Baltic Biogas Bus

Sharing our success and lessons learned 2009-2012

Biogas
- the natural choice for city buses

Better air quality

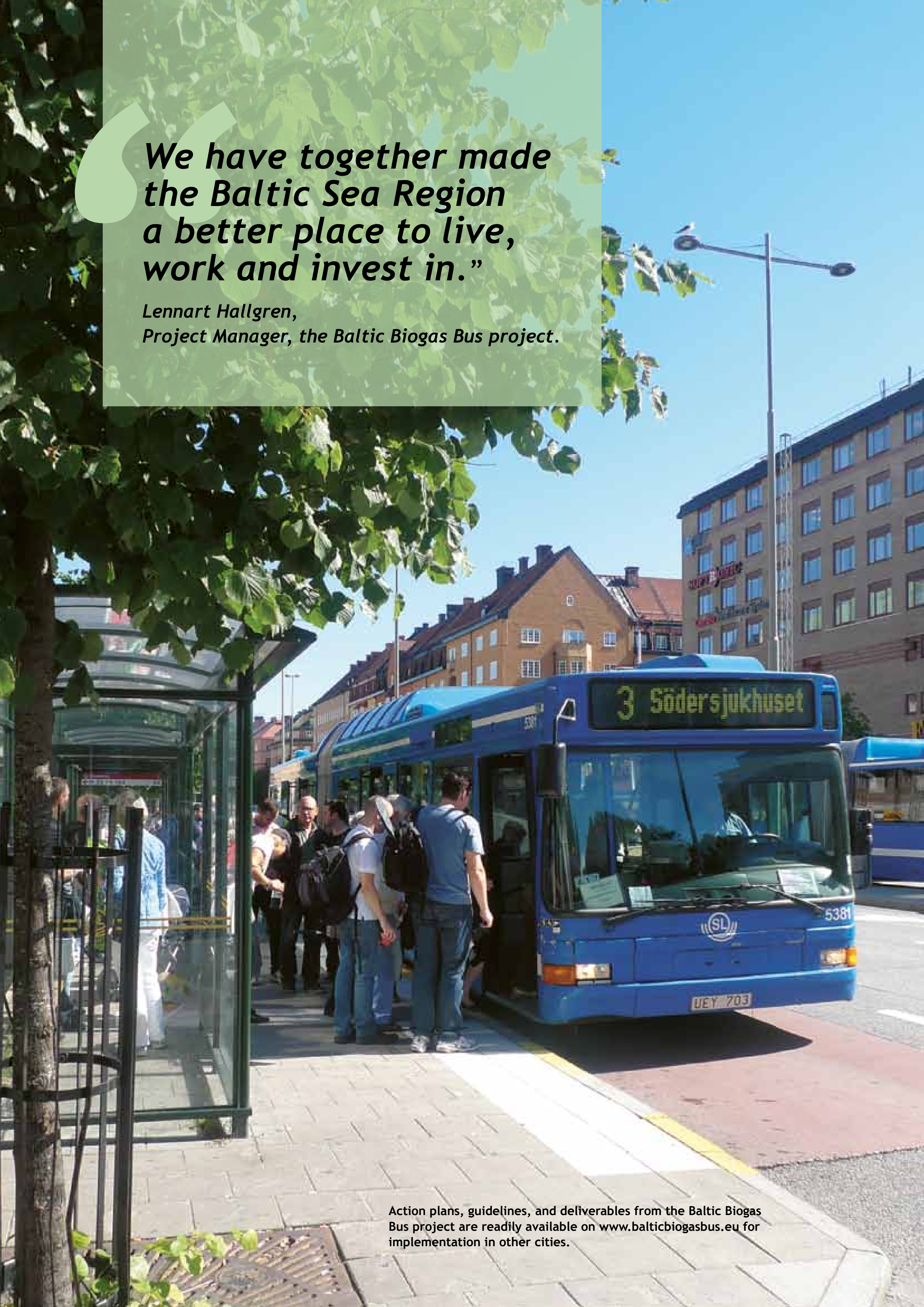
Improved energy autonomy

Minimised emissions

Renewable energy source

Baltic Sea Region Programme 2007-2013

PART-FINANCED BY THE EUROPEAN UNION (European Regional Development Fund)



"We have together made the Baltic Sea Region a better place to live, work and invest in."

Lennart Hallgren,
Project Manager, the Baltic Biogas Bus project.

Action plans, guidelines, and deliverables from the Baltic Biogas Bus project are readily available on www.balticbiogasbus.eu for implementation in other cities.

On the road to climate-neutral public transport

After three years, the Baltic Biogas Bus project is coming to an end. In the following pages, you can read about the outcomes of the project and our recommendations how to start using biogas as transport fuel.

However, already at this stage I would like to highlight some overarching results for urban public transport. The conclusions from the project leads me to claim that biogas buses are the best choice for urban public transport to lower emissions of greenhouse gases and improve inner city air quality while creating energy autonomy and more sustainable jobs. Biogas will also significantly contribute to reaching the EU 2020 targets.

To persuade other stakeholders of the benefits of the use of biogas, the project has consistently and successfully made use of existing good examples and best practices in this field. Thanks to the work and lobbying activities carried out by project partners, introduction of biogas buses in several cities in the Baltic Sea Region have been launched. The well composed group of partners has also provided excellent opportunities for exchange of ideas and knowledge as well as reaching a wider network when disseminating our message. To ensure the progress of the project, continuous contact between partners has been necessary and we have had several partner meetings every year. This has enhanced the possibility to learn from one another and to formulate our findings in a coherent way.

Dissemination of results and ideas has been a strategic part of the project. Our network of twelve partners in eight countries in the Baltic Sea Region has formed a showroom to demonstrate a sustainable transport system as part of the solution to reach EU's climate goals. A broad set of associated organisations in each country, the rest of Europe and beyond has reinforced the communication strategy.

Apart from dissemination, several activities have been executed generating strategies and policies how to introduce biogas in public transport as well as analyses of necessary measures to take when producing, distributing and using biogas in bus operations. I am confident that even though the project will come to an end in 2012, project partners will continue their work on using biogas as fuel in public transport.

On behalf of all partners of the Baltic Biogas Bus project, I would like to thank the Baltic Sea Region Programme and the Joint Technical Secretariat in Rostock for financing the project and relentlessly supporting it in many ways. I would also like to thank all our associated partners and attendants of project seminars who have shared their knowledge and ideas with us.

We have together made the Baltic Sea Region a better place to live, work and invest in.

Lennart Hallgren,
Project Manager, the Baltic Biogas Bus project

The project management team – representing Stockholm Public Transport – Anneli Waldén, Lennart Hallgren and Sara Anderson.

Contents

From regional strategies to biogas buses

The objective of the project is to stimulate cities within the Baltic Sea Region to use biogas as fuel for city buses — with the long-term aim to reduce environmental impact from public transport.

Extended use of biogas for city buses will lower emissions, improve inner city air quality, limit the impact from traffic on climate change and strengthen the role of public transport

During the three years of the Baltic Biogas Bus project strategies and policies on how to introduce biogas in public transport have been generated and analyses regarding biogas production, distribution and bus operations have been carried out.

Increased knowledge and understanding

Activities executed also aim to facilitate further expansion in cities which already have biogas buses. The project's network of twelve partners in eight countries offers an ideal platform for dissemination of knowledge, experience and technology. A broad set of associated organisations in each country, the rest of Europe and beyond reinforces the communication strategy. Teaming up with other biogas and transport projects is used as a way to raise the visibility of biogas buses while at the same time expanding the impact with the same communication budget.

Regional seminar, 9 Nov 2010, Uppsala, Sweden.

Dependency on fossil fuels makes public intervention to support energy innovation both necessary and justified. To make second generation bio fuels competitive to fossil fuels is a challenge – but biogas has already proven to be an excellent and commercially available second generation bio fuel.

The Baltic Biogas Bus project presents cost effective solutions on biogas production as well as distribution and use in buses. The monitoring of economic and environmental impacts demonstrates a renewable fuel for transport with excellent environmental performance.

Production and distribution process

Efficient use of biogas buses depends on a process with several steps: production from biodegradable materials (biological waste, sewage sludge and landfill gas) including purification to get a gaseous fuel (bio methane) for vehicles and distribution, either by trailer or in pipelines. Since the characteristics of biogas are similar to natural gas it is possible to inject purified biogas into the natural gas grid to create a cost effective solution.

Handling of biogas at bus depots includes creating an optimal refuelling system: a fast filling system similar to common diesel filling systems or a slow filling system fuelling the bus overnight.

The knowledge and experience from the project will form a bridge to the next generation of renewable fuels involving hydrogen. Consequently the project has analysed synergies in mixing biogas with hydrogen to get the most out of both renewable fuels.

Long-term strategy

There are good examples of the use of biogas buses in public transport, but wide acceptance and introduction in the Baltic Sea Region cities has not yet taken place. Many cities are still unaware or have incorrect information about the benefits of biogas buses. Furthermore, to shift from fossil fuel buses to biogas buses is complicated and a long-term approach is needed.

Biogas can be produced from a range of sources and biogas buses can be ordered from several bus manufacturers. Still the missing link for most cities is an integrated long-term strategy to work towards introduction of biogas buses in public transport. The project has assisted several cities in different European countries to define a feasible long-term implementation strategy for the shift to biogas buses.

Upgrading of the biogas bus fleet is the next step. The project has demonstrated solutions to overcome the practical barriers for upgrading. The project also stimulates the cooperation of a growing number of cities who have or want to acquire biogas buses and infrastructure to reach improved technology and lower prices. The growing demand has resulted in a more mature supply market — including infrastructure, filling stations and buses.

