

## Production and supply of biogas in the Stockholm region



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The Baltic Biogas Bus project will prepare for and increase the use of the eco-fuel Biogas in public transport in order to reduce environmental impact from traffic and make the Baltic region a better place to live, work and invest in.

The Baltic Biogas Bus project is supported by the EU, is part of the Baltic Sea Region programme and includes cities, counties and companies within the Baltic region.

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## 1. Introduction

This summary report is a compilation of six reports developed within the Baltic Biogas Bus project, BBB<sup>1</sup>. It gives an overview of biogas production potential within the Stockholm region and useful information on the history and lessons learned from establishing a renewable fuel system for biogas buses on a city level and regional level. Experiences are presented by one of the largest biogas consumer in Sweden, Stockholm Public Transport (SL) and their collaborative partners. Today (June 2012) 250 biogas buses operate in Stockholm County, the most densely populated region in Sweden, with slightly over 2 million inhabitants.

The report aims at providing biogas experts as well as laymen and the general public a short and comprehensive understanding of the Stockholm experience of biogas supply.

### 1.1. Historical background

In order to reduce dependency on fossil fuels within the transport sector, Swedish municipalities and companies are showing an increased interest in expanding the use of renewable bio fuels.

One of the leading actors in this sustainable development is Stockholm Public Transport, SL, owned by the Stockholm County Council<sup>2</sup>. SL developed an environmental program in the early 2000's with the long-term vision of developing a complete fossil fuel free bus fleet; a challenging task as the company is responsible for approximately 2 000 buses operating throughout the Stockholm region.

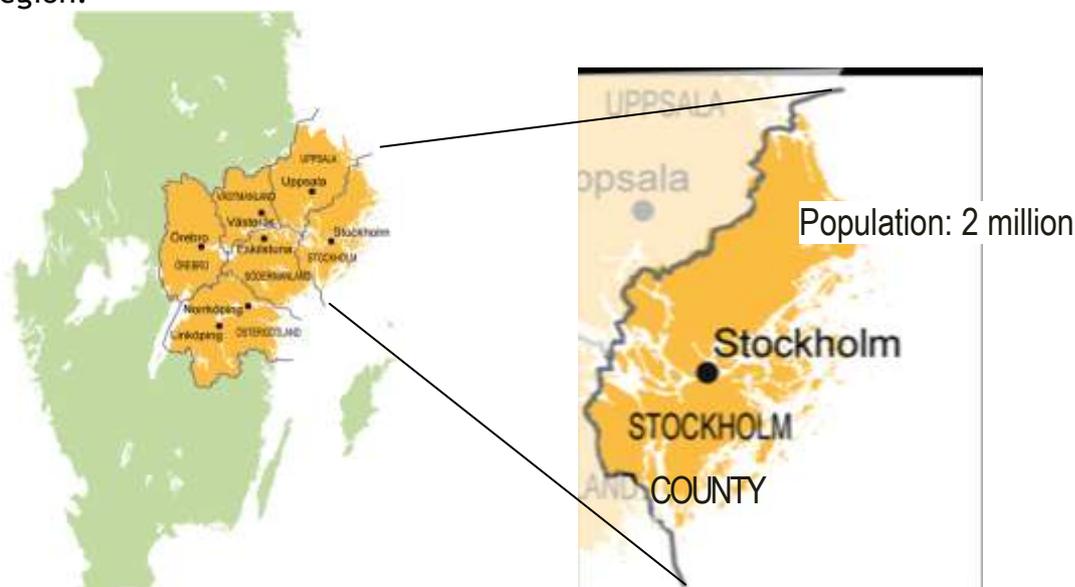


Figure 1. Stockholm County and neighbouring counties in Eastern Sweden.

<sup>1</sup> The Baltic Biogas Bus project is supported by the EU, is part of the Baltic Sea Region Programme and include cities, counties and companies within the entire Baltic region. The project period runs 2009-2012.

<sup>2</sup> SL is 100 %owned by the Stockholm county council and is responsible for infrastructure management, procurement, planning and follow-up of public transport, and responsible for approximately 2 000 buses.

At that time, the first obvious choice at hand was buses running on ethanol. Therefore, SL initiated a co-operation together with other cities to push the development and implementation of ethanol buses. Lack of a well-developed market and infrastructure for ethanol, as well as any other bio fuel, SL also sought to look into several other alternatives. One interesting alternative was biogas.

The largest waste water treatment plant (WWTP) in Stockholm is Henriksdal WWTP, owned by the Stockholm Water Company<sup>3</sup> and have been producing biogas for over 80 years. Traditionally, this was done to decrease and stabilise the sludge generated from the cleaning of waste water, and so the produced biogas was actually a by-product.

After a series of studies and discussions between SL and Stockholm Water Company, it was eventually decided that this produced biogas could be upgraded<sup>4</sup> and distributed via pipeline to SL's bus depot Söderhallen<sup>5</sup>, conveniently situated just nearby Henriksdal.



Figure 2. Location of Henriksdal WWTP biogas production plant and Söderhallen bus depot.

## 1.2. *SL and biogas today*

Great efforts have been made by a number of parties during the past decade in order to maintain, streamline and further develop the biogas system in the

<sup>3</sup> The Stockholm Water Company is 100 % municipally owned and runs the wastewater treatment plants (WWTP) in Stockholm City. The Stockholm Water Company responsibility covers the sewage network and treatment of wastewater from one million people and some industries.

<sup>4</sup> Upgrading of biogas means the gas is cleaned. In other words, unwanted gases such as carbon dioxide and other contaminants are separated from the methane. Cleaning the gas to vehicle fuel quality by Swedish standards means that the upgraded biogas must contain at least 97 % methane

<sup>5</sup> Garage for parking, fuelling and maintenance of buses

Stockholm region.

What started as a first trial of biogas supply for 15-30 biogas buses at one depot in year 2004, expanded to supply approximately 100 biogas buses in year 2009, and further expanded to include biogas supply from yet another WWTP (Käppala) and additional biogas bus depots in year 2010. Today (June 2012) there are over 250 biogas buses running on the streets in the Stockholm region and currently five bus depots equipped with biogas fuelling stations.

Biogas distribution via pipelines to the bus depots is SL's preferred option. In Stockholm city, the company Stockholm Gas owns the city town gas grid, mainly for supplying some industries and household gas stoves, This grid is however not feasible for biogas as vehicle fuel distribution. Therefore, Stockholm Gas also decided to implement a separate biogas pipeline distribution system for stable and high dependability for delivery of biogas to bus depots and public fuelling stations. Today, biogas distribution pipelines stretches underground and partly under water from Stockholm south, north and west surrounding the inner parts of the city, and further east approximately 60 kms<sup>6</sup>.



Figure 3. The expected final result of the planned biogas grid system in the Stockholm region<sup>7</sup>.

