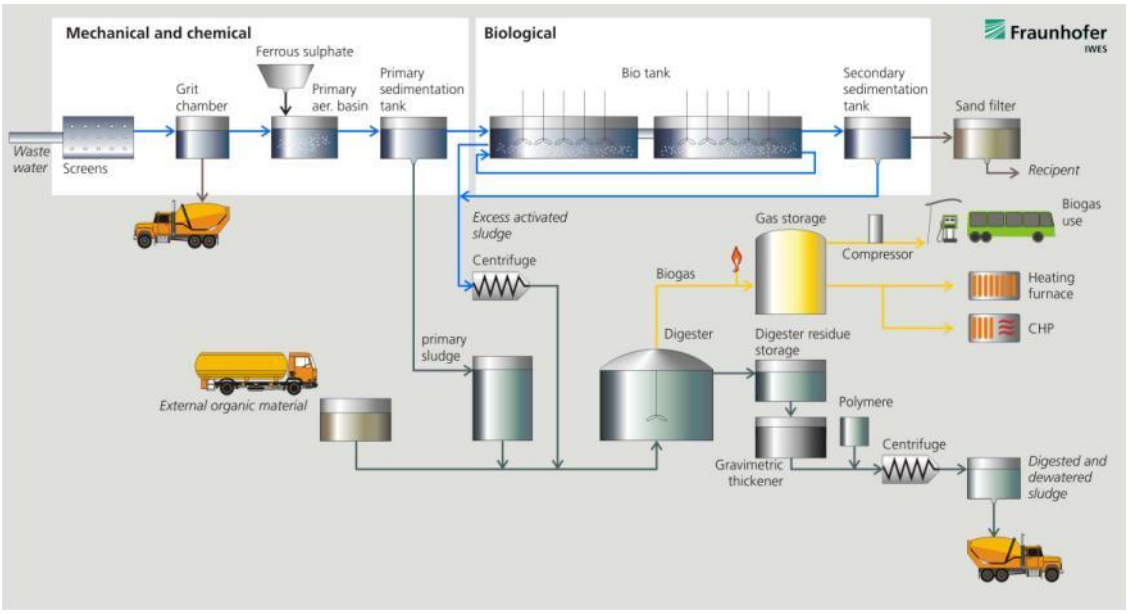


Figure 2: A schematic view of the wastewater treatment and biogas production process at Henriksdal WWTP

Feedstock for the biogas production process is primary and excess sludge recovered during the wastewater treatment process. Furthermore organic waste from the food industry and supermarkets as well as fat is used as feedstock. Organic municipal waste has only a share of less than 5 % of the total feedstock fed to the biogas plant. Nevertheless it has a high

contribution to the total biogas production of the plant because of its higher specific gas production than sewage sludge.

The wastewater treatment process at Henriksdal can be distinguished into three steps: mechanical, chemical and biological wastewater treatment. During these steps primary and excess sewage sludge are gathered. Before the gathered sludge is pumped into the digesters, it is dewatered through centrifuges to achieve dry matter content of about 4-8 % dry matter.

Dewatered sewage sludge is pumped in at the bottom of the digesters and flows out over a weir at the top. Stirring the sludge inside the digester takes place by stirrers consisting of three blades, a larger one at the bottom and two smaller ones in the middle and at the top, located on a common long stirring axis. Three times a day for approximately 3 minutes each time reversal of the stirrers takes place. Some mixing in the digesters is also done through sludge recirculation. Hereby the recirculated sludge passes externally placed heat exchangers. Anaerobic digestion occurs at mesophilic conditions with an average retention time of about 18 days.

Picture 3: Visit of the underground wastewater treatment plant at Henriksdal

Digester residue treatment

Digester residues at Henriksdal are separated by centrifuges into solid and liquid parts. The liquid residues are transported back into the wastewater treatment process. The solid digester residue is used as soil improver to establish vegetation areas on waste rock dumps and sand stores at quarries.