Project achievements and deliverables

Policy, strategy, financing, regulatory framework:

- Life Cycle Cost Analysis for biogas buses
- Tartu City transport plan including biogas
- Support cities to set up a strategy for introduction of biogas buses
- Analyses of differences in regulations and taxations on biogas buses
- Strategy, policy and action plan manual

Securing biogas supply:

- Desk study on biogas production options and production potential scenarios
- Lessons learned from biogas production
- Overview of biogas production from different types of sources

Biogas distribution infrastructure, bus depots and upgrading:

- Baltic Sea Region biogas infrastructure overview
- Integrated regional distribution infrastructure planning
- Analyse fuelling system alternatives
- Design new bus depots and adapt existing depots for biogas buses

Biogas bus use and supply:

- Biogas bus use operational experiences
- Outlook vehicle technology developments
- Feasibility study to introduce biogas buses in Tartu, Estonia and Rzeszów, Warsaw and Walbrzych, Poland
- Laboratory biogas bus emission measurements

All reports, manuals and guidelines are readily available for implementation in other cities, making replication easier. Please visit *www.balticbiogasbus.eu*

35,000 tonnes less CO_2 every year

Results from the Baltic Biogas Bus project show that biogas is the transport fuel with the best environmental performance. Increased use of biogas will significantly contribute to reaching the EU 2020 targets.

The Baltic Biogas Bus project and scientific analyses have shown that biogas is a renewable fuel providing a great reduction of CO_2.

Decreased emissions

Not only is producing biogas a way to decrease dependency on fossil fuels and decrease the impact on climate change, but it is also a fuel fit to reduce other negative environmental impacts. These mainly consist of decreased emissions of NOx and particulates, which are related to health risks, as well as lowering noise pollution.

Thereby the Baltic Biogas Bus project has actively contributed to the EU 2020 target of reducing greenhouse gas emissions by 20 per cent compared to 1990 levels by 2020 and to the target of increasing the share of renewable energy in final energy consumption to 20 per cent. The project furthermore promotes greater energy security in demonstrating regional renewable fuel autonomy by producing biogas for city buses.

In April 2012, an inauguration ceremony for the newly purchased gas-fuelled buses was held by the Lithuanian minister for transport in Kaunas.

International conference, 17 Oct 2011, St Petersburg, Russia.

Sustainable jobs

The implementation of biogas buses is a driver for more regional production of biogas and thereby creating new jobs in the area of renewable fuels and contributing to the EU 2020 target of 75 per cent employment of the 20-64 year-olds and the target that Research & Development of innovations should amount to 3 per cent of EU's GDP.

More than 400 biogas buses

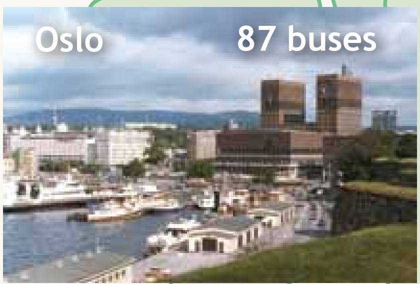
- **Within the project's lifetime, several cities of varying size have bought 300 gas-powered buses, which will reduce the CO_2 emissions in the Baltic Sea Region with approximately 35,000 tonnes a year, NOx emissions with 140 tonnes and particulates with 2 tonnes when running on biogas.**
- **The project will reduce diesel use by more than 11 million litres per year.**
- **New bus depots and filling stations have been created for biogas buses.**
- **Pipeline infrastructure and other long-term sustainable systems for distribution are constructed.**

Gas-fuelled buses in eight cities

Why biogas?

Public transport is the basis of sustainable urban transportation systems. Biogas-driven buses help improve urban air quality. Compared to diesel and petrol, biogas reduces local emissions substantially.

Biogas is also more climate effective as fuel than for energy production. Since biogas is produced locally, primarily in urban areas, this renewable eco-fuel improves energy autonomy.



The demand for biogas might soon outgrow the potential supply. Therefore we are investigating new sources for production."

Petra Seidenberg, ATI erc, Germany.

Biogas vs natural gas

From a chemical perspective, there is no difference between biogas and natural gas, they both mainly consist of methane. The big difference lies in how they are generated; while natural gas is a fossil fuel requiring millions of years to materialize, biogas can be produced from what traditionally is considered to be waste in no more than 14 days. This also means that biogas is 100 per cent renewable, whereas natural gas is being depleted.

The biogas ecocycle starts when waste is being produced. This can be organic waste from households collected at landfills and waste water treatment plants or agricultural byproducts. This is collected and placed in an anaerobe digester where it is left to undergo chemical reactions for about two weeks. The resulting biogas is a mixture of mainly methane and carbon dioxide. In order to use this as transport fuel it has to undergo an upgrading process, where most of the carbon dioxide and other chemical compounds are removed.

When biogas is being combusted, methane will be converted to carbon dioxide. However, since only biodegradable substrates have been used for the production of the gas, there is no net addition of carbon dioxide to the atmosphere.

Increased knowledge and more buses in traffic

The Baltic Biogas Bus project was initiated by Stockholm Public Transport and consists of twelve partner organisations from eight countries in the Baltic Sea Region.

Some partners are direct providers of public transport, but research institutes and city municipalities also participate in the project. The broad spectrum of partners provides good potential of acquiring the complete picture of the possibilities and challenges of using biogas as fuel for public transport.

Apart from the twelve partners several producers and distributors of biogas, bus suppliers, bus operators and other stakeholders participate in the project as associated partners, providing input and sharing experiences.

The project is partly funded by the European Union's Baltic Sea Region Programme and Norwegian funds and runs from 2009 to 2012.

Renewable fuel for climate-neutral public transport

The world is facing increased demand for transportation, at the same time as fossil fuel resources are diminishing. On top of this, concern for climate change due to the emission of green house gases is growing. This has boosted the interest for investments in new energy solutions. One solution gaining widespread recognition is that of using biogas as transport fuel.

Not only is producing biogas a way to decrease dependency of fossil fuels and decrease impact on climate change, but it is also a fuel fit to reduce other negative environmental impacts. These mainly consist of decreased emissions of NOx and particulates, which are harmful to citizens, as well as lower noise pollution.

Biogas is part of the natural carbon cycle and therefore has limited climate impact. Taking into account that it can easily be produced in urban areas, the Baltic Biogas Bus project considers biogas to be the most suitable fuel for public transport.

Biogas as fuel

Substituting diesel with biogas lowers greenhouse gas emissions substantially, often by more than 100 per cent. This might seem puzzling, but substrates which are potential sources for biogas production left for uncontrolled decomposition will lead to natural emission of methane to the atmosphere. If instead these substrates are used for biogas production, the methane will be collected in a controlled manner and can be used for transport fuel.

In the combustion process, methane will be converted to CO_2, and emitted to the atmosphere. Although CO_2 also is a greenhouse gas, it is a lot less strong one than methane. All in all, when using diesel for transport fuel and leaving potential biogas substrates for uncontrolled decomposition, both sources will contribute to the greenhouse effect. If instead biogas is produced and used for transport fuel, both the direct emissions will be substantially decreased and the source for methane emissions will be eliminated.

Gas bus in Tartu.

The Baltic Biogas Bus project handles four major components; strategies, supply, distribution and bus usage. Read more on the following pages. Project summary and recommendations on page 14.

STRATEGIES AND POLICIES

The first component "Policy, strategy, regulatory framework to facilitate biogas bus use" consists of strategies on how to implement biogas as fuel for public transport. The project draws on existing good examples of the use of biogas buses, and transfers this knowledge to other cities, which show an interest in using biogas as transport fuel.

One direct outcome of the project is a manual on how to introduce biogas buses in public transport. To a high extent, the manual builds on Stockholm Public Transport's own experiences, since biogas buses were introduced in the Swedish capital almost a decade ago. The manual describes lessons learnt from the Stockholm experience and gives guidance to other cities interested in introducing biogas buses.

Introduction of biogas buses

Today, all public transport in the urban area of Stockholm runs on renewable fuels, of which biogas is an important component. The aim is to phase out fossil fuels latest by year 2025 from public transport of the entire Stockholm region.

When the project started, Stockholm Public Transport was the only project partner having biogas buses in service. During the course of the project a lot of progress has taken place; Tartu in Estonia has concluded the development of an ambitious transport plan, in which biogas plays a prominent part. The idea of using biogas was not new to Tartu, but thanks to the project both funding and experience was made available.

CITY	START	CURRENT[1)]
Bergen	81	89
Helsinki	100	100
Kaunas	0	24
Oslo	0	87
Rzeszów	40	40
Stockholm	81	259
Tartu	0	5
Wismar	8	8
Total	310	612

Number of biogas buses from the start to the end of the project.

1) Some of these buses are not yet fuelled with biogas, but with natural gas since production and distribution facilities are not yet fully established. However, the number of buses presented will eventually run on biogas.

The member organization HOG Energy of Norway, has convinced the city of Bergen to invest in biogas buses in their public transport system. Norway is a country with abundant resources of oil and natural gas and investing in biogas is not the most obvious choice for decision makers. However, thanks to the environmental benefits, the city of Bergen has begun making these investments.

In Norway's capital Oslo, the public transport provider Ruter is making similar investments in biogas buses, which also goes for the city of Kaunas in Lithuania, Helsinki in Finland, Wismar in Germany and the city of Rzeszów in Poland.

International conference, 17 Oct 2011, St Petersburg, Russia.

All these partners have started the introduction of biogas buses in public transport by using natural gas for a transition period until production and distribution facilities of biogas have been put in place. Additionally natural gas can be used as a complement and back-up system for biogas, since there is no chemical difference between the two. Since the start of the project, more than 400 new buses that will eventually run on biogas have been introduced among partners and organisations affiliated with project partners.

The importance of long-term political decisions

HOG Energy in Norway has investigated how political decisions affect the usage of biogas in the Baltic Sea Region. It clearly shows the importance of long-term political will at local level to set up a system using biogas as transport fuel. It is of utmost importance to set up long-term sustainable environmental goals. Without long-term planning, including the establishment of contracts between users and suppliers, the necessary upfront investments are unlikely to take place.

Not only local and regional political will, but also national policies come into play. The regulatory framework including tax regulations/exemptions, subsidies etc. determine to a very high extent what biogas will be used for.

The investigation shows that initial subsidies can be a useful tool for propelling investments in producing biogas for public transport. Instead of using biogas for transport fuel, it could be used for electricity and heat generation. Due to disadvantageous tax regulations or the lack of initial subsidies for using biogas as transport fuel, this is the current situation in some of the countries in the Baltic Sea Region and for the time being a limited amount of biogas is used as transport fuel in these countries.

Life Cycle Cost Analysis

The Finnish research institute VTT has carried out a Life Cycle Cost Analysis (LCCA) of using biogas as transport fuel. It is shown that the possible financial gains compared to using it for other purposes to a high degree depend on local circumstances, such as local potential supply and demand and already existing distribution infrastructure. However, using biogas provides important socioeconomic gains which can be difficult to quantify and evaluate.

