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Co-evolution in the Process of Establishing Liquefied Methane as Truck Fuel

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Master of Science in Environmental Management and Economics
Master Degree Project No. 2011:38
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Acknowledgements

This thesis was written in the spring semester 2011 at School of Business, Economics and Law/ University of Gothenburg as part of the Master programme of Environmental Management and Economics.

The project was accomplished in co-operation with the environmental consulting company Ecoplan in Gothenburg and the Swedish Transport Administration Trafikverket.

I want to thank all people who were involved in this project but specially Staffan Johannesson and the whole team of Ecoplan who supported me throughout the thesis work. Furthermore, I appreciate the constructive advice of Anders Sandoff that was an essential part of this project and which helped to develop thoughts and theories.

A project can only be processed with many ambitious people working hand in hand to achieve goals. I am thankful that I was surrounded not just by single people but by a team. The result of this thesis shows, that co-operation and collaboration can lead us far – sustainability always in mind.

Markus Sporer

Göteborg, May 20th, 2011

Abstract

Sustainable transportation is one of the topics to be discussed in order to reduce the CO^2 production and to create a better natural environment. While a range of alternative fuels and engines for private cars are already available for customers, competitive alternatives to fossil diesel as truck fuel are yet to be established on the market.

In this study the new methane diesel technology developed by the Volvo group is used as an example to describe the process of establishing liquefied methane as an alternative to fossil diesel. The focus though is set on the co-evolutionary development of the different actors that were part of the process. Without a simultaneous development of truck manufacturer, gas suppliers, transport buyers and public institutions the technology could not have been launched.

To make this clear, a comparison of the Swedish market conditions for liquefied methane and the situation in Germany, where no co-evolutional process took place, is presented. The use of a theory which has its roots in biological sciences allows understanding essential relationships in the organizational context and helps to recognize the necessity of simultaneous development of different actors.

This study though shows that the current conditions are not yet optimal to run trucks on liquefied methane due to insufficient infrastructure and the lack of political will and actions plans outside Sweden.

Key words: co-evolution, methane diesel technology, liquefied methane, gas infrastructure, truck fuel, long-haul transportation

Contents

I. Directory of figures

II. Abbreviations

B2B	Business to Business
B2C	Business to Consumer
BIEK	Bundesverband Internationaler Express-und Kurrierdienste e.V./ Association of International Express- and Deliveryservices
BMWi	Bundesministerium für Wirtschaft und Technologie/ German Governmental Department for Ecomony and Technology
BRG	Business Region Göteborg
CNG	Compressed Natural Gas
Dena	Deutsche Energie Agentur/ German Energy Agency
DNA	Deoxyribonucleic acid
DSLV	Deutscher Speditions- und Logistikerverband e.V./ Association of German Freight Forwarders and Logistics Operators
EEG	Erneuerbare Energien Gesetz/ Renewable Energy Sources Act
FNR	Fachagentur Nachwachsende Rohstoffe/ Agency for renewable resources
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
R&D costs	Research and development costs
UN	United Nations
VDIK	Verband der internationalen Kraftfahrzeughersteller/ Association of International Motor Vehicle Manufacturers

1. Introduction

Sustainable development in the transport sector affords the cooperation of many actors. The process of simultaneous development might be the key to establish solutions to make long distance on road transport less dependent on fossil diesel and therefore more environmental friendly. Fuel is a major topic within the global transport sector. Private car users as well as business are interested in reducing the costs for fuel. Another important goal for many actors is the reduction of the CO^2 production that is at its peak by driving on fossil fuels.