### 1.3. An outlook into other regions in Sweden

Stockholm isn't the only region where actions have been taken to establish a functional biogas system for city buses, taxis and private cars. During year 2011 there were over 1 500 gas-powered buses in operation throughout Sweden<sup>8</sup>. Other Public Transport Authorities in Sweden involved in biogas expansion except SL are in the Counties of Skåne, Västra Götaland and Östergötland, where Skånetrafiken (the Skåne Council traffic) has the largest fleet of gas powered buses. Here, there are today 687 gas buses out of 1 034 buses in the public transport traffic. Although

<sup>6</sup> The pipeline grid is partly owned by SL and partly owned by the Stockholm Gas Company (SGAB)

<sup>7</sup> Stockholm Gas, 2011.

<sup>8</sup> Energigas Sverige (1995-2008) och SCB (2009-2011)

they are not all exclusively run on biogas, Skånetrafiken has committed to having a total fossil free biogas bus fleet by year 2020. To boost the supply there are also extensive plans to build what is to become Sweden's largest biogas production plant in the region, with the capacity of producing up to 110 GWh biogas annually<sup>9</sup>. Sales of biogas and natural gas as vehicle fuel for each County in Sweden year 2011 are illustrated in Figure 4.

### Gas sales per County in Sweden 2011

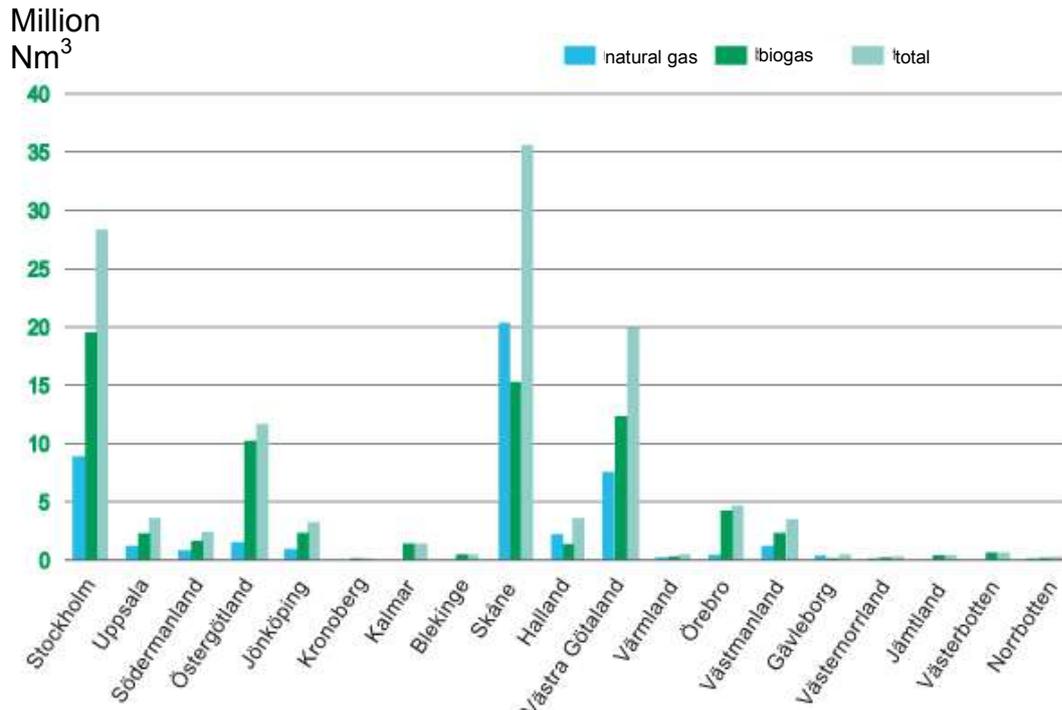


Figure 4. Total gas vehicle fuel sales per County in Sweden year 2011<sup>10</sup>.

Examples of other major biogas bus fleets are: the city of Gothenburg in Västra Götaland County (approx. 220 buses<sup>11</sup>) the cities of Linköping and Norrköping in Östergötland County (approx. 100 buses<sup>12</sup>), the city of Örebro in Örebro County (64 buses<sup>13</sup>), city of Uppsala in Uppsala County (66 buses<sup>14</sup>) and the city of Västerås in Västmanland County (55 buses<sup>15</sup>). In addition, there are thousands of gas powered private cars, company cars, taxis, waste collection trucks and heavy duty vehicles on Swedish roads. These are all results of active choices towards environmental sound transportation, as well as tax exemptions and other financial stimulations, which will be further elaborated in section 3.

<sup>9</sup> Jordberga Biogas AB, via E.ON Gas Sverige AB (2012). The four partners involved are Swedish Biogas International (55%), E.ON Gas (20%), Skånska Biobränslebolaget (20%) and Nordic Sugar (5%)  
<http://www.mynewsdesk.com/se/pressroom/eon/pressrelease/view/biogasanlaeggning-byggs-paa-jordberga-765210>

<sup>10</sup> Gasbilen, 2012

<sup>11</sup> Biogas Väst, 2012

<sup>12</sup> Östgötatrafiken, 2012

<sup>13</sup> Örebro municipality, 2012

<sup>14</sup> Gamla Uppsala Buss AB, 2012

<sup>15</sup> Västmanlands Lokaltrafik AB, 2012

## 2. Environmental aspects

### 2.1. *Why biogas?*

Biogas produced from waste is today considered one of the best bio fuels available for vehicles from an environmental perspective, looking at the life cycle analysis. Today, Sweden is at the forefront in the field of biogas as vehicle fuel, due to extensive environmental political initiatives.

### 2.2. *Driving forces*

The environmental target within the EU Renewable Energy Directive (2009/28/EC) is 10 % renewable energy for the transport sector by year 2020<sup>16</sup>. In Sweden, the government has even more ambitious long-term visionary targets of a completely independent fossil free vehicle fleet by year 2030<sup>17</sup>. These targets call both for financial stimulations and long-term political engagement.

Political, environmental and economic pressures have been pushing for introduction and increases in renewable energy sources in Sweden for decades. The transport sector is highly prioritized as it is heavily dependent on fossil fuels (whereas Sweden's energy mix for heat and electricity already to a large extent is supported by hydropower and nuclear power. The long-term sustainability of the latter energy source can be debated, but outside of this paper.). In line with this, a great number of development and pilot projects have received national, local and/or EU financial support to stimulate biogas as vehicle fuel production, distribution and utilization in buses, waste collection lorries as well as taxis and some private cars in Sweden. Many other European and non-European countries have larger gas vehicle fleets than Sweden, but these almost exclusively run on natural gas. Countries with higher biogas production than Sweden, such as Denmark and Germany, have directed the use of biogas for electricity production.