Local emissions of particulates and NOx decrease substantially when using biogas as transport fuel. This is especially important in urban traffic, since air quality in cities normally is worse than in rural areas at the same time as population density is a lot higher. Improving inner city air quality would mean reducing health hazards for a huge number of people.

Gas bus in Helsinki.

STRATEGIES AND POLICIES – Conclusions

- **Long-term political commitment and ambitious goals is key for a successful biogas system**
- **Initial support functions, such as tax exemptions or subsidies for setting up a biogas system can play an important role, but in the long run biogas as transport fuel is economically viable**
- **Transition to a biogas system can be carried out stagewise**
- **Biogas as fuel has proven to work very well in several cities in the Baltic Sea Region**

Gas bus in Wismar.

SUPPLY OF BIOGAS

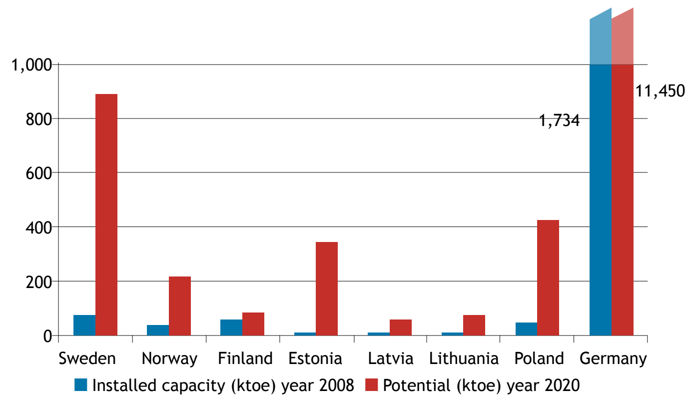
The second component of the project is "Securing biogas supply" to meet the demand for biogas buses in the Baltic Sea Region.

The potential of biogas in the Baltic Sea Region

Guaranteeing stable supply of biogas is crucial to motivate investment in the sector. A study was conducted by the Motor Transport Institute of Poland (MTI) to map the theoretical supply in the region, which can serve as a basis to convince more transport companies to start using biogas instead of diesel as transport fuel.

The potential is often more than ten times as high as actual production in many countries. Traditionally, biogas is produced from wastewater treatment plants and landfills, since investment costs in these sectors are relatively low.

The study shows that the largest unrealised potential exists within the agricultural sector. However, there is a gap between theoretical and practical potential, whereas the latter to a high extent is defined by investment costs, property rights, regional demand, existing distribution infrastructure and the regulatory framework.



Biogas available capacity and potential in the Baltic Sea Region.
(source: Gunaratne et al, 2010.)

Research & development

Another partner, the research and development institute ATI erc of Germany, has conducted several studies using less conventional substrates to produce biogas as well as investigating the most energy efficient hythane mix (biogas mixed with hydrogen) for buses. As explained above, traditional sources for producing biogas are not yet fully exploited and there is still a lot of potential to expand production in the region. But due to the increasing interest in biogas, demand might soon outgrow potential supply and it is therefore necessary to investigate new sources for production.

SUPPLY OF BIOGAS – Conclusions

- **There is still a high potential among traditional sources for increasing biogas production in the Baltic Sea Region**
- **New sources for production of biogas might be necessary to meet the future demand for biogas as fuel**

PRODUCTION PLANT

DISTRIBUTION VIA PIPELINE

FILLING STATION

BUS DEPOT

DISTRIBUTION OF BIOGAS

Once the biogas has been produced, it has to be distributed. The third component, "biogas bus use and supply" dealt with analysis and design of distribution networks, bus depots and fuelling systems.

An overview of the future pipeline distribution system in Stockholm, indicating production plants, bus depots and filling stations.

Distribution technology

Compared to natural gas, which normally has to be transported long distances, biogas has the advantage that it is often produced in or near city centres. In Stockholm, the construction of a gas grid encircling the city was finished in January 2012. The owner of the grid, Stockholm Gas is already planning further investments to extend the distribution network.

However, a network of pipelines requires substantial investments and is only feasible if large amounts of biogas will be transported. For smaller distribution networks it is normally more feasible to transport biogas by truck or, if possible, by ship.

HOG Energy has investigated different possibilities to make distribution of biogas more cost efficient and come up with guidelines of what system to invest in depending on the amount and distance for the biogas to be transported. The distribution cost can make up a substantial amount of the life cycle cost of biogas, which is shown in the LCCA carried out by VTT. Already existing pipelines designed for natural gas can help lower this cost significantly, since biogas can readily be mixed with natural gas thanks to it having the same chemical composition.

Fuelling systems

At the end of the distribution line is the depot where fuelling of biogas buses takes place. Fuelling is carried out either through "slow filling" or "fast filling". The fast filling system resembles a conventional petrol or diesel fuelling station, whereas the slow filling takes several hours, normally overnight. Stockholm Public Transport uses both systems and carried out a comparison between the two. From an investment and operational cost perspective, there is a small difference with fast filling being a bit more expensive.

However, choosing between the systems should be based on specific needs; fast filling is more appropriate if it is to serve public users, whereas slow filling might be more useful for a local transport company, since fewer or possibly no buses are used during night time. The study shows that there is a higher stress factor using the fast filling system, which increases risks for accidents when fuelling.

DISTRIBUTION OF BIOGAS – Conclusions

- **Taking local circumstances into account when developing the distribution system can lower distribution costs substantially**
- **Fast fillig and slow filling are complementary available functioning techniques**

USE OF BIOGAS BUSES

The last component concerns the use and supply of biogas buses. Since biogas buses are relatively new on the market, production volume is limited.

Increased demand for biogas buses

Public transport companies are often relatively large customers and therefore have good possibilities to influence suppliers through experience sharing and specific demands. Since production volumes for biogas buses are significantly lower than for common diesel buses, economies of scale are limited and diesel buses are still considerably cheaper. However, with a growing market indicating a huge potential, suppliers have dedicated more money to improving biogas buses lately and costs have dropped accordingly at the same time as performance has improved.

Results from emission test

Comparisons between emissions from normal diesel buses and biogas buses have been carried out by VTT and MTI, both in laboratory and in real life conditions. Results from laboratory tests show that especially emissions of particulates decrease substantially when using biogas engines. There is also a decrease of NOx emissions, and noise measurements show favourable results for biogas buses as well.

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 operational costs into a "Well to Tank" and a "Tank to Wheel" perspective.

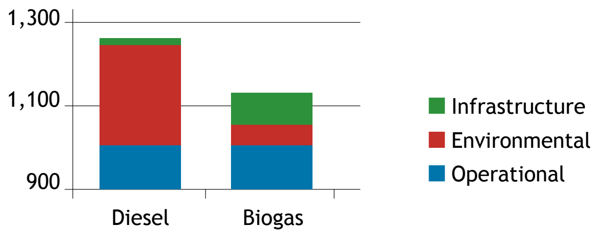
The calculations have been carried out both including and excluding costs for the specific biogas infrastructure needed. Since new infrastructure is needed for biogas it will face a disadvantage when compared to fossil fuels, for which infrastructure is already in place.

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 is 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_2, emissions of particulates and NOx.

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



Cost comparison between biogas and diesel in SEK per 100 km.

USE OF BIOGAS BUSES – Conclusions

- **From a financial perspective, biogas can compete with diesel**
- **From a socioeconomic perspective, biogas is the best fuel for inner city transport, since hazardous emissions are considerably reduced**
- **Increased demand for biogas buses will lower the investment costs and affect the development of more efficient vehicles and engines**

Biogas – the basis of sustainable urban transport

Results from the Baltic Biogas Bus project lead us to state that biogas is undoubtedly the fuel with the best environmental performance fit for transport and especially inner city public transport.

However, to set up a biogas system to be used for transport fuel, the long term political will is important as well as a regulatory framework not discriminating the use of biogas as transport fuel.

To make this a reality, the following is recommended:

- Set up ambitious long-term sustainable environmental goals at regional and national level
- Local transport authorities must be willing to set up long-term contracts with suppliers in order to secure their investment
- Use biogas where it obviously provides the best environmental effects. Greenhouse emissions are always reduced, no matter what the area of usage of biogas. However, using it as inner city transport fuel provides additional positive environmental effects which can not be counted for when for example using biogas for heat and electricity generation
- Different kinds of subsidies is an option to propel development, but in the long run biogas can compete financially with other kinds of transport fuel

STRATEGIES AND POLICIES

SUPPLY OF BIOGAS

USE OF BIOGAS BUSES

DISTRIBUTION AND FUELLING OF BIOGAS

Working together on climate-neutral public transport

One of the most important tasks of the project was to disseminate the good examples of using biogas as transport fuel in cities, showing both the environmental and possible financial benefits. Therefore, a lot of effort was put on communication. Second opinions and partner exchange missions have deepened mutual understanding and promoted technology transfer.

Regional seminar, 1 Dec 2010, Riga, Latvia.

Seminars and meetings

Two regional dissemination seminars were given in each partner country during the course of the project. A total of 18 regional seminars have been conducted. These seminars were directed towards politicians and other stakeholders in the transport sector. Three main events have been successfully conducted: the Launch event 2009 in Tartu, Estonia, the Mid-event symposium 2011 in Rzeszów, Poland, and the Final event 2012 in Bergen, Norway.

Additionally, two international conferences have been held in St Petersburg. For the time being, interest in biogas is limited in Russia, mainly because of the high supply of natural gas and oil. But even if it is difficult for biogas to compete financially in the short term, the environmental aspects are becoming more and more important also in Russia.

Totally, more than 2,000 participants have been directly reached through seminars and events.

Media coverage

Throughout the project, media and the general public showed a lot of interest in the investigated topics. National broadcasting services as well as regional and local newspapers in several countries have reported about the project and conveyed the messages of the project to potentially several hundred thousands of people.

Over 40 articles have been published in newspapers and magazines with more than 350,000 readers, 20 radio and TV reports have been broadcasted and 15 project newsletters have been produced and distributed to hundreds of subscribers.