As for small and medium vehicles, many alternatives are already available on the market or will be in the near future, but there are close to zero alternatives to fossil diesel for heavy trucks available. Transportation with heavy trucks is completely dependent on fossil diesel and is therefore highly influenced by the rising oil price. New engines that work with liquefied methane like the combined methane-diesel engine of Volvo can be part of getting more independent and creating new possibilities of heavy good transportation on the road. A lack of infrastructure for liquefied methane and limited experience with the new engines make many potential customers skeptical concerning those developments.
Volvo therefore started a process of information and co-operation with several partners to develop the infrastructure for liquefied methane in Sweden. Gas producers, infrastructure builders, transport buyers as well as national states are important stakeholders in this development. Investments from all actors are needed to develop and apply such new technologies. No single actor will go that way without other institutions and organizations following. The actors in Sweden, namely Volvo, Fordonsgas, EON, AGA, Renova, DHL, Götene Kyltransporter and the responsible governmental institutions managed to establish conditions that made it possible for all involved actors to push the development towards the use of liquefied methane as truck fuel forward. Communication between the actors played a decisive role in this process but the general search for a competitive advantage using the means of sustainability, might be the main driver of the constant collaboration between the actors of different business fields.

The concept of organizational co-evolution can help to understand the relationship between different actors developing a market or an industry and it can lead to possible paths for the future. Established in biological sciences by Ehrlich & Raven (1964) as "interspecific combinations of organisms evolved in part response to one another" this theory is successfully used in a socioeconomic context since the 1990's (Norgaard, 1994). The fact, that organizations change in relation to their environment is already recognized (Porter, 2006) but how each other's development influences the development of new more sustainable technologies remains to be explored. The constellation around the new methane diesel technology provides a suitable framework to study the co-evolutional relationship within the liquefied gas sector. No actor can push the development of sustainable road transport forward without evolutional reactions of the others.

Co-evolutionary theory in an organizational context does not just involve the actors on the company level but also the societal level (Porter, 2006). Society is a main driver towards sustainable processes and mechanism. Politics have to respond to this strong request and therefore legislation concerning governmental support and subsidies for new technologies will be analyzed. Moreover politics has also a duty to inform the public and possible actors of a co-evolutional process. Possibilities and opportunities have to be presented and political sub-institutions should take a lead in organizing development processes. In the present case Business Region Göteborg will be presented as such a supportive institution.
Last but not least, political institutions have to take the lead and practice a good example when it comes to more efficient engines and sustainable mobility. Car fleets owned and used by municipalities should therefore be the first to run on environmental friendly types of fuel. Earlier studies concerning strategies towards sustainable systems show, that "sustainability involves structural changes over longer periods of time, and requires co-evolutionary changes in technology, economy, culture and organizational forms" (Loorbach et al., 2009).

A project about sustainable long-haul goods transportation can - from a geographical point of view - not be limited to Sweden but has to include important markets like for instance Germany. This study is therefore part of a greater project called Scandria, including nineteen participating organizations and institutions from Scandinavia and Germany. The goal is to create visions for a sustainable transport corridor. The solution of using liquefied methane as truck fuel is just one of several suggestions to reach that goal, but has great potential to contribute to a sustainable development within the transport sector. The Scandria project is funded by the Baltic Sea Region Programme of the European Union which shows the interest in the solutions found by the project, not just on a local but on a European scale.

The governmental situation concerning sustainable goods transportation and the planned infrastructure may vary between countries but they have to be included and have to be seen as an additional decisive factor in the co-evolutionary process around the liquefied methane development. Moreover, it is of great interest to study if organizational co-evolutionary developments can encroach upon other countries which are also striving towards an environmental friendly transportation sector. Current socioeconomic research has not dealt with this issue yet, whereas similar evolutional developments in different habitats in biological science have already been mentioned by Charles Darwin (1859) in his groundbreaking work "On the Origin of Species".

This particular study offers the possibility to analyze the co-evolutionary situation between the actors involved in the development of a market for liquefied methane as truck fuel for long-haul transportation in Sweden and Germany. To study this central relationship phenomenon the main actors are contacted and the governmental framework for renewable energies is introduced. The concept of co-evolution shall thereby help to understand how the collaboration between the actors worked and to what extend other factors and situations - like the German legislation for renewable energies - can influence the process.