In the case for SL, it is the Stockholm County Council that sets the environmental goals for the transport company, and has been a driving force in the transition of phasing out fossil fuels. SL has tough environmental targets of

1. At least 75 % of the bus fleet within SL will by the end of 2016 be running on renewable fuels,
2. 100 % of the bus fleet within SL will be running on renewable fuels no later than 2025

It must be highlighted that the political will does not automatically appear by itself. It is also the environmental engagement and commitment by general public that is pushing for political action. Even at the personal level, great motivation and conviction of the possibilities and benefits of the biogas fuels, can make real changes. As in the case of a Swedish obstetrician who single-handedly made sure

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<sup>16</sup> Directive 2009/28/EC of the European Parliament and of the Council, of 23 April 2009, on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

<sup>17</sup> The government's climate proposition from year 2009, Propositions 2008/09:162 and 163

source separation of food waste was introduced at a large hospital. More about this can be read in section 2.7.2.

### 2.3. *Maintaining environmental sound production*

As mentioned in section 2.1 biogas mainly consists of methane. This can be a confusing fact, as methane is estimated to be the second largest contributor to global warming of the long lived greenhouse gases after carbon dioxide.

However, combustion of biogas converts the methane into carbon dioxide (CO<sub>2</sub>) which is already part of the carbon cycle (i.e. not fossil CO<sub>2</sub>) and there is no or little net increase in greenhouse gases as long as the substrate used for the methane production is renewable. Nevertheless, if the biogas is not combusted and directly emitted into the atmosphere, it is indeed contributing to the global warming. As such, it is essential that biogas systems are designed and controlled to minimise methane leakages.

Methane losses can occur in every step of the biogas chain, i.e. during production, distribution and consumption.

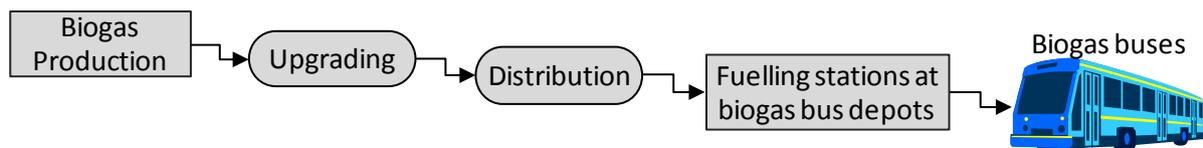


Figure 5. Schematic picture of the main steps of the biogas chain.

Fortunately, there are a great number of actions that can be taken to minimize and prevent these methane emissions. It is possible through careful consideration of the aspects involved already in the early phases of conceptual and detailed design, construction and procurement of suppliers of components/facilities, as well as during operation.

In-depth knowledge of methane emissions within the biogas industry can be a powerful tool of information and dissemination to other stakeholders. How to tackle these problems can answer to questions of concern or scepticism from opponents or the general public regarding any doubts of biogas as a true environmental sound and sustainable option to conventional fossil fuels or other renewable alternatives.

### 2.4. *Future legislation*

Legislation regarding emission requirements has become increasingly tougher during the last four decades. What was seen as impossible and unrealistic twenty years ago has now become reality and the legislation is continuously putting more pressure on vehicle manufacturers and providers of transport fuel to decrease environmental impact.

Within the EU there are three main driving forces regarding supply of transport fuel:

- Decrease dependency from politically unstable regions of the world
- Decrease dependency from fossil fuels and other non-renewable fuels
- Decrease emissions that affect human health and the environment in a negative way

This has led to increased support for production of different renewable energies within the EU. However, simultaneously there is a requirement that renewable fuels be produced in an efficient way, so that most of the energy content in the raw material is transformed to fuel. In this aspect diesel production is still more efficient than most renewables. However, with an expanding sector and more experience to draw from, considerable production improvement regarding the efficiency of renewable fuels is foreseen.

Through different bodies of international cooperation and legislation there is a trend towards more harmonization regarding emission legislation, emission measurements and definition of different fuel types.

## Biogas supply

Biogas is produced naturally in oxygen free environments such as in the earth, sea bottoms, peat land and human and animal bowels. The process is called anaerobic digestion, where microorganisms break down organic material producing mainly methane and carbon dioxide. Biogas can also be produced from a wide range of organic material. Examples include sewage sludge at WWTP, source separated household food waste, industrial food waste, slaughterhouse waste, agricultural by-products, energy crops and cattle manure. The biogas can be used for heat, electricity or vehicle fuel production and the digestion residues (bio solids) left can be used as bio-fertilizer. Biogas can also be extracted from landfills where organic waste is naturally degraded. This production and utilization is illustrated in Figure 6.

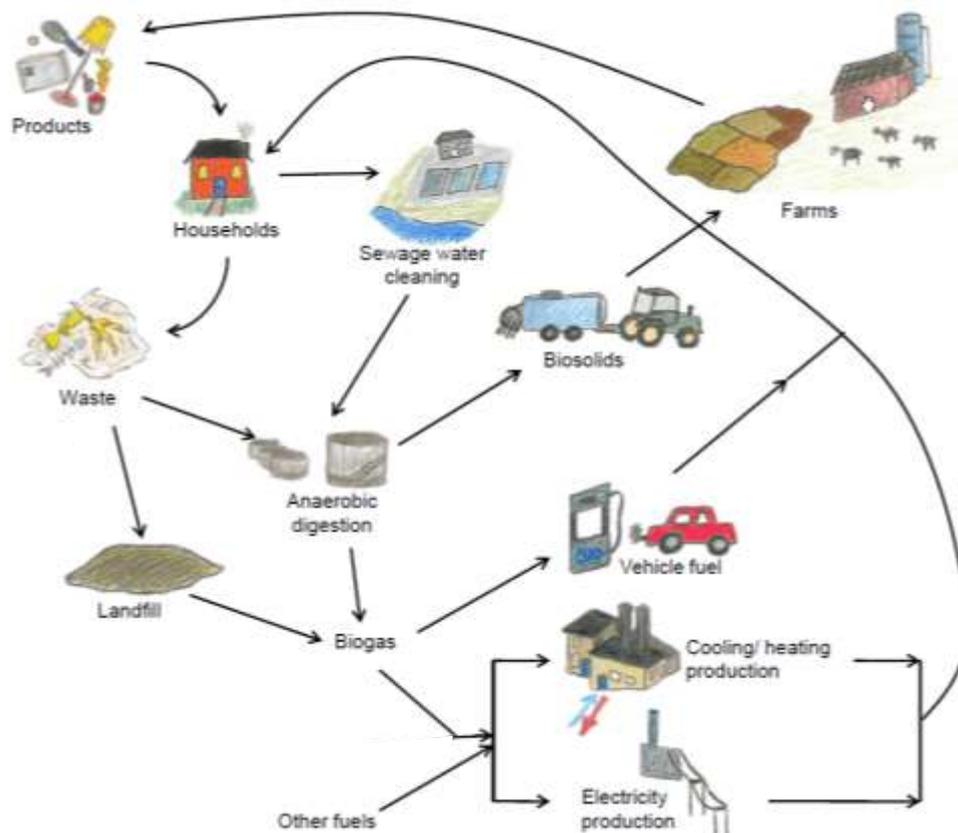


Figure 6. Schematic illustration of production and utilisation of biogas.