The interest is not confined to Europe; for example, several Chinese delegations have visited Stockholm Public Transport during the last couple of years to learn more about the advantages of using biogas as transport fuel. Additionally, Stockholm Public Transport has participated in conferences both in Asia and in the Americas showing the good example of using biogas as fuel for public transport.

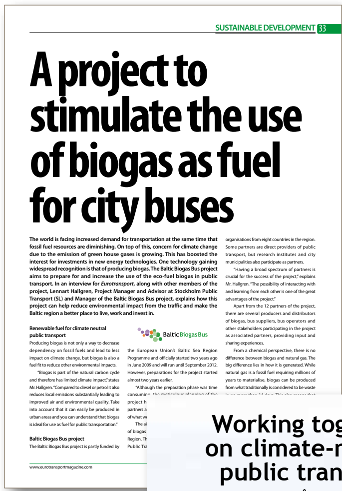
Regional seminar, 22 Sep 2010, Kaunas, Lithuania.

The Baltic Biogas Bus project has recorded its own information material about biogas production and bus operation in Stockholm, biogas production and bus operation in Tartu and the seminar and partner meeting in Riga, which are all available on the web.

Website

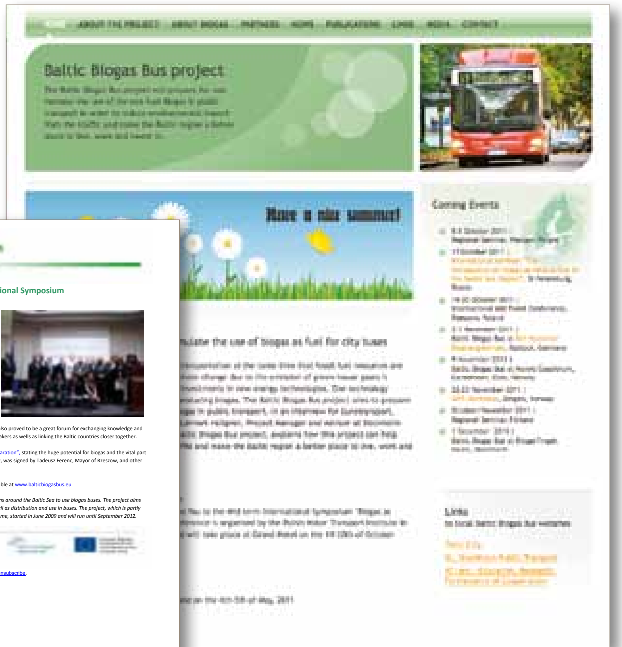
All reports produced during the course of the project, newsletters, presentations and a lot of other information is available on the project website, www.balticbiogasbus.eu, which has attracted over 5,000 visits.

Internal and external communication initiatives



Core messages:

- Biogas is almost 100 per cent renewable
- Biogas is very efficient as fuel
- Biogas improves urban air quality and climate
- Biogas produced locally, improves energy autonomy and creates jobs



For moving images, slide shows and photos, please visit www.balticbiogasbus.eu

Seminars and events 2009-2012

Launch event, 1 Dec 2009, Tartu, Estonia

Regional seminar, 10 Mar 2010, Oslo, Norway

Regional seminar, 6-7 Sep 2010, Walbrzych, Poland

Regional seminar, 22 Sep 2010, Kaunas, Lithuania

Parallel session at Bioenergie Forum, 27-28 Oct 2010, Rostock, Germany

Regional seminar, 9 Nov 2010, Uppsala, Sweden

International seminar, 25-26 Nov 2010, St Petersburg, Russia

Regional seminar, 1 Dec 2010, Riga, Latvia

Regional seminar, 23-24 Mar 2011, Tartu, Estonia

Parallel session at Gasskonferensen, 4-5 May 2011, Bergen, Norway

Parallel session at Recycling Conference, 5-8 Oct 2011, Warsaw, Poland

International conference, 17 Oct 2011, St Petersburg, Russia

Mid-event symposium, 19-20 Oct 2011, Rzeszów, Poland

Regional seminar at Norsk Gassforum, 9 Nov 2011, Gardemoen, Norway

Parallel session at 5th Bioenergie Forum, 3-4 Nov 2011, Rostock, Germany

Regional seminar at Biogastinget, 1 Dec 2011, Stockholm, Sweden

Regional seminar, 1 Feb 2012, Riga, Latvia

Regional seminar, 20 Apr 2012, Kaunas, Lithuania

Regional seminar, 15 May 2012, Espoo, Finland

Final event, 22 May 2012, Bergen, Norway

Regional seminar, 14 Aug 2012, Tartu, Estonia

Public transport and biogas buses of the future

What would our transportation systems look like if our children were to decide? The question received several answers when the Estonian partner of the Baltic Biogas Bus project, Tartu City and Stockholm Public Transport, asked young citizens to use their imagination and draw the transport solutions of tomorrow. Fuels such as grass, waste and water were suggested.


10 NÕLVAKU PÕLLU
10 NÕLVAKU PÕLLU
SCANIA
AS SEBE
GNG


Drar in vattenånga om det inte regnar,
Vatten

“Stable and secure biogas supply is key. Without it, no transport company will commit to any major investment. Our study shows that the production potential in the Baltic Sea Region is great.”

Wojciech Gis,
ITS/Motor Transport Institute, Poland.

Transnational cooperation around the Baltic Sea

The Baltic Biogas Bus project is part of the EU Baltic Sea Region Programme which runs from 2007 to 2013. The strategic objective of the programme is to make the Baltic Sea Region an attractive place to invest, work and live in by promoting regional development through transnational cooperation.

Eleven countries around the Baltic Sea work together to find joint solutions to common problems within four prioritised fields:

- **FOSTERING INNOVATIONS.** The priority supports innovation sources and facilitation of transnational transfer of technology & knowledge, in particular targeted at small and medium size enterprises (SMEs). Another objective is to strengthen the capacity of people for absorbing new knowledge.
- **INTERNAL AND EXTERNAL ACCESSIBILITY.** The priority addresses transport imbalances, and will minimise the impact of barriers for smooth transport of goods and passengers. The objective is to improve the external and internal accessibility of the Baltic Sea Region.
- **BALTIC SEA AS A COMMON RESOURCE.** The objective is to improve the management of Baltic Sea resources in order to achieve a better environmental state. The priority focuses on joint transnational solutions declining the pollution of the Baltic Sea and improving sustainable management of the sea as a common resource.
- **ATTRACTIVE AND COMPETITIVE CITIES AND REGIONS.** The priority targets the policy making for sustainable urban and regional development. It concentrates on making the Baltic Sea Region cities and regions more competitive on a European scale.

Apart from the eight EUmember states bordering the Baltic Sea, Norway, Russia and Belarus are also eligible to apply for funding from the programme. The total programme funding is 237 million Euro. On top of this, each partner co-funds the project with an amount ranging from 15 to 50 per cent.

“Some of the research partners in the project are carrying out studies on bus technology development and emissions. Valuable know-how that can be used in the dialogue with bus suppliers.”

Lennart Hallgren,
Stockholm Public Transport, Sweden.

Ruter, Public Transport for Oslo and Akershus. *www.ruter.no*

HOG Energy. *www.holga.no*

Skyss-Hordaland County Council. *www.hordaland.no*

SL, Stockholm Public Transport. *www.sl.se*

Biogas East. *www.biogasost.se*

VTT Technical Research Centre of Finland. *www.vtt.fi*

Tartu City. *www.tartu.ee*

Riga City Council Traffic Department. *www.rdsd.lv*

Buses of Kaunas City. *www.kaunoautobusai.lt*

ATI erc – Education, Research, Furtherance of Cooperation. *www.ati-erc.de*

ITC Innovations and Trendcenter. *www.itc-bentwisch.de*

ITS Motor Transport Institute. *www.its.waw.pl*

Baltic Sea Region Programme 2007–2013

The Baltic Biogas Bus project is supported by the EU, and is part of the Baltic Sea Region Programme. Twelve companies, organisations, cities and counties in eight countries within the Baltic Sea region are participating in the project. Through work packages the participants are responsible for different aspects of the project – production, distribution and use of biogas, as well as spreading information and knowledge.

Read more at *www.balticbiogasbus.eu* and *www.eu.baltic.net*

Regional cooperation maximises project impact

Stockholm Public Transport, Sweden

Stockholm Public Transport (SL) is Sweden's leading provider of public transport services. On a normal weekday more than 700,000 Stockholmers use our services and board approximately 2,5 million times. During peak hours, almost 8 out of 10 travelers go by metro, commuter trains, tramways and buses. The system offers 25,000 daily trips on 2,000 buses and 1,000 trains, serving 244 stations and 14,000 bus stops.

One of SL's goals is to provide a 100 per cent fossil free public transport not later than 2025. Today, all track vehicles run on certified green energy and the number of renewable fuelled buses increases steadily. SL has used biogas fuelled buses in the inner city services since 2004. Further biogas expansion of both depots and buses in the region will take place in the next years. SL is Lead partner in the Baltic Biogas Bus project with an ambition to provide experience to our neighbouring countries, learn more from the project and of course, promote the use of biogas in the Baltic Region.

Stockholm Public Transport

AB Storstockholms Lokaltrafik
www.sl.se

HOG Energi, Norway

HOG Energi (formerly Hordaland Oil and Gas) is a coordinating body for activities involving energy in Hordaland, established to secure Hordaland's position as a leading energy region. HOG is a member organization with regional and local communities, organizations and enterprises, such as Hordaland County Council, City of Bergen, University of Bergen and BKK (leading power company in Western Norway) as members.

The aim of the organization is, in cooperation with others and in an environmentally friendly way, to utilize natural and human resources for economic growth in the energy sector in Hordaland. Carbon capture and storage (CCS), offshore wind and biogas production are among HOG's most prioritised tasks. 89 natural gas buses run in Bergen today and the city is planning a biogas production plant. HOG joined the Baltic Biogas Bus project in order to learn from other partners' experiences with biogas in buses and to share their competence regarding gas distribution.

HOG Energi
www.holga.no

Ruter, Norway

Ruter is Norway's leading provider of public transport services and is responsible for public transport in the Oslo region. 285 million travelers use our services yearly (metro, commuter trains, tramways, ferries and buses). The system offers more than 3,6 million yearly trips.