1.1 Research Question

The co-evolutionary concept can be a means to find out about the obstacles as well as the catalysts accompanying the process of implementing liquefied methane profitably in the Swedish market. The focus lies on the early stage of this process which makes Sweden the main research site. The conditions and the background of this topic in combination with the concept of organizational co-evolution lead to the following research question:

How does a co-evolutionary development between business and its environment influence the success of implementing liquefied methane as truck fuel in Sweden?

As the development of the market situation for liquefied methane for long-haul transportation in Sweden is heavily dependent on connections to countries in central Europe which are the main trade partners, the German situation for liquefied methane as truck fuel shall be considered. Due to this constellation the German state becomes an actor in the co-evolutionary process that can be seen in Sweden. A sub-question is therefore:

What influence does the situation in Germany have on a sustainable transport corridor based on liquefied methane between Sweden and Germany?

This question arises also, since this study is written in cooperation with the Swedish Transportation Agency "Trafikverket" which is involved in the Scandria project about a corridor for sustainable transportation between north-eastern Germany and southern Scandinavia. From this project it is known that the development in Germany is strongly influencing transportation progress in Sweden, as both countries are involved in strong and valuable trade connections with each other including large amount of goods exchange on the road.

1.2 Purpose Statement

Studies on the impact of co-evolutionary processes on the development of more environmental friendly fuel technologies like biogas and liquefied methane in general, contribute to understanding the mechanisms which drive sustainable transportation. Additionally, the motivation of the actors and the awareness of each other actor's development can be checked which helps to head for more effective co-operations and collaborations in the field of sustainability.

Analyzing the relationship of the actors of the Swedish market for liquefied methane as truck fuel with help of the theoretical model of organizational co-evolution contributes to two fields of interest. On the one hand, the relatively new theory of organizational co-evolution can be further developed and used in the context of sustainability. To make use of the advantages of such an analysis, it is an important step to transfer the main co-evolutional criteria from the biological sciences to an organizational context, where not just unconscious decisions but also rational models influence the development of strategic decisions. This transfer is part of the present study and explains the mechanisms of how co-evolution can contribute to the success of advanced technology including the co-operation of actors coming from diverse business fields.

On the other hand, the collected data from the situation around the development of liquefied methane as truck fuel in Sweden will contribute to understand the situation and constellations in other markets - like Germany. Co-evolution requires suitable actors who are willing to take risks in order to achieve more sustainable solutions. This study shows in what way the conditions for introducing liquefied gas as fuel in Germany differ from the ones in Sweden and what this means for the future development of truck fuel solutions in Germany as well as in Sweden.

Combined, the theoretical and practical results contribute to a better understanding of co-operations between several organizational and institutional actors and the possibilities that arise in the case of such collaborations. The present example of co-evolution towards sustainability in the transport sector can be seen as a role model for other organizational fields.

2. Background

2.1 Scandria Corridor

Sustainable transportation is a common vision in Europe. The European Union has therefore identified regions where transportation within and between countries play a major role. The Scandria corridor including Scandinavia and Germany is one of them and shall help to identify obstacles and challenges but also advantages and possibilities that the region offers to reach a more sustainable and environmental friendly transport system.

Figure 1. Scandria Corridor

The Scandria project is a cooperation of 19 partners from Scandinavia and Germany which participate in creating an innovative green transport corridor between Scandinavia and the Adriatic Sea with a project focus on Scandinavia and Germany. Sustainable transport is one of the main goals of the project to promote this European core area. Scandria is funded by the Baltic Sea Region Programme of the European Union. (Scandria, 2011). The sister project of Scandria is called SoNorA (South-North-Axis) and completes the Scandinavian-Adriatic Corridor from Germany to the Adriatic Sea.

This project can be seen as the main motivation to learn more about the relationship between the different actors that are currently working on the sustainable transport vision. These actors can be business organizations, national states, national agencies and private organizations. They all play their role in sustainable development of the transport sector.