Biogas utilization

Most of the produced biogas is upgraded to vehicle fuel in a water scrubber upgrading plant with a capacity of 1,400 Nm^3 raw biogas per hour. The produced biomethane with a methane content of about 97 Vol. % is transported via private gas pipeline to a bus depot and to gas filling stations in Stockholm. Most of the public city buses in Stockholm run nowadays on biomethane. Furthermore company cars from “Stockholm Vatten” use biomethane as fuel.

Picture 4: On the top of a digester at Henriksdal biogas plant (left), inspection of the company owned biogas filling station for cars from Stockholm Vatten (right)

3. Västerås biogas plant of VafabMiljö

Picture 5: The Västerås biogas plant [picture: VafabMiliö]

The second biogas plant visit was in Västerås. Mr. Leksell, chief engineer from VafabMiljö and responsible for the biogas plant operation, presented the biogas plant and shared with us his operational experience. The biogas plant is operated by VafabMiljö, the local waste management company. Feedstock for the biogas production is source separated organic waste from about 300,000 citizens of Västerås and its vicinity. Furthermore ley crop silage as well as grease trap removal sludge from restaurants and canteens are used as feedstock.

Picture 6: Mr. Leksell explained the biogas plant concept

The biogas plant has started its operation in 2005 as a demonstration plant which should demonstrate a cost effective system, producing biogas as vehicle fuel and ecolabelled fertilizer through the co-digestion of municipal organic waste and agriculture crops. The aim of the biogas plant is to treat organic waste through biogas production on an environmental friendly way to close nutrient cycles between urban areas and the agricultural sector by using the digester residues as organic fertilizer. The flow chart in Figure 3 provides an overview about the biogas production process.