One of Ruter's goals is to provide a 100 per cent fossil free public transport not later than 2020. Already today, track vehicles run on certified green energy and buses using renewable fuels increase steadily. Ruter started using biogas fuelled buses in 2010, and by 2012 there will be 87 biogas buses in the Oslo region.

Ruter is a dissemination partner in the Baltic Biogas Bus project with an ambition to learn more from the project and start using biogas buses in Oslo.

Ruter As
Kollektivtrafikk for Oslo og Akershus
www.ruter.no

ITS/Motor Transport Institute, Poland

Motor Transport Institute (MTI) is a leading scientific institution in Poland with almost 60 years of experience. The results of our work are a source of knowledge for the entire automotive branch of trade and industry in Poland, and the opinions issued by MTI represent an expert foundation to form legal acts concerning, among others, road traffic safety, type approval regulations and environmental protection.

MTI is continuously researching and developing environmentally friendly technologies and biogas is one of the focus areas of the institute. Promoting and developing the core messages of the project is important for MTI as an innovator in the domestic automotive industry. Participating in the project has provided the opportunity to learn about best practices of biogas use as bus fuel. As an effect of participating in the project, MTI has become the Polish information center of biogas technologies.

Motor Transport Institute
www.its.waw.pl

The Baltic Biogas Bus project is very valuable to Tartu. The idea of using biogas here is not new, but thanks to the project both funding and experience is now available to us.”

Margus Hanson, Member of the Estonian Parliament and former Vice-Mayor of Tartu, Estonia.

Margus Hanson, Member of the Estonian Parliament and former Vice-Mayor of Tartu City, Estonia.

Tartu City, Estonia

Tartu is the centre of the South-Estonia region, hosting the oldest and largest university in the country. The development and management of the town is effected by the Town Government, which is also acting as one of the partners in the Baltic Biogas Bus project.

Tartu aims to provide a modern environment and to promote innovation and development. First steps have been made to make the town’s transport system more safe, customer friendly and environmentally sustainable. Biogas will play an important part in the city’s transport development plan which runs from 2012 through 2020. At the moment there are 24 contractual bus lines and 3 commercial bus lines in Tartu. In 2011 the number of passengers using public transport in Tartu was over 12,3 million. Tartu aims at learning from other partners’ experience of using biogas through different project activities. The objective of joining the project was to implement the acquired knowledge in Tartu and to encourage the use of biogas in public transport systems in the Baltic Sea Region.

Tartu Linnavalitsus
Tartu City local government
www.tartu.ee

Hordaland County Council/Skyss, Norway

Skyss is owned by Hordaland county authority. Skyss’s purpose is to plan, purchase and market public transport services. Contracts for the operation of bus routes and the Bergen light-rail system (Bybanen) are awarded to traffic companies via tender competitions. Skyss is responsible for planning itineraries, developing ticket systems, information and marketing. Skyss is a dissemination partner of the project and as such has helped to organise regional seminars focusing on biogas as transport fuel.

Skyss-Hordaland County Council
www.hordaland.no

JSC "Buses of Kaunas city”, Lithuania

Kauno Autobusai is one of the leading public transport companies in Lithuania. The mission is to provide public transport services with regular bus routes in Kaunas city and suburbs. Kauno Autobusai operates 168 buses on 31 bus routes, with more than 650 bus stops. Every day, on average about 90,000 passengers use the services provided.

The company aims to continuously improve the quality of its services with a radical renewal of the vehicle fleet. In 2012 the company acquired 24 modern buses running on natural gas. Once a biogas distribution system is in place, these buses will run on biogas.

The company is a member of the National Road Carriers Association Linava State, it has close business relationships with related businesses in Lithuania and abroad. Kauno Autobusai is a dissemination partner in the Baltic Biogas Bus project.

JSC "Kauno autobusai” Joint Stock Company
www.kaunoautobusai.lt

ITC Innovations and Trendcenter GmbH, Germany

The ITC – Innovations and Trendcenter – is a technology centre of the community of Bentwisch near Rostock. ITC supports innovative small and medium sized companies and start-up projects by renting out production facilities, offices and industrial real estates. Additionally, ITC lends professional support to these companies regarding business and strategy development. ITC cooperates with more than 250 such companies in the region.

ITC is a dissemination partner in the Baltic Biogas Bus project. By using its network in northern Germany, ITC supports the goal to introduce biogas as fuel in the public transport sector.

ITC Innovations and Trendcenter GmbH
www.itc-bentwisch.de

ATI erc GmbH, Germany

ATI erc gGmbH is a non-profit company and a regional development agency for high-tech and innovative companies and projects in the region of northeastern Germany. The institute focuses on promotion of education, research and cooperation at European and international levels. The institute hosts and implements scientific events, training programs, research projects and projects to further European and international cooperation.

ATI erc supports companies interested in innovative international business. Within the project, ATI erc has contributed with several feasibility and expert studies, the organization of two seminars in St. Petersburg to discuss biogas as transport fuel in Russia as well as disseminating the core messages of the project in northern Germany.

ATI erc gGmbH
www.ati-erc.de

Riga City Council Traffic Department, Latvia

Riga City Council Traffic Department is a legal entity of Riga City Council and is responsible for the local transport system of the city of Riga, which is comprised of buses, trams and trolleybuses. The traffic department is looking for possibilities to reduce environmental impact and using biogas is a very interesting option. Riga City Council Traffic Department is a dissemination partner of the project with the main task of organising two regional seminars with the goal of widening the knowledge of local stakeholders and other concerned parties regarding sustainable transport development using biogas as transport fuel.

Riga City Council Traffic Department
www.rdsd.lv

VTT Technical Research Centre of Finland, Finland

VTT Technical Research Centre of Finland is an impartial expert organisation. VTT's research covers a broad range of technologies. In the field of engines, fuels and emission, VTT is the leading research institute in the Nordic countries. The focus of the research is on reducing both exhaust emissions and energy use and its negative impact. The entire chain from fuels and engines to various emission control technologies is covered. VTT's role in the project is to produce comparable emission and energy use data of buses representing different technologies by the means of life cycle analysis. Using the data, positive and negative aspects of biogas buses could be further analysed. By participating in the project, VTT had the possibility to establish research co-operation with institutes in neighbouring countries.

VTT Technical Research Centre of Finland
www.vtt.fi

Stein Bjørlykke, HOG Energi, Bergen, Norway.

Biogas Öst, Mälardalen Energy Agency, Sweden

Biogas East (Biogas Öst), a regional organization promoting biogas in mid-eastern Sweden, aims to strengthen cooperation between municipalities, producers, distributors and end-users of biogas, thereby increasing the number of production plants, filling stations and vehicle fleets fuelled by biogas. Biogas East's objective is to coordinate dialogue between stakeholders, evaluate the market and realise various projects aiming at increasing the production and use of biogas.

Biogas East's primary task in the Baltic Biogas Bus project is to distribute results and knowledge gained by the project via its extensive network.

Malardalen Energy Agency/Biogas Öst
www.biogasost.se

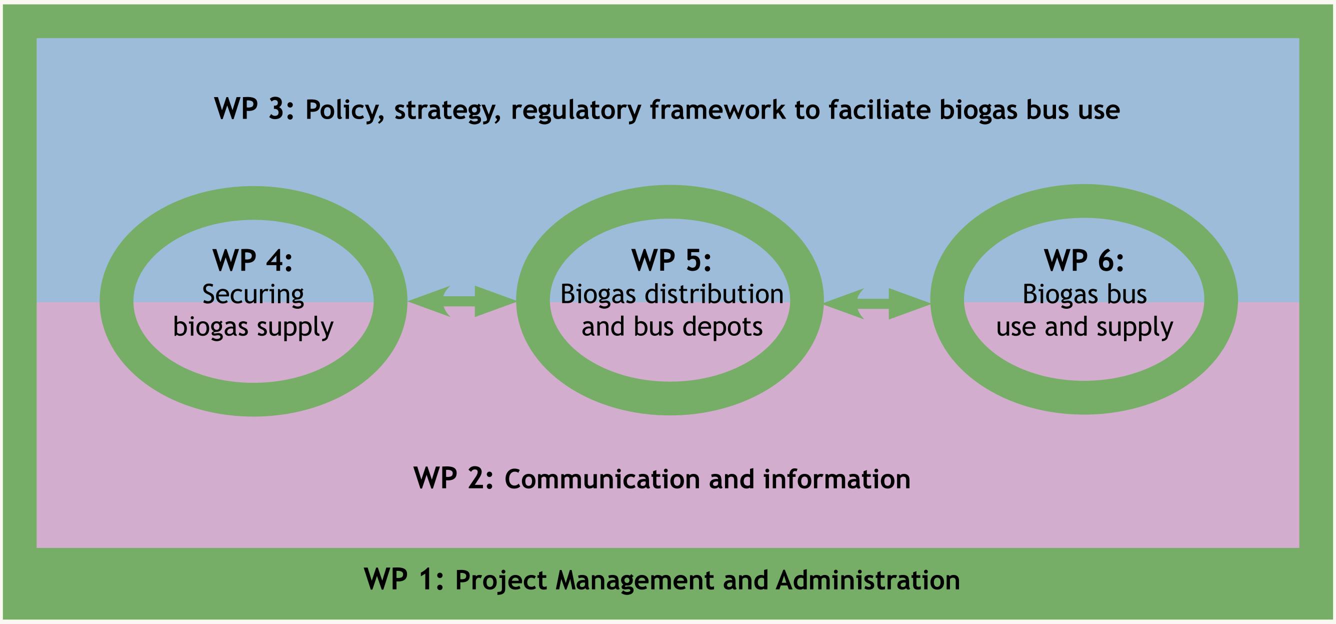
“Considering our resources of oil and natural gas, investing in biogas is not the most obvious choice in Norway. However, both Bergen and Oslo understand the environmental benefits of this eco-fuel.”

Stein Bjørlykke, HOG Energi, Bergen, Norway.

Focusing on the biogas value chain - production, distribution and use of biogas

The Baltic Biogas Bus project is organized in six Work Packages (WP) that cover the biogas value chain – from introduction strategies to supply, distribution and use.

WP 3-6 have produced several written reports. The following pages constitute a short description of each report and the major conclusions. Final versions of all reports can be found at *www.balticbiogasbus.eu*



The Baltic Biogas Bus project — and its six Work Packages, WP — covers the biogas value chain.