## 2.5. Current situation

The four most common types of biogas plants in Sweden are WWTP, co-digestion plants, farm-based plants, and industrial plants. In addition to these, there are also a great number of landfills with gas extraction systems installed for collection and utilisation of the generated biogas. Not all produced biogas is used as vehicle fuel, although it is the single largest area of utilisation today (44%). The proportion of biogas sources in year 2010 are illustrated in Figure 7.

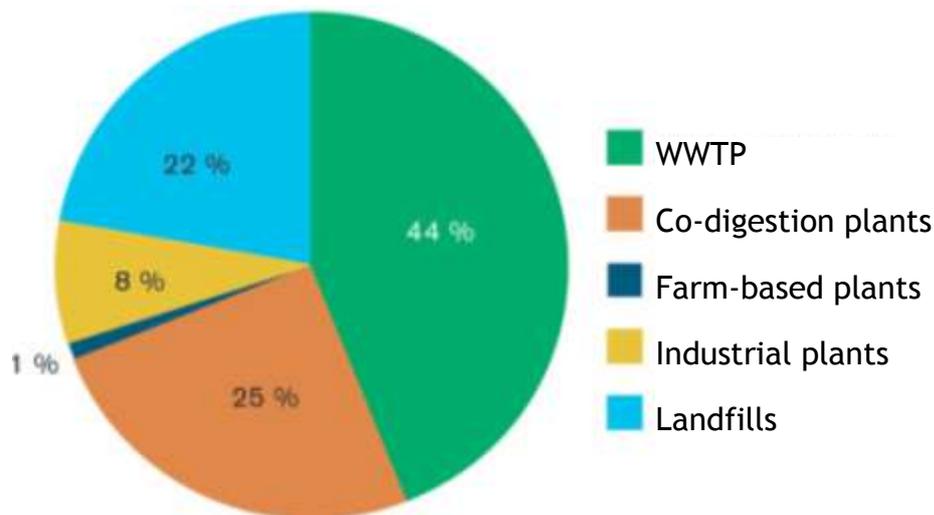


Figure 7. Biogas production in Sweden in year 2010 divided per category<sup>18</sup>.

Both production and sales of biogas as vehicle fuel have experienced a great market expansion in Sweden the past decade. Only between year 2010 and 2011 the sales of biogas increased by 27% and approximately 121 million Nm<sup>3</sup> gas as vehicle fuel were sold in year 2011, constituting to 62% of biogas (remaining 38% were natural gas).

In the County of Stockholm the consumption of gas as vehicle fuel in year 2010 was 13 million Nm<sup>3</sup> (126 GWh) biogas and 4.5 Million Nm<sup>3</sup> (48 GWh) natural gas, where SL is the largest consumer.

The largest quantities of biogas in Stockholm region are produced in four large WWTPs; Henriksdal WWTP, Käppala WWTP, Bromma WWTP and Himmerfjärdsverket WWTP. As mentioned previously, Henriksdal WWTP is the largest one. There are also plans to construct a large-scale biogas plant for anaerobic digestion of energy crops and industrial food by-products South of Stockholm City, with a capacity of up to 100 GWh annually. Despite a large annual production, the demand for biogas exceeds the supply. As a consequence, Stockholm must import some of its biogas from other regions and use natural gas as a back-up. The increasing biogas demand also pushes for making investigations into other biogas production sources and the biogas potential, both in Stockholm and a greater area including the neighbouring regions.

## 2.6. Biogas potential

A projection of future production, distribution and demand of biogas as vehicle fuel up until year 2020 was made in year 2009, and included Stockholm County and neighbouring Counties of Uppsala, Västmanland, Södermanland, Örebro and Östergötland. The projection of production was based on current WWTP with biogas production, existing and planned expansions and new biogas production plants in the region, and an increased source separation of food waste from households as a contributor of good biogas substrate. The projection of demand

<sup>18</sup> Biogasportalen, 2012

was in turn based on decisions and visionary plans to expand biogas bus fleets, taxis, company cars and estimations of interest within the private sector.

The results indicate several potential future scenarios until year 2020, depending on how optimistic the biogas market expansion is likely to be. A high scenario per County and in total in the whole region is illustrated in Figure 8.

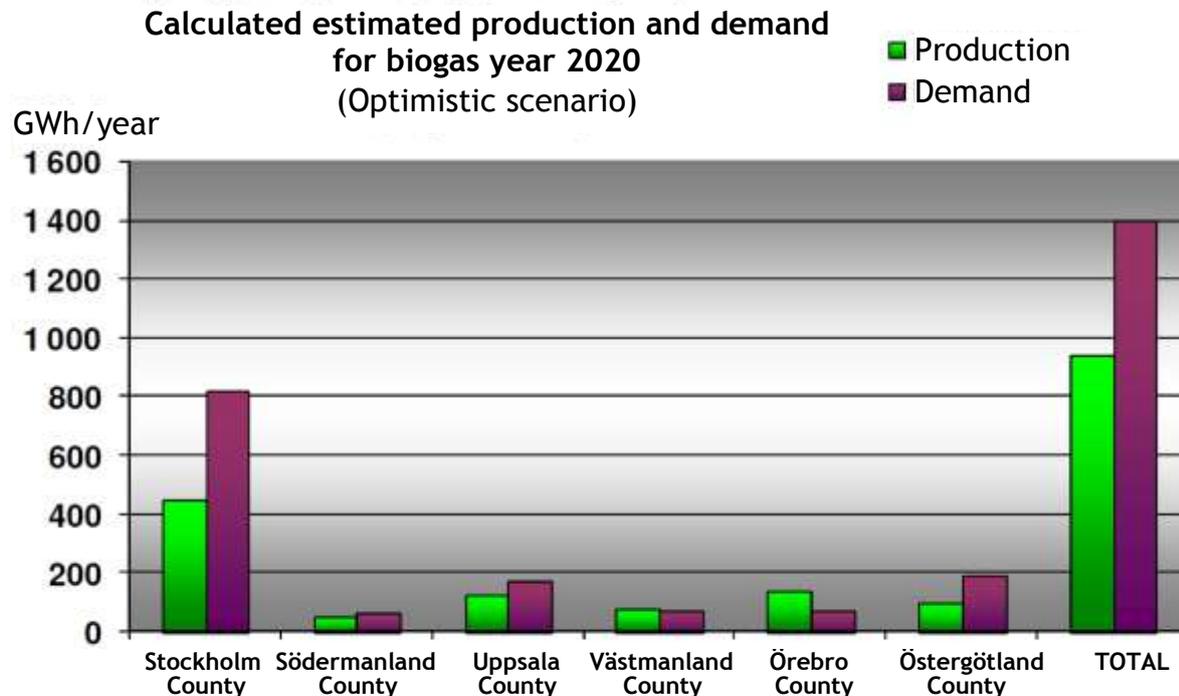


Figure 8. Calculated estimated production and demand for biogas year 2020 per County and in total in the region.