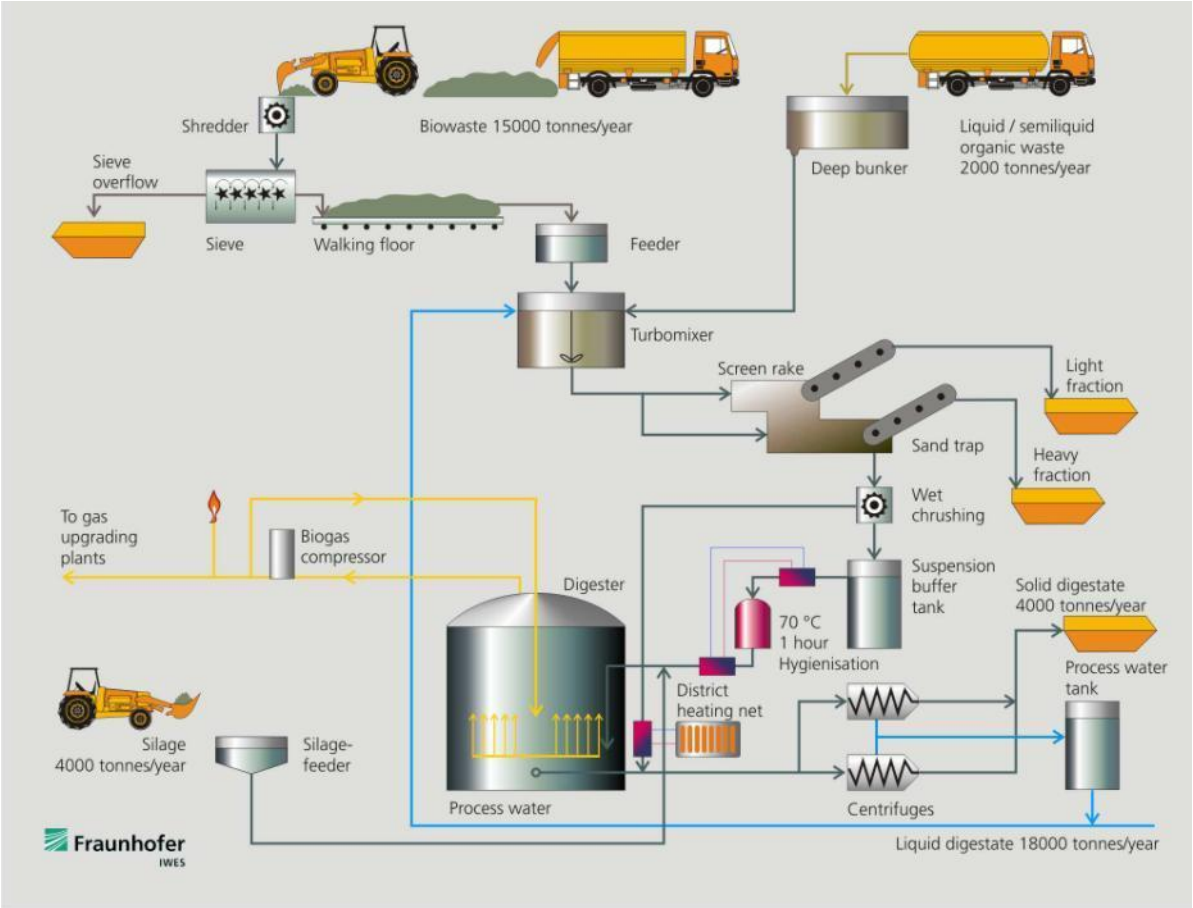


Figure 3: A schematic overview of the biogas production process at Västerås [Fraunhofer IWES 2009]

The citizens of Västeras are collecting organic household waste in separate biowaste bins. This, as well as liquid organic waste, is collected and transported to the biogas plant by waste trucks from VafabMiljö. Also the ley crop silage is harvested through Vafabmiljö. In total an average of 20,000 tons of feedstock are digested per year.

All incoming organic household waste is pretreated and crushed with the aim to remove indigestible impurities through sieves and metal separators to make the feedstock more homogeneous. The crushed and cleaned household waste is mixed together with liquid waste (fats) as well as recirculated liquid digester residue to achieve a pumpable suspension of about 8 % dry matter content. This suspension is cleaned again from smaller sized impurities and stored in a buffer tank to ensure a regular feeding of the biogas plant. According to EU-Reg. 1774/2002 the organic waste is a “category 3” material that has to be sanitized before it is allowed to be used as fertilizer. The sanitation process occurs in three tanks, 16 m³ each, which are working in a cycle batch process. Sanitation by more than 70 °C for at least one hour is necessary.

Heat used for the biogas plant and for the sanitation process is delivered by district heating from a nearby waste incineration plant.

Ley crops produced by local farmers are stored at the biogas plant site in long plastic hoses where they are preserved as silage. Ley crop silage is charged quasi-continuously into the digester.

Digester sludge mixing in the digester is done by injected compressed biogas. The digester and suspension buffer tank of the biogas plant is shown in Picture 7.

Picture 7: Digester and suspension buffer tank of the biogas plant

Digester residue treatment

The produced digester residues are separated into a liquid and solid phase by two decanter centrifuges. The liquid digester residue is stored in a process water tank. It is either used as process water or as liquid fertilizer. Digester residues used as fertilizers are transported by VafabMiljö to local farms. According to the regulations of KRAV, the Swedish certification system for organic agriculture, digester residues produced at the biogas plant are accepted as fertilizer for organic farming.

Biogas utilization

Vafabmiljö is responsible for the biomethane supply of all gas driven cars in the region of Västeras. About 700 m³ biomethane per hour are therefore produced by a water scrubber upgrading plant at the biogas plant site. These upgrade biogas from the biogas plant as well as from a nereby wastewater treatment plant. Two gas filling stations in the city of Västerås are supplied with biomethane through a small regional gas grid. Other filling stations are supplied with compressed biomethane via CNG trucks. Furthermore, 2 Mio. tons of LNG are used as a back up system to ensure a safe gas fuel supply for the region.