Strategy for implementation of biogas

WORK PACKAGE 3

Within WP 3 issues that involve strategies, policies, financing and regulatory framework are handled. This entails providing tools to help cities formulate biogas bus introduction strategies. An important part of the work package has been to collect information from lessons learnt regarding using biogas as transport fuel. This resulted in a manual, which can be used as a step by step guide by cities who wish to start using biogas in their public transport system. Tasks within the work package have also consisted of some of the partners getting directly involved in supporting cities and regions in the transformation from traditional fuels to biogas use in public transport. In these cases, partners have worked as advisors and experts. Additionally, overall costs of biogas compared to other transport fuels have been analysed in order to provide stakeholders with solid financial and economical data when considering introduction of biogas as transport fuel.

WP 3 COORDINATION AND CONTACT

Mona Arnold, VTT Technical Research Centre of Finland: *mona.arnold@vtt.fi*

3.1: MANUAL FOR STRATEGY, POLICY AND ACTION PLAN ON "HOW TO INTRODUCE BIOGAS BUSES" IN PUBLIC TRANSPORT

The report presents strategies how to implement biogas as fuel for public transport and draws on existing good examples of the use of biogas buses. Different environmental, political and economic factors which are transforming the public transport sector from being based on fossil fuels to one being based on renewable fuels are analysed. Climate change, peak oil, security of energy supply, air quality, increased need for transportation and increasing congestion in cities are recognized as the most important drivers for change. Other factors, such as regional infrastructure development, employment opportunities and sustainable waste management are considered as added values.

Factors hindering the development of biogas bus projects are described and strategies to be implemented regionally, nationally and internationally in order to promote such projects are described as a stepwise action plan.

Conclusions and recommendations

The economic role played by fossil fuels is a decisive factor for the shaping of future public transport, but especially climate change and other environmental considerations have nurtured renewable energies. Nowadays, renewable energies are often manifested in strategies and political targets at national level.

For a biogas bus project to be successful, generally it is recommended that the best available technology of today is to be used, do not wait for a perfect solution. Furthermore long term contracts between user and supplier have to be established in order for the necessary investments to take place. Finally, it is important to set ambitious goals and to increase the knowledge of the benefits of using biogas as transport fuel. Apart from these general recommendations, the report also describes more specific recommendations for successful biogas bus projects.

Responsible partner: Stockholm Public Transport. www.sl.se

3.2: TARTU CITY TRANSPORT PLAN 2012-2020, INCLUDING STRATEGY AND POLICY PROPOSITIONS TO INCLUDE BIOGAS BUSES

The report presents the activities and decisions taken in the process of implementing strategies to introduce biogas in Tartu City public transport. It provides a practical example of how to work with the strategies and guidelines set out in report 3.1. Tartu City has, within its long term traffic plan 2012-2020, developed a strategy to implement biogas buses.

Conclusions and recommendations

The report shows how the manual can be implemented successfully. The city of Tartu has ratified the traffic plan, which includes the introduction of biogas buses.

Responsible partner: Tartu Linnavalitsus, Tartu City Local government. www.tartu.ee

3.3: SUPPORT CITIES IN POLAND TO SET UP A STRATEGY FOR THE INTRODUCTION OF BIOGAS BUSES

The Motor Transport Institute of Poland, MTI, has supported the cities of Rzeszów, Warsaw and Walbrzych to set up strategies for introduction of biogas buses in public transport. The steps taken in developing these strategies are documented in the report. The steps include; support and technical advice on the development strategy for the use of biogas, investigations of the availability of biogas and the distribution options of biogas to selected bus depots. Analysis of economics and technical viability of the project is also presented.

Conclusions and recommendations

The report includes the processes of identifying stakeholders in public transport and bus fleets, the preparation of adequate information, the work informing stakeholders at seminars and individually on the usage of biogas for transport applications.

Responsible partner: Motor Transport Institute. www.its.waw.pl

3.4: SUPPORT CITIES IN MECKLENBURG-VORPOMMERN IN GERMANY TO SET UP A STRATEGY FOR THE INTRODUCTION OF BIOGAS BUSES

ATI has approached and assisted cities and regions in Mecklenburg-Vorpommern to include biogas buses in their transport plans. Although the production of biogas is high and growing, the introduction of biogas use for buses has not yet taken off in Mecklenburg-Vorpommern. Currently the use of biogas as fuel is slowly starting in Germany.

Conclusions and recommendations

The public transport companies of the City of Wismar, the county of Nordwestmecklenburg and the Isle of Rügen were identified for a possible introduction of biomethane buses. With support from ATI erc gGmbH and the BBB project the first biomethane pilot bus will run in Grevesmühlen, county of Nordwestmecklenburg. Also in Wismar 8 gas buses will be fuelled by 2013 with 100 % biomethane from the green gas grid.
It is shown that pilot demonstration projects are needed to get started and to show the benefits of using biogas as transport fuel.

Responsible partner: ATI erc gGmbH. www.ati-erc.de

3.6: LIFE CYCLE COST ANALYSES TO OBJECTIVELY LIST POSITIVE AND NEGATIVE ASPECTS OF BIOGAS BUSES

A Life Cycle Cost Analysis (LCCA) has been produced, showing the positive and negative economic aspects of biogas buses compared with other options. This is meant to serve as a base when deciding on whether to implement biogas in public transport. The LCCA includes specific data for electricity, gas, and diesel transportation, as well as data on existing biowaste management systems from different regions. The analysis is made in a well to wheel perspective, including costs related to biogas production, distribution, vehicle technology, bus depots and maintenance. The report also discusses political and socio-economic benefits of energy supply security and fossil fuel independence.

Conclusions and recommendations

The LCCA gives valuable support for assessing the need for investments in biogas production, infrastructure and buses. It is shown that the possible financial gains compared to using biogas for other purposes to a high degree depend on local circumstances, such as local potential supply and demand as well as already existing infrastructure. However, using biogas instead of other transport fuels, provides important socioeconomic gains that are more difficult to quantify, especially improved air quality.

Responsible partner: VTT Technical Research Centre of Finland. www.vtt.fi

3.7: COMPARATIVE ANALYSES OF THE IMPACT OF DIFFERENCES IN REGULATIONS AND TAXATIONS ON BIOGAS AND BIOGAS BUSES

The report investigates how political decisions affect the usage of biogas in the Baltic Sea region. The impact of measures taken in different countries towards renewable fuels in general, and biogas in buses in particular, is analysed. The importance of long term planning and the regulatory framework including tax regulations/exemptions, subsidies etc is discussed.

Conclusions and recommendations

The report shows the importance of long term political will at local and national levels to set up a system using biogas as transport fuel. Long term sustainable environmental goals are of utmost importance. Without long term planning, including the establishment of contracts between users and suppliers, the necessary upfront investments are unlikely to take place.

Responsible partner: HOG Energi. www.holga.no

Supply of biogas

WORK PACKAGE 4

Within WP 4 studies on biogas production technologies and evaluations of the potential for biogas production are conducted. It is necessary to estimate and secure supply of biogas in the region, otherwise local transport companies are not likely to make investments. Apart from traditional sources to produce biogas (waste from landfills and sludge from wastewater treatment plants), other possibilities are also examined to meet the increasing demand in the region. Production potential is examined at national levels, but since distribution costs of biogas can be quite high, more in-depth studies of certain local settings are also conducted. Providing this kind of information to decision makers makes the shift to biogas from more common transport fuels more likely. Several of the tasks focus on lessons learnt and technical improvements when producing biogas in order to improve efficiency.

WP 4 COORDINATION AND CONTACT

Steffi Groth, ATI erc gGmbH: *groth@ati-erc.de*

4.1: THE "BALTIC BIOGAS FORESIGHT": DESK STUDY ON WIDER RANGE OF BIOGAS PRODUCTION OPTIONS AND EXPERIENCES INCLUDING PRODUCTION POTENTIAL SCENARIOS FOR BALTIC SEA REGION

The report gives an overview of the theoretical supply of biogas in the Baltic Sea region. Traditionally, biogas is produced from wastewater treatment plants and landfills, since investment costs in these sectors are relatively low, but other sources are also available for biogas production. Experiences on different technologies and the related quantities of raw material for those technologies are discussed.

Conclusions and recommendations

The potential is often more than ten times as high as actual production in many countries. The study shows that the largest unrealised potential exists within the agricultural sector. However, there is a gap between theoretical and practical potential, whereas the latter to a high extent is defined by investment costs, property rights, regional demand, existing distribution infrastructure and the regulatory framework.

Responsible partner: Motor Transport Institute. www.its.waw.pl

4.2: BIOGAS PRODUCTION EXPERIENCES AND LESSONS LEARNED

Stockholm Public Transport started introducing biogas buses in 2004. The report summarises the experiences, lessons learnt and best practices concerning initiating production and use of biogas in public transport. The report describes several different biogas production alternatives, as well as gas collection and upgrading technologies used by Stockholm Public Transport throughout the years.

Conclusions and recommendations

Essential key success factors related to biogas production and upgrading have been identified through the experiences of Stockholm and other Swedish and European cities. The long term commitment from involved parties such as authorities and involved individuals as well as agreements between producer and user, are key factors for success. To make solid predictions of future biogas use, the involvement of both producers and users is important.

Responsible partner: Stockholm Public Transport. www.sl.se

4.3: PRODUCING BIOGAS VIA GASIFICATION FROM ALL TYPES OF SOURCES

Traditionally, biogas is produced from sludge at waste water treatment plants and at landfills. An alternative promising technology is biomass gasification. Pilot plants have shown good results and commercial scale plants are currently being constructed. The report analyses the potential to produce biogas both from wet organic compounds and from gasification of wood and also gives an overview of existing, planned and possible biogas production plants and methods in Norway. Existing infrastructure for natural gas buses is also presented.

Conclusions and recommendations

The potential of producing biogas from biomass gasification looks promising, but more research is needed in this field.