As indicated in the chart, the biogas production may not be sufficient to meet the visionary demand. The total estimated biogas production in an optimistic scenario is 944 GWh/year and the demand is 1 400 GWh/year. In reality, scarcity of biogas will push stakeholders to look into other fuel alternatives. However, a conclusion of this is that the interest of biogas is high in the region and if the production is heavily boosted the market demand will follow.

For this reason, another study was performed in year 2010 looking into theoretical production potential based on potentially available substrates in the same region. This study was based on previous reports looking at statistics and assumptions. For example, organic food waste from households was based on average collection potential per person, industrial waste was based on assumptions and statistics on waste volumes in different industries, sewage sludge volumes were calculated based on a key figure of average sludge volumes per person, manure were based on poultry and cattle animal production, and agricultural products were based on available acreage. It should be emphasized that the agricultural acreage potential as substrate for biogas production to a great extent constitute of straw. Straw is hard to degrade and producing biogas from it can be problematic.

As an addition to this, the study also looked into the theoretical potential of biogas

production by gasification<sup>19</sup> of forestry raw materials. This is a new technology in Sweden and the first plant is currently under construction<sup>20</sup>. In order to get a figure of this potential the study included all productive forest land in each County. In reality, the forestry raw materials are used for a great variety of production purposes and there is significant and ever increasing competition for the raw materials. As such, the potential for biogas production should really only be regarded as potential.

The result indicates a great theoretical potential for biogas production of up to approx 14.9 TWh/year in the Stockholm region including neighbouring Counties. Breaking it down, this includes 5.4 TWh of biogas from anaerobic digestion and 9.5 TWh from gasification. The potential per type of substrate in the whole region is also presented in Figure 9.

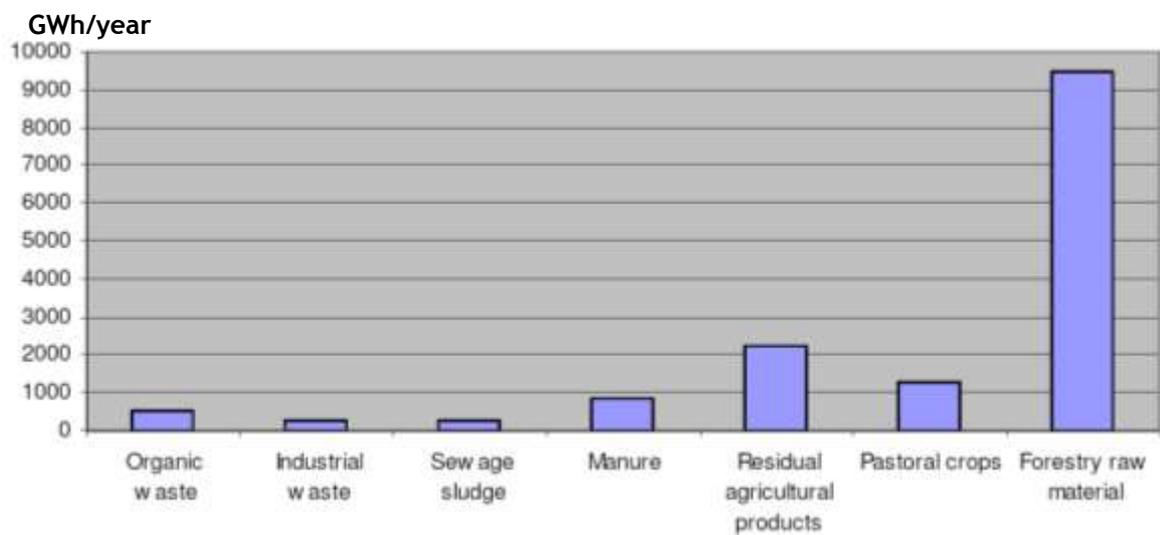


Figure 9. Biogas production potential for different substrates in larger Stockholm region, GWh/year

The whole theoretical potential presented in the study is almost 30 times the current production in the region and a figure greatly exceeding the current national production.

Some specific important possible sources for increased biogas production have also been investigated in more detail:

- Landfill
- Food waste

<sup>19</sup> Gasification is a process involving thermo chemical conversion of solid or liquid carbon-based materials into a product gas. The product gas can then onwards be purified into various end-products, e.g. biodiesel or to biomethane.

<sup>20</sup> The so-called GoBiGas project in Gothenburg. The plant is to be built in two stages, where the first stage (~20 MW<sub>gas</sub>) is planned to be taken into operation in the end of year 2012. Main contractor is Göteborg Energi, an energy company 100% owned by the City of Gothenburg.

## 2.7. In-depth case studies

### 2.7.1. Landfill gas as fuel for vehicle

As mentioned briefly in the previous section, landfill gas is generated when organic material in landfills is naturally degraded. The content of the gas depends on the types of waste present, but normally consists of methane (45-55 %), carbon dioxide (25-40 %), other gases, sulfurous compounds and pollutants such as quicksilver and chlorinated hydrocarbons. The mix of gases and pollutants makes landfill gas more “dirty” than biogas and therefore more problematic to clean. Nevertheless, this is what SL and the municipal waste company Telge Recycling<sup>21</sup> wanted to take a closer look into. In year 2009 the companies jointly performed a feasibility study. The question to address was if it would be economically feasible to clean the biogas produced at the landfill “Tveta” and two nearby so-called biocells<sup>22</sup> to vehicle fuel and further distribute for fuelling at an existing SL bus depot. To do this, estimations were made on the content and volumes of different types of organic wastes in the landfill and biocells and the current and future production of landfill gas was calculated.

The result showed that the amount of extractable landfill gas during the first 5 years amounts to about 4.5-3 million m<sup>3</sup> raw gas per year (2009 as baseline year). Within 6-10 years the estimation is 2.5-1.8 million m<sup>3</sup> per year, and in 11-15 years 1.5-1.0 million m<sup>3</sup> per year. It is not possible to collect all landfill gas generated, and so the figures are estimated at an extraction rate of approximately 80 %. The landfill gas production wears off substantially over time as no new waste is added. The amounts are illustrated in Figure 10.