Picture 8: Ley crop silage storage in plastic hoses at the biogas plant site (left), Source separated household waste (right)

Picture 9: Delivery of source separated household waste in a container (left), delivery of liquid organic waste (right)

Picture 10: Biogas driven company car at the biogas plant site

4. Linköping biogas plant of Svensk Biogas

Picture 11: The Linköping biogas plant

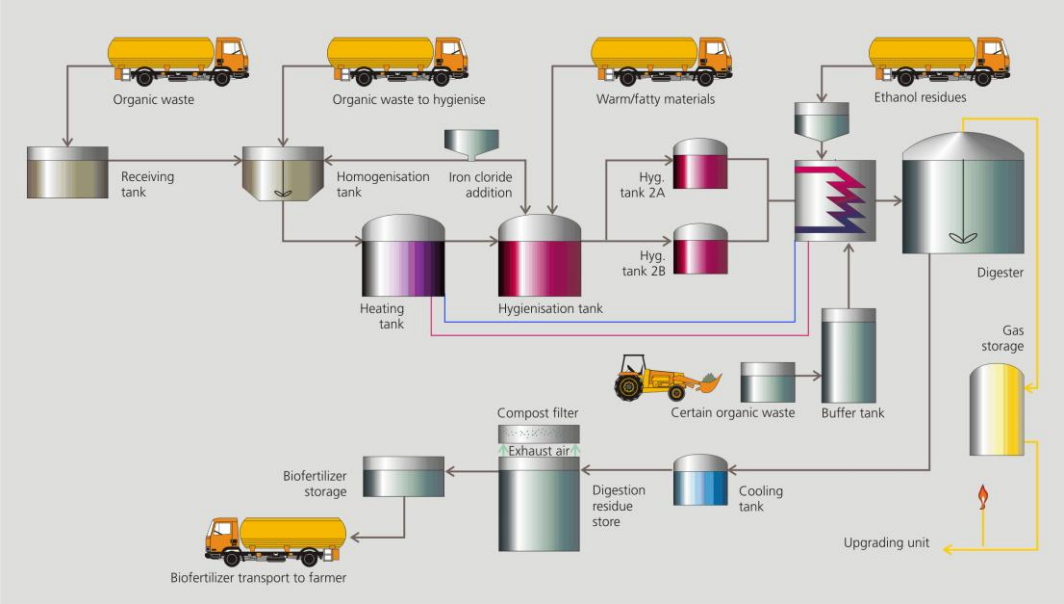
The first visit on the second tour day was at Linköping biogas plant. Mrs Lina Wiberg a research and development engineer from Tekniska Verken presented the biogas plant concept and handed out an informativ guide about the biogas plant.

Picture 12: Theoretical presentation of Svensk Biogas and its biogas plant concept by Lina Wiberg (Research and development engineer from Tekniska Verken)

The biogas plant in Linköping is operated by Svensk Biogas a subsidiary of Tekniska Verken in Linköping AB. Svensk Biogas operates two biogas plants and several public gas filling stations in the region around Linköping. In 1996 the biogas plant was implemented to treat slaughterhouse waste from the food industry in the region. During the last 15 years the biogas plant has expanded its production continuously. Stillage from the ethanol production as well as

food residues from the industry are used as feedstock sources. In 2012 Svensk Biogas started to treat source separated municipal household waste of about 300,000 private households. Therefore they built a new hall to separate and pretreat the incoming waste.

Municipal household waste is collected by the citizens in green plastic bags in one garbage bin together with normal waste. At the biogas plant regular waste in black plastic bags is separated from the organic waste in green plastic bags by an automatic sorting machine which sorts the bags of waste depending on their color. Regular household waste is incinerated by an incineration plant next to Linköping biogas plant. The heat demand of the biogas plant for the upgrading process and to warm the digesters and its sanitation step is supplied via district heating system from the waste incineration plant.