Responsible partner: HOG Energi. www.holga.no

4.4: ANALYSIS OF DIFFERENT PRODUCTION PROCESSES, WHICH PRODUCE BIOGAS WITH A HIGHER AMOUNT OF HYDROGEN

The usage of Hydrogen/CNG/CBG blends could bridge the gap between conventional fossil fuels and the clean future of using hydrogen as fuel. Therefore, the report discusses alternative biogas production processes, especially that of hythane, which is a mixture of 80% biogas (methane) and 20% hydrogen. Tests have demonstrated that adding a small percentage of hydrogen to biogas can improve the performance of biogas vehicles in certain ways and lower fuel costs in comparison to pure hydrogen. In the second part of the report, experiences of buses running on CNG/Biomethane, HCNG and hydrogen (both fuel cell and internal combustion engine buses) are evaluated.

Conclusions and recommendations

To produce hydrogen from a state of the art anaerobic digester, producing biogas, the best technology is the well-known steam-reforming process. Hydrogen and hythane are still being developed as transport fuels and are not yet in commercial use. Buses running on pure hydrogen (both ICE and fuel cell) are still very expensive, mainly due to the lack of economy of scale. HCNG is often seen as an effective bridge into an emission-free hydrogen economy. Tests show that especially NOx emissions, but also particulates and hydrocarbons, can be lowered by using hythane instead of biogas. However, this comes at the expense of lower energy efficiency. Probably cities with severe air pollution would be most suitable for hythane buses.

Responsible partner: ATI erc gGmbH. www.ati-erc.de

4.5: ASSESS POSSIBILITIES AND BENEFITS OF MIXTURE OF BIOGAS AND HYDROGEN TO REACH OPTIMAL BALANCE BETWEEN ENGINE EFFICIENCY, PRODUCTION AND DISTRIBUTION COSTS

Using hythane as transport fuel has been shown to have a positive effect on emissions. However, an inappropriate blend can lead to considerably lower energy efficiency and also spark failure. Additionally, too much hydrogen will lead to an increase in volume, further lowering the efficiency of the fuel. The report discusses the technically and economically optimal blend of hydrogen and biogas for use as transport fuel in buses.

Conclusions and recommendations

Higher hydrogen percentage in hythane results in increased volume and higher energy content. The technological development to raise the energy content in gas fuel is promising, but further investigation is needed.

Responsible partner: ATI erc gGmbH. www.ati-erc.de

4.6: REGIONAL SWEDISH BIOGAS PRODUCTION GROWTH SCENARIOS, HOW TO CONVINCE NEW PRODUCERS AND GUIDE THE IMPLEMENTATION

This report assesses the production potential for biogas in the Stockholm region. Data has been compiled from several other reports and studies concerning production from different substrates. A number of prerequisites affecting the expansion of biogas production in Sweden and the defined area are also discussed. Among the drivers for biogas production are national environmental targets and future plans of local public transport companies. The report was further expanded to include and analyse the potential for production of biogas from food waste disporators, the amount and major reasons for methane loss in a well to wheel perspective and the direct potential for Stockholm Public Transport to use biogas as fuel for buses in public transport. Additionally, a framework to benchmark sustainability of biome- thane supply chains is described.

Conclusions and recommendations

The study concludes that the production potential of the studied area is estimated at almost 30 times the current production. The largest potential stems from gasification of forestry raw materials. Important potential is also found in residual agricultural products, pastoral crops and manure, whereas the current largest source of biogas production, sewage sludge, has the smallest potential. Today, not all of the raw gas is upgraded to vehicle gas. It is recommended that a larger proportion be upgraded.

Responsible partner: Stockholm Public Transport. www.sl.se

4.7: BIOGAS RAW MATERIALS MAPPING FOR TARTU CITY AND REGION AND BUSINESS PLAN FOR PRODUCTION PLANT

The report describes the inventory of potential biogas sources (waste water treatment plant; land fill; food industry; slaughterhouses; agriculture; etc) in Tartu City and the surrounding region. This mapping is part of the base for making the strategy to introduce biogas buses. Depending on where potential substrates are located, the most optimal location for a first biogas production plant will be chosen.

Conclusions and recommendations

The report shows the process of biogas raw materials mapping for Tartu city and the region and describes the business plan for a production plant. There are several potential sources for production of biogas and the potential is quite high and predicted to rise. However, issues like transportation costs and the type of substrate to be transported as well as possible future competition for some of the substrates complicates the analysis. The Tartu City feasibility study can serve as a good example for other cities and regions planning to take similar steps introducing biogas in public transport.

Responsible partner: Tartu Linnavalitsus, Tartu City Local government. www.tartu.ee

4.8: FEASIBILITY STUDY TO PRODUCE BIOGAS FROM A NUMBER OF FOOD PRODUCTION WASTES IN ROSTOCK AREA

The report investigates the possibility and potential to use food wastes for biogas production. Currently, most biogas is produced from landfills, sewage sludge and agriculture byproducts, whereas waste from the production of food and fish is often discarded. The study focuses on the Rostock area. Analyses are carried out regarding; available volume of food wastes, normal composition of the content of and available technology for biogas production of such heterogeneous wastes.

Conclusions and recommendations

Especially in big cities, there is a huge potential of using wastes from food production and kitchen slops. Only in Germany, the potential is equivalent to about 7 billion m3 biogas (app. 70% methane content). Hazardous wastes can constitute a problem and has to be taken into account when constructing production and upgrading facilities.

In Rostock food waste from private households and leftovers from beer production make up the biggest share of the theoretical biogas potential. To transform theoretical into practical potential, the legal framework in Germany should include more incentives for using waste products for energy and fuel production.

Responsible partner: ATI erc gGmbH. www.ati-erc.de

Distribution of biogas

WORK PACKAGE 5

Within WP 5, alternative fueling systems, infrastructure planning, logistics and related topics are handled. This includes comparing different ways of distributing biogas taking into account economical and environmental factors. Also conversion of depots for biogas use as well as planning and construction of pipelines for biogas distribution are outcomes of WP 5. Comparisons of different fuelling systems have been made using experience from Stockholm Public Transport. These experiences and literature studies have been used by cities in the process of implementing biogas systems in public transport with the help of project partners. The comparison of other parts of the distribution network builds to a large extent on studies carried out by HOG Energi as well as lessons learnt of other partners.

WP 5 COORDINATION AND CONTACT

Stein Bjørlykke, HOG Energy: *stein@holga.no*

5.1: INTEGRATED REGIONAL DISTRIBUTION INFRASTRUCTURE PLANNING

The report provides an introduction of available biogas distribution systems and discusses different options on how to implement a functional biogas distribution infrastructure for effective and sustainable biogas supply to bus fleets. The report draws on the experiences gained at Stockholm Public Transport. The involvement and securing of contacts with necessary stakeholders, evaluations, design and construction of the necessary distribution systems, and the future plans for the Stockholm region are all described. Based on technical and economical comparisons, the study analyses when to use different options for distribution: via pipeline network, compressed gas in bottles or liquefied gas distribution.

Conclusions and recommendations

A continuous dialogue, established at an early stage with stakeholders combined with the setting up of long-term contracts to secure biogas supply is key to secure the success of a distribution system. Thorough evaluation of existing pipelines and other possible infrastructure solutions can help lower investment costs. 4 bar pipelines is the most commonly used distribution system in Stockholm. A higher pressure in the system results in higher demands on safety which affects the costs and time for construction completion.

Responsible partner: Stockholm Public Transport. www.sl.se

5.2: ANALYSE FUELLING SYSTEM ALTERNATIVES

The report compares different fuelling system alternatives, including biogas, natural gas and hydrogen gas. The analysis is mainly based on knowledge and experiences from Stockholm Public Transport. Slow and fast fuelling alternatives for the different fuels have been compared as regards to costs, safety, fuelling time and environmental aspects. The experience gives important input in design of new biogas bus depots when bus logistics and land use planning are discussed.

Conclusions and recommendations

From a cost perspective, there is little difference between fast and slow fuelling. The former requires more staff, whereas the latter shows higher investment costs. Regarding security and work environment, slow fuelling is less stressful and provokes fewer errors committed by fuelling staff.

Responsible partner: Stockholm Public Transport. www.sl.se

5.3: DESIGN FOR NEW BUS DEPOTS AND ADAPT EXISTING DEPOTS FOR BIOGAS BUSES AND HYBRIDS

The report describes the process used to evaluate depots in regards to whether they are suitable for biogas use or not. Differences between design of new depots and adapting existing depots are discussed and the concept of a mobile modular fuelling station is described.

Conclusions and recommendations

Lessons learnt from different depots in Stockholm are described and can serve as useful information for cities starting to use biogas as transport fuel.

Responsible partner: Stockholm Public Transport. www.sl.se

5.4: BIOGAS TRANSPORT AND DISTRIBUTION - "EVALUATION OF ALTERNATIVES AND COST EFFICIENCY"

The report maps the most cost efficient way to transport natural gas/biogas from the production plant to filling stations. Three alternative ways of transportation are compared and discussed; compressed biogas (CBG) in steel and composite containers, liquefied biogas (LBG) and transportation through pipeline. These alternatives are compared using two different scenarios of distance to be transported and amount of buses to be supplied with biogas.

Conclusions and recommendations

When transporting long distances in bulk, LBG is the most feasible option. However, depending on the distance to be transported and how much biogas is to be supplied, different options will be preferred. For CBG, steel vessels are competitive for short distance and limited amounts. Otherwise, composite vessels are the preferred option.

Piping of biogas requires heavy investments, which can be feasible if the number of buses to be supplied is large enough. However, the cost of liquefaction, upgrading and compression will influence severely on transportation costs. Since technologies are quickly developing, new membrane techniques and upgrading through liquefaction has to be considered when designing new infrastructure for biogas transport.

Responsible partner: HOG Energi. www.holga.no

5.5: ANALYSIS THE SPECIFICATION FOR AND LOGISTICS OF USING BIOGAS CARTRIDGES SYSTEMS

High pressure cartridges have become an accepted flexible modular solution for transportation of biogas. The report analyses the specification for and logistics of using a biogas cartridge system. The system is examined from several viewpoints, including cost, distribution and security aspects.

Conclusions and recommendations

From a technological point of view the removable storage system is feasible in different ways. Most certainly, the safety regulations, standards and guidelines to be fulfilled pose the biggest obstacle for the implementation of an exchangeable storage system. Principally, exchangeable storage systems have not been considered in the ECE guideline.

The potential for using high pressure cartridges is promising, but more research is needed to evaluate the safety requirements and the performance of such a system.