One of the promising solutions developed and used in this corridor is the Methane-Diesel-Technology of Volvo. It was developed for heavy trucks and can run on diesel and liquefied methane. The possibility to run on liquefied bio methane makes it a promising development towards CO^2-neutral heavy goods on road transportation. Within the Scandria project the Swedish transport agency Trafikverket leads the research on biogas as truck fuel in the corridor. To understand the development of the liquefied methane sector in

Sweden and to figure out why the development is not the same in Germany the concept of organizational co-evolution shall help to analyze the situation.

2.2 Biogas/ Natural Gas

Natural gas is known as one of the most important fossil energy carriers. Consisting mainly of the gas methane, it is used for pure energy production, for heating but also as fuel for cars to a different extend in the several countries. Gas holds 24% of the worldwide energy consumption and is therefore after oil and coal the third most important source for energy production (dena, 2010). The overall natural gas resources are estimated to be 509.000 billion m^3 (dena, 2010). Those numbers are steadily growing as new sources of gas are discovered due to new methods and technologies. It remains though a finite resource and creating less CO^2 during use compared to oil consumption it is still fossil CO^2 that is set free. It is therefore often criticized as not being an environmental friendly alternative to oil. Nevertheless it opens the door for a range of opportunities and new technologies contributing to a more sustainable energy mix.

In the transportation sector several forms of natural gas are used as fuel. Most common are compressed natural gas (CNG) and liquefied natural gas (LNG) which consists mainly of the natural gas methane and is stored at a temperature of -162 degrees Celsius to be kept in its liquid form. Additionally, a product called liquefied petroleum gas (LPG) which is a mixture of butane and propane can be used in cars. The global demand for natural gas has continuously increased over the last 20 years. This is mainly due to the energy production sector. The global demand for natural gas though decreased in 2009 for the first time and is expected to return to the 2008 level in 2013. Nevertheless, the demand for LNG is rising constantly and several new LNG plants have been commissioned. This demand comes mainly from South America and Asia where LNG is more common as an energy source than in central Europe (Kjärstad, 2011).

Biogas, which consists mainly of methane, on the other hand is a non-fossil alternative to natural gas. It occurs in an anaerobic process when microorganisms break down organic material like crop and liquid manure (Horbelt, 2010). After a special treatment and cleaning, the gas has similar characteristics as natural gas which makes it easy to be used in the same way. In a liquefied form, biogas can be used as fuel for cars and trucks which makes it a CO^2-neutral alternative to natural gas (Horbelt, 2010). Storage and transportation of biogas is comparatively uncomplicated which makes it a suitable energy resource used for energy production, heating and as environmental friendly fuel. The production rate of biogas is about to grow rapidly within the European Union. Especially the Renewable Energy Directive of the European Union (2009/28/EC) supports the development of energy production from biomass and is an important corner stone for national policies in the member states of the European Union. The directive establishes a common framework for the production of renewable energy sources and sets goals for the member states for the year 2020. Production of electricity and heating is included as well as the issue of sustainable transport. Having an established framework as a motivation and a goal for the member states sets good conditions for the rising consumption and use of biogas as fuel for trucks.

2.2.1 Biogas/ Natural gas as vehicle fuel in Germany

Vehicles running on gas are still quite rare on German streets and highways. In 2009 only 0,2% of the total market were gas-driven vehicles while gas had a share of just 0,3% of the total German fuel consumption. As there are around 50 million vehicles registered in Germany, 85.000 of them are gas-driven. 1800 of them are heavy buses and trucks. Those vehicles are mainly running on natural gas but the admixture of biogas up to 50% to natural gas seems to be an attractive way for the future and is already practiced at the natural gas stations in Munich (SWM, 2010). In 2009 natural gas at the amount of 1,7billion kWh was sold. (dena, 2010).