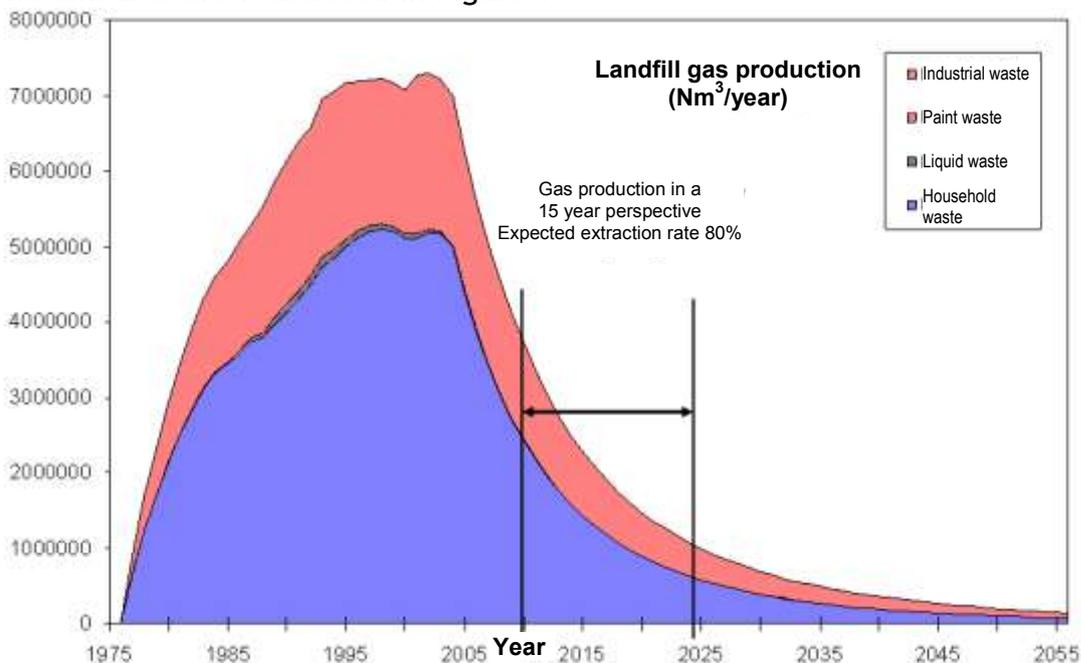


Figure 10. Calculated landfill gas amounts from Tveta and the two nearby biocells (2009).

<sup>21</sup> Telge Recycling is a waste management company 100% owned by Södertälje municipality in Stockholm County, approximately 30 km South of Stockholm City.

<sup>22</sup> Household waste put in a large waste pile for natural degradation with gas extraction system.

The calculation shows that the total gas production over 60 years is in the magnitude of 220 million m<sup>3</sup>. By the summer of 2009 about 185 million m<sup>3</sup> had already been produced. According to calculations about 90 million m<sup>3</sup> of this gas has been captured, partly by the existing gas extraction system.

As the potential landfill gas volumes available are high, the second step was to look at the gas cleaning alternatives and the distribution options possible to the bus depot. Several scenarios were evaluated as there are several methods for distribution and handling of the gas. The best scenario was concluded to be upgrading of the landfill gas at Tveta and distribution of the biogas as CBG<sup>23</sup> via gas pipeline to the depot, a distance of approximately 7 km. This was then further investigated in terms of investments and operational costs.

The study concluded that the scenario may be economically reasonable. Estimated operational and capital costs were calculated to about 7.2-11.5 SEK per Nm<sup>3</sup> of upgraded biogas (CBG) during an operational time of 15 years. Due to several other reasons, there has been no further collaboration between the companies up until today. Nevertheless, the feasibility study can be used as a tool and provides a good insight into ways of evaluating possible solutions for biogas supply, especially in landfills with a large amount of household waste and biodegradable material left.

### **2.7.2. Food waste as substrate for biogas production**

In Sweden the government has set up 16 environmental objectives to improve sustainability and the environment. One of the objectives was formulated as follows:

*“By 2010 at least 35% of food waste from households, restaurants, caterers and retail premises will be recovered by means of biological treatment.”*

This was updated in 2012 to the following:

*“...at least 50 percent of food waste from households, restaurants, caterers and retail premises will be recovered by means of biological treatment so that plant nutrients are recovered, where at least 40 percent is treated so that also the energy is recovered, no later than year 2018.”*

This has called for action and many Swedish municipalities have been source separating food waste at restaurants, catering kitchens and households for decades. However, municipalities in Stockholm County have far from reached this goal. By the end of year 2010 a total of 11% of the available food waste was collected separately for biological treatment whereof 4.7% went to biogas production. As such, food waste is still the largest not yet utilised biogas substrate in the Stockholm region.

Sometimes however, it only takes a strong devotion from a few to try to change this. An obstetrician at Danderyd hospital in Stockholm County, Dr Jan Rapp, had been concerned about the climate change threat caused by the increase of carbon

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<sup>23</sup> Compressed Biogas. Commonly, the compression in gas pipelines is 4 bars

dioxide from use of fossil fuels. Therefore, he began to inform and convince politicians, hospital responsible and neighbours on the benefits of increased food waste source separation for increased biogas production. His ambitious efforts during year 2010 led to an increase of collected food waste within the city of Stockholm responsibility by 20% to 6 300 tons/year. Also, his employer Danderyd hospital increased their efforts of food waste collection. For his engaged environmental work, Jan Rapp was awarded “Stockholmer of the Month” in December 2011.



Figure 11. Food waste is collected from patient meal left-overs, staff rooms and restaurants/catering in Danderyd hospital. Dr Jan Rapp holds his food waste-separation-at-source box.

To look a bit closer into possibilities of accessing even larger quantities of this food waste in an easy way, a study on experiences from grinder-to-tank-collection of food waste from restaurants and catering kitchens was performed by SL in 2012. Generated food waste quantities from restaurants and catering kitchens in the county, possible tank collection and possible biogas production were also estimated.

Grinder-to-tank means food waste is thrown in an inlet which is either directly combined with a grinder and tank beneath, or transported by suction to a centralised tank. The tank is then emptied by sludge suction vehicles and directly transported to a biogas production plant, without further pre-treatment required.



Figure 12. Envac food waste suction system inlet, Ecosir biowaste system inlet, Sludge suction vehicle, CIJA tank

Collection of food waste in bins or bags from restaurants and catering kitchens often causes problems related to hygiene and work environment - both for kitchen staff and waste collectors. In order to improve the collection and facilitate treatment by anaerobic digestion, the city of Stockholm initiated a development project in year 2005 where a dozen grinders-to-tank systems were tested. The city of Stockholm financed the systems with up to 350 000 SEK for equipment and installation. The property owner financed necessary extra plumbing and electricity connections. The results were overall very positive. All participating restaurants have chosen to continue to use the grinder-to-tank collection after the project ended.

To look into the larger potential in Stockholm a theoretical estimation of the amount of food waste available for grinder-to-tank collection was done. The calculation indicates almost 7 000 tons/year. This would be about 5 % of the total calculated available amount in all of Stockholm County in year 2030, amounting to approximately 125 000 tons<sup>24</sup>.