Responsible partner: ATI erc gGmbH. www.ati-erc.de

5.6: BALTIC SEA REGION BIOGAS INFRASTRUCTURE OVERVIEW EXISTING AND PLANNED

The existing biogas infrastructure in different parts of the Baltic Sea Region varies substantially because of historical, political and geographical differences. The report gives an overview of the current (bio)gas infrastructure of the region.

Conclusions and recommendations

In many parts of the Baltic Sea Region there is already a gas grid for natural gas, which provides the possibility to distribute biogas at a low cost.

Responsible partner: Motor Transport Institute. www.its.waw.pl

5.7: FEASIBILITY STUDY ON EXPANDING FUELLING STATION WITH BIOGAS SUPPLY AND ADAPTING BUS DEPOT FOR BIOGAS IN TARTU

The study assesses the profitability of a compressed natural gas filling station in Tartu City, which will serve gas buses for Tartu City urban routes. The profitability of fast and slow fuelling systems was compared. Currently, there is no competition in the field of gas fuelling stations but there is also a limited client base. The environmental benefits and the relatively low price of gas provides a promising future for gas as engine fuel. The environmental benefits of investing in a gas fuelling station are also discussed.

Conclusions and recommendations

The profitability calculation shows an almost equal operating cost of the different systems. The net present value of investing in both types of fuelling stations are positive, but a fast fuelling station is more profitable, since its sales predictions are higher. Higher sales revenues will cover the higher investments and slightly higher operating costs.

The profitability calculations of the bus depot demonstrate that establishment of the bus depot is feasible in Estonian conditions (there is no big and significant difference between a regular diesel bus depot and a gas bus depot in Estonian legislation) and the payback period for the depot is 13 years.

Responsible partner: Tartu Linnavalitsus, Tartu City Local government. www.tartu.ee

Tartu city of good thoughts

5.8: FEASIBILITY STUDY FOR NEW PILOT BIOGAS FUELLING STATION IN POLISH CITY RZESZÓW

The study assesses the feasibility of establishing the first biogas fuelling station in Poland. A cost benefit analysis is carried out, not only including the cost of establishing the fuelling station, but also taking into account purchase and maintenance costs for biogas buses compared to diesel buses.

Conclusions and recommendations

From a financial aspect, biogas buses can not compete with diesel buses in Poland currently. To a large extent, this depends on the high depreciation rate and maintenance costs for biogas buses. However, with improving technologies and higher demand, these costs are predicted to decrease. On top of this, environmental benefits of using biogas buses are well documented, which increases the probability that the use of biogas buses will soon take off in Poland.

Responsible partner: Motor Transport Institute. www.its.waw.pl

Use of biogas

WORK PACKAGE 6

WP 6 concerns operational experiences from biogas bus use, evaluation of technological development and verification of biogas emissions. Consisting of many partners with experience of using biogas buses, the Baltic Biogas Bus project has the possibility to specify requirements for producers in order for them to meet high expectations and fruitful cooperation with the leading European biogas bus producers.
Both laboratory and direct measurements of emissions and energy efficiency of biogas buses have been carried out. Emission measurements provide clear evidence of the positive environmental benefits of using biogas as transport fuel. Furthermore, the technological development among producers and improved knowledge among end users show that the cost of using biogas buses is now at par with conventional diesel buses.

WP 6 COORDINATION AND CONTACT

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6.1: GAS BUS TECHNOLOGY AND OPERATIONAL EXPERIENCES IN HELSINKI AREA

Operational experiences from Helsinki and other regions featuring biogas buses have been collected. These experiences have been compared with other fuels e.g. ethanol and diesel. Environmental benefits of biogas bus engines compared to diesel or ethanol are well documented, but energy efficiency is lower. Dual fuel engines using gas as the main fuel increase the efficiency, but typical transient city bus cycles with low average load are challenging applications for dual fuel engines.

Conclusions and recommendations

Gas buses show good emission stability over time, especially for particulates. The best diesel buses are rather clean when new, but emission levels tends to increase over time. The relatively low energy efficiency of biogas buses can be compensated by low fuel price, but in the long run high energy efficiency must be targeted when developing future generation gas engines. Most probably some increase in energy efficiency can be achieved by optimizing/modifying the spark ignited engines, but dual-fuel engines with gas as main fuel would im- prove energy efficiency significantly.

Responsible partner: VTT Technical Research Centre of Finland. www.vtt.fi

6.2: BIOGAS BUS USE AND OPERATIONAL EXPERIENCE

The report describes the operational experiences of biogas bus use in Stockholm since the introduction in 2004. Specific problems, and how they have been dealt with, regarding bus maintenance, fuelling techniques and gas quality are described. Furthermore, future possibilities and obstacles for use of biogas in the region are outlined.

Conclusions and recommendations

The report shows how the performance of buses combined with the improved knowledge among operating personnel have made bus use more efficient.

Responsible partner: Stockholm Public Transport. www.sl.se

6.3: INVESTIGATE STANDARDS OF A HIGH PRESSURE VESSEL FOR BIOGAS IN BUSES

The study describes the pressure vessels in natural gas vehicles. The report assesses what size and pressure range of vessels are feasible. It further describes German safety regulations regarding high pressure vessels.

Conclusions and recommendations

The very small difference in chemical composition between CNG and biomethane has no impact for the requirements of high pressure vessels. Hence biomethane can be used in CNG vehicles and infrastructure. Furthermore, the pressure range of gas storage devices for CNG/ biomethane can be set to 200 – 250 bar.

Responsible partner: ATI erc gGmbH. www.ati-erc.de

6.4: INVESTIGATION OF THE USAGE OF SOLID OXIDE FUEL CELLS (SOFC) IN BIOGAS BUSES

Development of solid oxide fuel cells has made promising progress lately and can form a bridge between combustion and electric engines. Fuel cells operating on hydrogen have been seen as a possible replacement for internal combustion engines in the long run. However, new technology can replace the generator coupled to the vehicle's engine to produce electricity using e.g. biogas. The report analyses the usability of SOFC fuel cells for Auxiliary Power Units (APU) operated with biogas. The report specifically addresses what engine-power class is needed for bus operation, what quality of biogas is necessary and the economic considerations when using SOFC.

Conclusions and recommendations

SOFC show a very high efficiency, but none using biogas is yet commercially viable. For operation of the SOFC, raw biogas as well as biomethane can be used. Current SOFC APUs do not meet targets set by vehicle manufacturers, but requirements on buses are lower than for passenger cars and can form a first market segment for the new technology. It is estimated that the new technology could be used for biogas buses within the next 2 to 5 years. Further research for using biogas for fuel cell operation in vehicles is recommended.

Responsible partner: ATI erc gGmbH. www.ati-erc.de

6.5: CHASSIS DYNAMOMETER MEASUREMENT

The report investigates advantages of biogas buses in cities regarding emissions and energy consumption through direct laboratory measurements. Four buses were used in the tests; one modern diesel bus, two CNG buses and one ethanol bus with diesel combustion. The measurements included regulated emission components and fuel consumption. Three different duty cycles were used; the European Braunschweig cycle, a corresponding city centre cycle from Helsinki and a suburban cycle from the Helsinki area.

Conclusions and recommendations

Comparing the different cycles, it is clear that higher average speed reduces overall emissions. The CNG buses generally emitted more total hydrocarbons than the other buses in inner city cycles, mainly because combustion of methane is limited at low temperatures. However, for particulates, CNG buses showed significantly lower emissions than the other buses.

Responsible partner: VTT Technical Research Centre of Finland. www.vtt.fi

6.6: EMISSION MEASUREMENT OF RETROFITTED BIOGAS BUSES IN REAL ROAD CONDITIONS

The study reports on emission measurements carried out in real road conditions in Poland. Measurements were carried out both on CNG buses as well as diesel buses in inner city traffic. Particulates, NOx, hydrocarbons (CO_2 and CH_4) and energy efficiency were measured.

Conclusions and recommendations

Particulate emissions are lower with methane buses compared to diesel buses regardless of the test cycle. The combustion technology of methane engine has a significant effect on NOx emissions; stoichiometric combustion and 3-way catalyst are favourable to NOx. Green house gas emissions (CO_2 & CH_4) of methane buses are quite the same compared to diesel buses. Energy consumption of methane buses is higher in comparison with diesel buses.

Responsible partner: Motor Transport Institute. www.its.waw.pl

6.7: TECHNICAL REQUIREMENTS FOR A BIOGAS-FUELLED BUS DESIGN

The report gives an overview of procurement requirement specifications for biogas buses and is meant as information for institutions with interest in, but limited experience of, biogas buses. The report covers different engine types, CNG system, transmission, chassis and gas quality requirements.

Conclusions and recommendations

Individual bus procurers have good opportunities to influence producers, since volumes are still limited.
With more investments in biogas buses, the performance is likely to rise.

Responsible partner: HOG Energi. www.holga.no

6.8: FEASIBILITY STUDY TO INTRODUCE BIOGAS BUSES IN TARTU, ESTONIA

The report assesses the feasibility of introducing biogas buses in Tartu, Estonia. The study addresses overall economic feasibility, including purchase costs, depreciation and maintenance, as well as regulations of pollutant emissions. The report also describes the process of involving political decision makers and local bus companies.

Conclusions and recommendations

The biogas production potential in Tartu is promising and biogas buses have been included as an important part of the new traffic plan.

Responsible partner: Tartu Linnavalitsus, Tartu City Local government. www.tartu.ee

6.9: FEASIBILITY STUDY OF INTRODUCING BIOGAS BUSES IN RZESZÓW, POLAND

The report assesses the feasibility of introducing biogas buses in Rzeszow, Poland. The action has been discussed with the political decision makers in the city and bus companies that can introduce biogas in city buses.

Conclusions and recommendations

Important first steps have been taken to facilitate the introduction of biogas buses in Rzeszow have been taken, but more investigation on the economic side is required.

Responsible partner: Motor Transport Institute. www.its.waw.pl

WEBSITES

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Baltic Biogas Bus

Sharing our success and lessons learned 2009-2012

On the road to climate-neutral public transport

- Biogas is almost 100 per cent renewable
- Biogas is very efficient as fuel
- Biogas improves urban air quality and climate
- Biogas produced locally improves energy autonomy and creates jobs