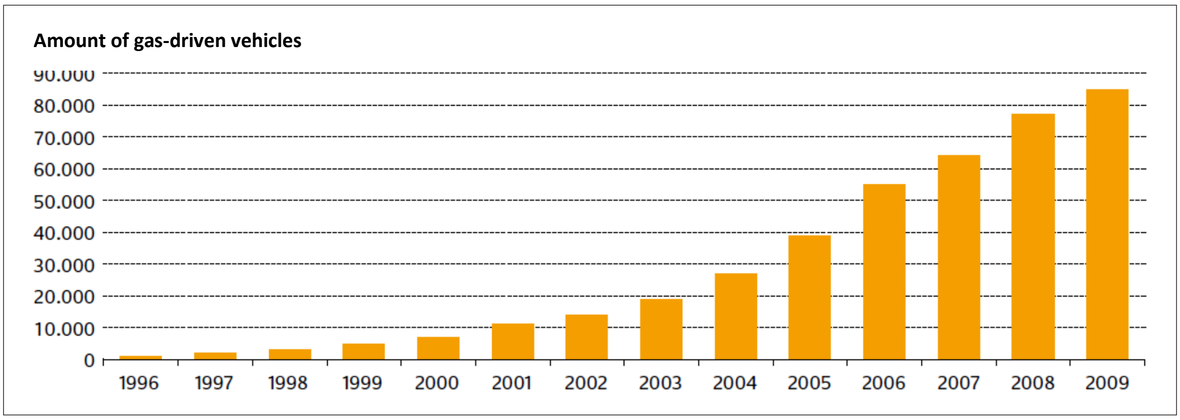

Figure 2. Amount of Gas Vehicles in Germany (dena, 2010)

Today, there are around 6000 biogas production sites in Germany producing a total amount of 2.300 Megawatt (gibgas, 2011). The produced biogas is mainly used for energy-production and for heating. As the conversion of biogas into a suitable fuel for cars and trucks is not longer a technological challenge this way of using the biogas is facing a growing popularity.

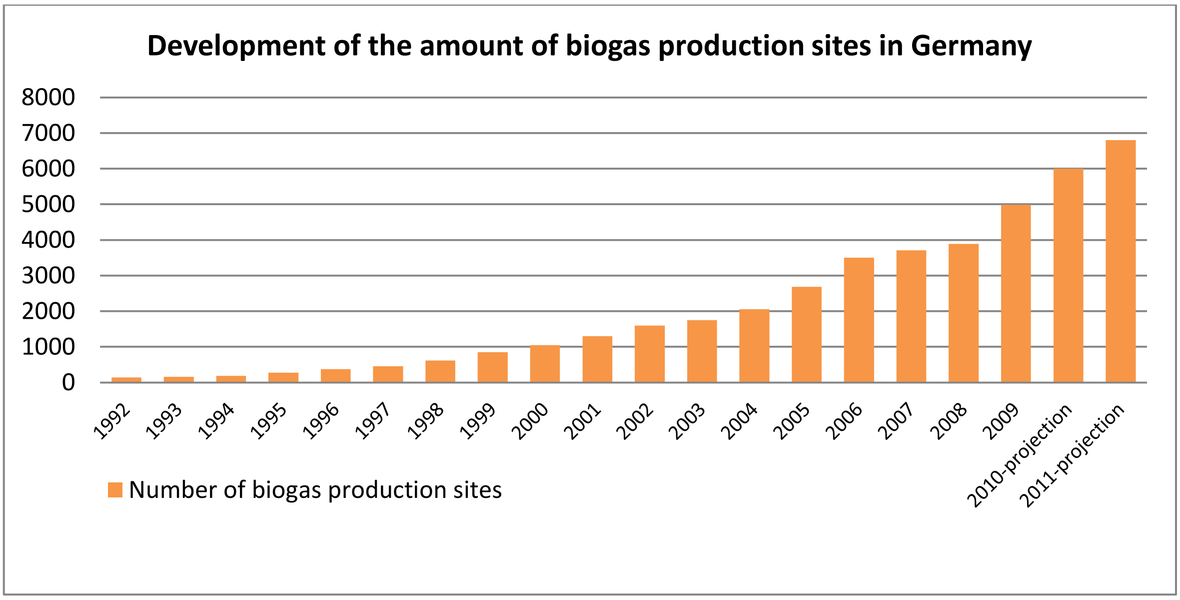

Figure 3. Development of the amount of biogas production sites in Germany (Biogas e.V., 2010)