With this large potential it is important to look at the advantages and disadvantages of the grinder-to-tank system, if there are incentives for expansion to more restaurants and large kitchens. Experiences show that the system is cleaner, no heavy bags are managed and a higher rate of food separation is reached. Less food waste in the remaining mixed waste going to combustion leads to a lighter, drier fraction that is easier compacted in the waste collection trucks, which reduces the overall amount of heavy lorry transportation. The great drawback with the grinder-to-tank system is that the payback time, compared to bin or bag collection and treatment, often is too long to motivate investment for a single restaurant. In order to increase grinder-to-tank collection of food waste, it is necessary that property holders receive funding for enabling the required actions.

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<sup>24</sup> This is based on a reportedly estimated population increase in the County to about 2.5 million in year 2030 and that inhabitants on average source separate 50 kg/cap, year

### 3. Lessons learned and strategic work for future biogas development

The start-up process of production and supply of biogas is complex and many factors must be in place in order to take the necessary steps towards success. Several actors must collaborate, clear environmental and/or economic incentives must be identified, localisation of facilities and distribution infrastructure must be made, market analyses and projections of future possibilities of expansions should be considered, etc. There are lessons learnt from Stockholm's and SL's unique establishment of biogas supply systems which can be useful for other stakeholders planning biogas supply systems and biogas bus fleet, as well as for newcomers to perhaps overcome hesitation. This chapter attempts to describe what should be considered when deciding to start production of biogas as vehicle fuel, especially for buses.

#### 3.1. Market situation and long-term visions

Although the biogas as vehicle fuel has experienced a great market expansion in the past decade, as can be seen in Figure 13, the biogas market is still unstable and has to a large extent been relying on local and state financial support. In a more stable biogas market, long period contracts will lead to less subsidies.

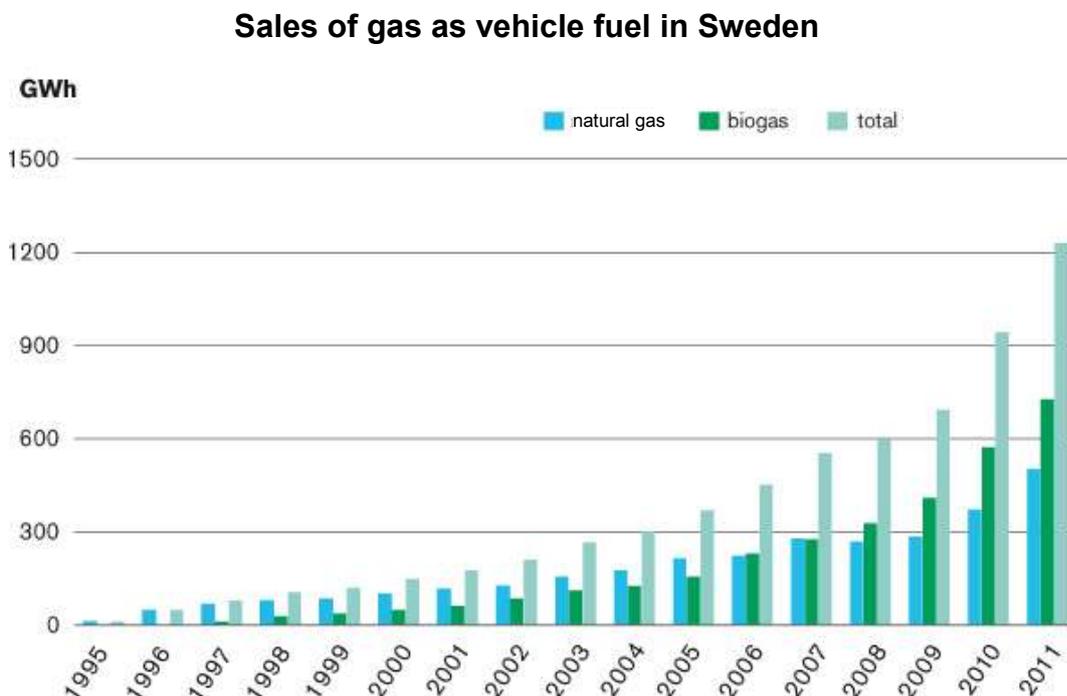


Figure 13. Sales of gas as vehicle fuel in Sweden from year 1995 to 2011<sup>25</sup>.

As SL began establishing a biogas bus fleet without any existing market, an essential key to the success was formulating long-term contracts with a stable supplier. The same applies looking at the supplier's perspective, as Stockholm

<sup>25</sup> Gasbilén, 2012

Water Company at the same time secured a stable, long-term customer.

For any biogas producer it is important to identify if a biogas project will be viable and profitable with possibilities not only to sell the biogas and have a market/deposition of the bio-fertiliser or sludge, but also to secure long-term access to substrate with raw material supplier contracts. Forecasts about the future demand should also be made before a long-term commitment in order to define if the large investments involved in the biogas supply chain will be profitable in the long-term. These forecasts should be detailed and made in collaboration with suppliers and final customers.

Biogas production show low short-term profitability which makes it sensitive to market changes. In this area especially, legislation could help to stimulate growth by providing some security in an unstable market. This legislation may come in many forms but the widely used is financial incentives with subsidies or tax exemptions. Depending on their responsibilities and power over the local public services, local authorities can force or support the creation of secured long-term contracts between the waste suppliers and the public transport customers such as in the case of Stockholm.

It is evident that the complexity of the biogas system chain requires co-operation between many different stakeholders.

### **3.2. *Local conditions vary***

One of the most important factors of a biogas supply system is to take local conditions into consideration through the whole biogas system chain. Are existing WWTP already producing biogas? Which substrates can be used for biogas production? Are there any potential large-scale consumers with a clear interest in biogas? Is there any existing gas infrastructure, such as a natural gas grid in the city or region where biogas can be injected? Where are suitable locations for placement of production plants or fuelling stations? Localisation of the different facilities is important for distribution purposes. If the city is densely populated and exploited, available land can be difficult to find, privately owned land may be allocated to housing, and infrastructure for gas distribution a tricky business. In the case of Stockholm, the first biogas bus depot and WWTP supplying the biogas happened to be next door to each other, which facilitated the development and collaboration.

Another important factor is what political structure is in place. Is there willingness for municipal or regional participation? Although financial investment support, subsidies or tax exemptions might be regulated at national level, local or regional politicians have great impact on decisions concerning city planning, public infrastructure development, permits and grants. In Stockholm, the company running the WWTPs is owned by the city of Stockholm and SL responsible for the public transport is owned by the Stockholm County Council. This greatly facilitated the decision procedures.

### 3.3. Operational and environmental costs

Regarding operational costs for biogas buses, Stockholm Public Transport has empirical data showing that they have decreased considerably since they were first introduced in the Swedish capital and that they now are at level with those for diesel buses.

The conducted study compares results from previous studies from 2006 and 2008 and projects trends. A well to wheel analysis has been used, dividing the perational costs into a “Well to Tank” and a “Tank to Wheel” perspective.