Picture 13: Process overview of the biogas plant at Linköping

The biogas plant has two digesters and one post digester. The retention time is about 40-50 days in the digesters, plus about 50-60 days in the post digester, before the residue is pumped into an uncovered digester residue storage tank (Picture 13).

Organic waste materials digested at the biogas plant are category 3 materials according to EU-Regulation 1774/2002 and has to be sanitized by 1 hour at 70 degrees. Because of the sulphur rich feedstocks, ferrous chlorides are dosed to the homogenization and hygienization tank to reduce the quantity of hydrogen sulphide in the raw gas that can cause corrosions in machines is poisonous and can lead to odour nuisance. Before ferrous chlorides were used for the desulphurization, Linköping was also called “the smelly town”.

Biogas from the neighboured wastewater treatment plant and from the biogas plant is upgraded by two water scrubbers (1,500 m³ raw gas per hour, each) and one amine scrubber (2,000 m³ raw gas per hour) at the biogas plant site.

Digester residues produced at the plant are certified as fertilizers that replaces artificial fertilizers on farms.

Picture 14: Visit of a biogas filling station operated by Svensk Biogas (left); Biogas driven waste collection truck from Teckniska Verken (right)

5. Lidköping biogas plant

Picture 15: Biogas plant from Swedish Biogas international at Lidköping

The second visit on the second tour day was at Lidköping biogas plant. Mr Ulf Johnsson from Greenlane, the manufacturer of one of the upgrading plants, has presented the biogas and upgrading plant concept. The Linköping biogas plant has one of the world´s first liquid biomethane production plant. One week before the plant visit the first truck was charged with liquid biomethane and forwarded it to Gothenburg. Thus, our group was the first who visited the new constructed LBG-plant.

Owner of the biogas plant is Swedish Biogas international AB. The implementation of the biogas plant was done through a co-operation between Swedish Biogas International, Göteborg Energi and Lidköping municipality. The plant is implemented to supply cars and trucks with biomethane and LBG (Liquid BioGas = Liquid Biomethane Gas) as fuel.

Agricultural crops and municipal organic waste are feedstock for the biogas production. All incoming feedstock materials are crushed, mixed and heated to 38 °C before they are charged into the digesters. Produced digester residues are used as organic fertilizers on agricultural fields.

Biogas produced at the plant is upgraded to biomethane by a water scrubber plant from Greenlane. After the first upgrading step, biomethane with a methane content of about 97 Vol. % is produced. This biomethane is either used as compressed gas to directly supply gas filling stations in the region around Lidköping or as liquified gas for filling stations that are further away.

Picture 16: Water scrubber upgrading plant (1st upgrading plant)

Picture 17: Inspection of the water scrubber upgrading plant with Mr. Ulf Jonsson from Greenlane

Picture 18: Inspection of the biogas filling station in front of the biogas plant (for compressed biomethane)

LBG (Liquid BioGas) production plant

A majority of the biomethane is liquefied in the condensation plant. In order to liquefy the gas, the majority of the remaining CO_2 (after the first upgrading step) is separated by a Pressure Swing Absorption (PSA) to almost 100 % biomethane content before the gas temperature is lowered. The liquefied gas is stored in an insulated tank. Fordonsgas Sverige AB transports the gas in insulated trailers to gas filling stations in Gothenburg.

The problem of gaseous fuels is their low energy density and the need for large storage tanks. Due to this high volume, long distance transports are problematic. Liquefied gas increases the energy density and enables longer driving distances between re-fuelling. The LBG production facility uses the method for liquefied natural gas (LNG).