The calculations have been carried out both including and excluding costs for the specific biogas infrastructure needed. Since new infrastructure is needed for biogas it will face a disadvantage when compared to fossil fuels, for which infrastructure is already in place.

The positive economic development over time for biogas as fuel in buses is due to new gas buses having more efficient engines and lower maintenance costs. This partly is a result of the production development, but an even more important factor is the improved user knowledge among drivers and service staff, which has been gained throughout the years. A new gas grid in Stockholm will lower the overall biogas costs and stimulate more local production of biogas.

Not counting for expenses related to infrastructure, the cost for biogas is close to diesel in some traffic areas. When costs for infrastructure are included the total operational costs are 5-8 per cent higher. However, with future increasing costs for fossil fuels, biogas will be even more competitive.

The environmental costs are the alternative costs for global and local emissions that are emitted from biogas and diesel buses including greenhouse gases, CO<sub>2</sub>, emissions of particulates and NO<sub>x</sub>.

When environmental costs are included, biogas is without a doubt the best fuel available.

**Total cost, operation, infrastructure and environmental cost (marginal cost sek per 100 km)**

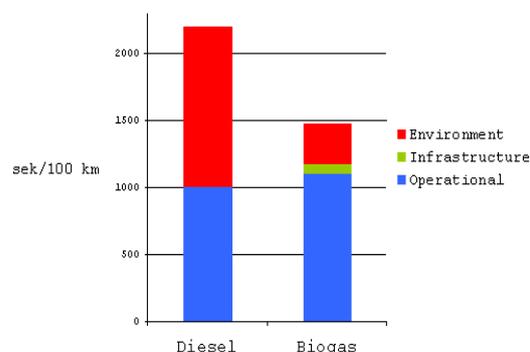


Figure 14: Total cost, operation, infrastructure and environmental cost. Source: Trafikanalys

### **3.4. *Setting up contracts***

When setting up a contract regarding supply of biogas as transport fuel, there are several things to keep in mind. First and foremost, a long term commitment from both parties is necessary to ensure the required investments in biogas infrastructure. If contracts are not long term, necessary production and distribution investments might not be economically feasible.

Responsibilities regarding upgrading and distribution must be clearly defined. For upgraded biogas, it is important to stipulate both the quantity and quality to be delivered and how this will be verified and by whom. Depending on the foreseen production and consumption pattern of biogas, not only the quality and quantity of the biogas produced plays an important part, but also at what point in time deliveries will take place. It might be necessary to include the rights of each party to involve a third party if the produced biogas exceeds or is less than the demand. Production and consumption quantities might change over time, therefore stipulating responsibilities for both parties to continuously update forecasts could be included in the contract.

Finally, to make sure the agreement turns into a successful cooperation, the contract should define one representative each from both parties to handle challenges and differences in opinions that might arise. If necessary, additional working groups could also be formed. Below are recommendations of items which could also be included in a contract between a producer and consumer of biogas as transport fuel:

- Permits - who is responsible for obtaining necessary permits
- Deliveries - when and how the biogas should be delivered and at what point the responsibility of the biogas is transferred between parties
- Compensation and indexation
- Investment grants - if these exist, who is entitled to them
- Payment terms
- Insurance requirements
- Damage responsibilities
- Contract period

### **3.5. *Essential factors for biogas stimulation and development***

Legislation in Europe is evolving quickly, new and stricter standards come out regularly. National and European legislation trends must be envisaged to make the smartest investment in infrastructures that will not become obsolete before the benefits are realized. Legislations are also often not adapted well to new technologies because they are designed before the technology has fully developed. As such, it is important to keep continuous track of the latest legislation and changes to come.

A strong commitment from key individuals and local authorities is fundamental for

a successful project. Good examples presented in this report are city authorities, County Councils and private persons like Dr. Jan Rapp. A first priority for someone that is interested in producing biogas is to identify all stakeholders that could take part in the project and contact them to find what interest there is.

It is also important to focus on making sure that all the biogas produced gets utilised, both for the sake of the environment and for the possibilities of better overall economy for the producer. Developers should consider alternative uses in the case that the demand for biogas decreases, such as on-site use of the gas heat and electricity. This way, the producer will either have several “bio products” to sell, or gets more self-sufficient of energy for in-house utilisation.

As indicated in this summary report, the demand is potentially higher than the production of biogas in the region. To stimulate and promote the biogas production as vehicle fuel and market development, there are a number of factors identified by biogas producers, distributors, consumers, trade organisations and other environmental promoters that should be considered, mainly at the political level:

- The price on biogas as vehicle fuel in Sweden should increase to enable a better economy for biogas producers using other substrates than WWTP sludge. In turn, to ensure a continued high demand for gas as vehicle fuel, the price on other conventional fuels should be comparably higher.
- Shorter waiting times for environmental and building permits are important to facilitate investments.
- Large-scale source separation of food waste should be implemented in all municipalities in the region.
- Smaller WWTP may be given support to optimise their processes and possibly find financially profitable solutions to invest in small-scale upgrading of the biogas to vehicle fuel quality.
- Research and pilot plants is supported to facilitate increase knowledge in sustainable biogas production and bio-fertiliser management.
- Regional and local gas distribution pipelines are developed further to increased accessibility to the biogas.
- The government should present clear, long-term visions and tools for how to sustain biogas as a vehicle bio fuel for the future, both for producers and consumers.

## 4. Conclusions

As demonstrated in the case of Stockholm, biogas projects can be very successful. Being one of the pioneers in this field, Stockholm and SL have faced difficulties and challenges that other cities may avoid by taking into account the lessons learned and best practices gained. This paper, along with the underlying reports as a whole, is intended as a tool aiding initiation of other viable biogas supply projects in the Baltic Sea Region and beyond.

- There is still a high potential among traditional sources for increasing biogas production.
- The sources for production of biogas might be necessary to meet the future demand for biogas as fuel.

For interested readers the baseline reports can be studied in detail via the Baltic Biogas Bus project ([www.balticbiogasbus.eu](http://www.balticbiogasbus.eu)):

1. "Biogas production - Experiences and lessons learned" (2010) Stockholm Public Transport
2. "Methane losses in the biogas system" (2012) Sweco, Stockholm Public Transport
3. "Utbud och efterfrågan på fordonsgas i Biogas Öst regionen" (2010) Sweco Environment AB, Clients: Biogas Öst, Baltic Biogas Bus, Stockholms Stad, AGA, E.ON, Stockholm Gas, Gasföreningen. *In Swedish*
4. "Production potential for biogas in the Stockholm region"(2010) WSP, Stockholm Public Transport
5. "Study about landfill gas usage in vehicles" (2011) Study about Renewable Vehicle Fuels in Sweden, Stockholm 2011-03-15, Sweco, Stockholm Public Transport
6. "Overview - Biowaste slurry collection" (2012) Sweco, Stockholm Public Transport
7. "The Stockholm Experience - A Decade of Experiences with Biogas Bus Operations"