Picture 19: Pressure swing adsorption upgrading plant (2nd upgrading plant) (left); LBG (Liquid BioGas) production plant (right)

Picture 20: LBG storage tank (left) and frozen tube at the LBG storage tank (right)

Picture 21: Presentation of the Flotech upgrading plant systems in the conference room at the hotel

6. Historical tour through Lidköping´s old town

Lidköping - a city with about 25,000 inhabitants - is situated on the southern shore of Lake Vänern, the biggest lake of Sweden (and 3rd biggest in Europe).

Mr. Lars-Göran Nilsson an employee of the museum of Lidköping guided the group through the historical centre of Lidköping and informed about Lidköpings changeful history.

Picture 22: Sightseeing tour through Lidköping

Picture 23: Old court house at Lidköping

7. Borås biogas plant at Borås

The last biogas plant visit was in Borås in the region of Gothenburg on the third day of the study tour. Mrs. Paulina Helander explained to us the biogas plant concept and guided us through the biogas plant site. The biogas plant at Borås is a joint facility consisting of Sobacken municipal waste handling facility and Borås Energi & Miljö. It was put into operation in 2005 to treat the organic fraction of household, restaurant and slaughterhouse waste. Today also remainders from the food and pet food industry are digested.

Waste from the city of Borås, Bollebygd municipality and Marks municipality (about 300,000 households) is treated at the biogas plant. Municipal organic waste is separated by the citizens into white plastic bags in one waste bin together with nondigestible household waste (collected in black plastic bags). At the biogas plant white and black plastic bags are separated by an automatic sorting machine called ”Optibag” which sorts the bags of waste depending on their color, white or black. As a result of a vigorous public education campaign and financial disincentives for not sorting waste, it is estimated that 85% of the residents in Borås are currently sorting correctly.

The biogas plant is dimensioned to treat 30,000 tons of waste per year and has an average biogas production of 300 m³ per hour.

Picture 24: Presentation of the biogas and waste management concept at Boras by Paulina Helander

Picture 25: Delivery of household waste by lorry (left) and transportation to the separation (right)

Picture 26: Separation process of incoming household waste by optical sensors

Picture 27: Pet food as feedstock for the biogas production

Biogas utilization

All biogas produced at the biogas plant is transported via pipeline to a WWTP over a distance of 7 km. Biogas from both plants is upgraded in a PSA to biomethane and used as vehicle fuel

in the region. Because of an enlargement of the biogas plant a water scrubber will be implemented at the biogas plant site this summer.

Picture 28: Company biogas filling station at the biogas plant site (left), new implemented water scrubber upgrading plant

Annex I - List of participants

	First Name	Surname	Company	Job function	Country
1	Robert	Bosnjak	Energy Institute Hrvoje Požar	Deputy head of energy system planning department	Croatia
2	Daniel	Golja	Energy Institute Hrvoje Požar	Senior researcher	Croatia
3	Dominik	Rutz	WIP Renewable Energies	Project Manager	Germany
4	Ilze	Dr.sc.ing. Dzene	Ekodoma, Ltd.	Project Manager	Latvia
5	Luis	Fernandes	Sintra's Municipal Energy Agency (Agência Municipal de Energia de Sintra - AMES)	Member of the board	Portugal
6	Pedro	Oliveira	Sintra's Municipal Energy Agency (Agência Municipal de Energia de Sintra - AMES)	Technical Director	Portugal
7	Daniel	Schinnerl	Grazer ENERGIEAgentur	Project Manager	Austria
8	Bojan	Ribić	ZAGREB HOLDING - Waste Management Division	Project Manager	Croatia
9	Michiel	De Meulenaere	University Brussels	Master student renewable energy	Belgium
10	Rahman	Md Toufiqur	University Linköping	Master student renewable energy	Sweden
11	Marco	Blazvic	Croatian Energy Market Operator (HROTE)	Head of Gas market organization section	Croatia
12	Uwe	Hoffstede	Fraunhofer IWES	Head of biogas plant technology	Germany
13	Henning	Hahn	Fraunhofer IWES	Project Manager	Germany

Annex II – Study tour programm and invitation

Fraunhofer IWES

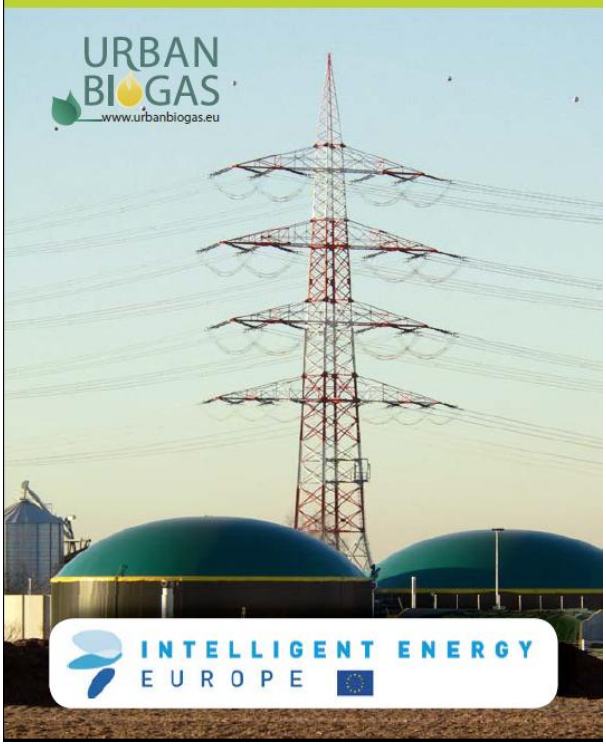
FRAUNHOFER INSTITUTE FOR WIND ENERGY AND ENERGY SYSTEM TECHNOLOGY IWES

URBAN BIOGAS www.urbanbiogas.eu

SWEDEN

BIOGAS STUDY TOUR

28TH MAY TO 31TH MAY 2012



MONDAY, MAY 28, 2012

Arrival

19:30 informal get together
Meeting at the hotel bar, Stockholm

TUESDAY, MAY 29, 2012

7:30 Breakfast
8:30 Transfer to biogas plant Henriksdal
9:00 Visit of biogas plant Henriksdal
Characteristic features: Digestion of sewage sludge and household waste, upgrading is done by water scrubber

11:30 Transfer to Västerås
13:30 Lunch
14:30 Visit of biogas plant Västerås
Characteristic features: Digestion of municipal organic waste and grass silage, upgrading is done by water scrubber

16:30 Transfer to Linköping, Hotel
19:30 Dinner

STUDY TOUR PROGRAMME

WEDNESDAY, MAY 30, 2012

7:30 Breakfast
8:45 Transfer to Linköping
Characteristic features: Digestion of different types of organic waste materials, upgrading is done by water scrubber

9:00 Visit biogas plant Linköping
11:00 Transfer to Lidköping
12:30 Lunch
13:30 Transfer to Lidköping
15:30 Visit biogas plant Lidköping
Characteristic features: Digestion of municipal organic waste materials, upgrading is done by water scrubber, LBG production

17:30 Transfer to hotel Lidköping
19:00 Dinner
followed by an informal programme

THURSDAY, MAY 31, 2012

7:30 Breakfast
8:30 Transfer to biogas plant Borås
10:30 Visit biogas plant Borås
Characteristic features: Digestion of household waste and non-domestic organic waste, upgrading is done by pressure swing adsorption

12:30 Lunch
13:30 Transfer to Landvetter Airport
followed by Göteborg City if requested

DETAILS

Location: Sweden

Language: English

Participants: UrbanBiogas project partners, especially city representatives

Participation fee: The guided tour is free of charge. Other expenses have to be covered by the participants. Travel costs within Sweden are financed by the project UrbanBiogas.

Registration: Deadline May 8th
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INTELLIGENT ENERGY EUROPE

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