The German government has set the goal that until 2020 the yearly amount of bio-methane that shall feed to the total gas amount used in Germany, is 6billion m³ (10billion m³ in 2030). This volume sets the basis for using biogas as fuel. The German gas industry at the same time has set its goal for 2020 to be a mixture of natural gas/biogas to the rate of 80/20. To reach this, 9.3% of the volume of biomethane that is suggested by the government for 2020 would be needed. (dena, 2010)

To reach a profitable level, planning with this amount of gas as fuel a number of 1.4million vehicles in the year 2020 will be necessary whereof 30.000 vehicles should be heavy trucks as the German Energy Agency (dena) indicates. This number makes a yearly growth of the number of new gas-driven vehicles of 29% necessary. It is expected that the development of the gas-infrastructure including gas-stations and services and new innovative technologies especially for heavy trucks will help to achieve those levels.

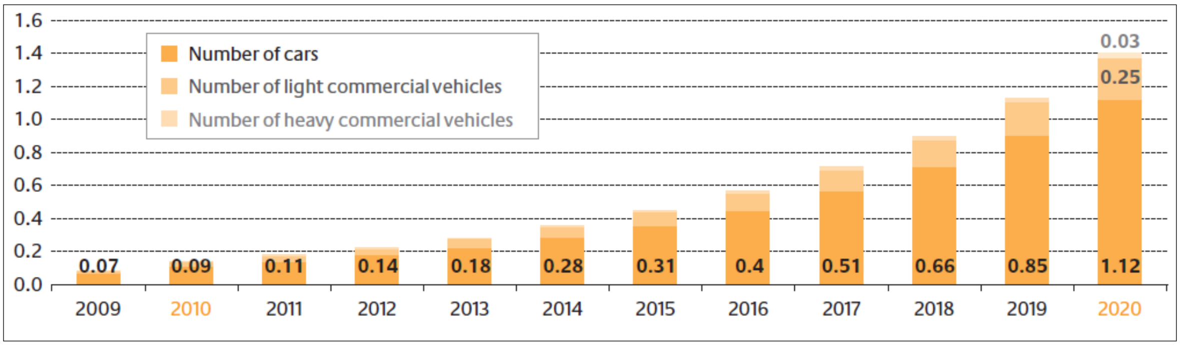

Figure 4. Necessary growth of gas driven Vehicles in Germany (dena, 2010)

The natural gas infrastructure in Germany is already well developed when it comes to pipelines which are available to a total length of 400.000km. Though, the number of filling stations amounts to only 900 compared to 14.500 traditional oil-stations (dena, 2010). Most of these gas filling-stations are situated in town-centers and on the mark of private companies. Only 26 are situated directly at the highways, which makes the gas-use difficult for long-haul transportation.

Apart from natural gas, biogas and mixtures of both, liquefied petroleum gas (LPG) has already a much larger share of consumers. With 300.000 vehicles and over 5000 filling stations all over the country this fuel is widely accepted (dena, 2010). This development is among others a consequence of the relatively easy installation of a LPG-filling station and the fact that they are often directly financed and maintenanced by the fuel provider causing no further costs for the station owner. Moreover, Germany is the only European country that charges lower tax on LPG (1,28€ct/kWh) than on natural gas like CNG (1,39€ct/kWh) (dena, 2010).

Nevertheless, this is a positive signal for the German gas-market as it shows that consumers are interested in gas as fuel. They seem to be willing to buy gas-vehicles if it is cheaper, but due to a good infrastructure of filling-stations, as convenient to get as traditional fuels on oil-basis.

2.2.2 Biogas/ Natural gas as vehicle fuel in Sweden

In Sweden 230 biogas production sites can be found which are producing a total amount of 1363GWh of energy (2009). The gas was used for different purposes. 49% where used for heat production, 36 % where processed to reach a better quality for using the gas for example as vehicle fuel. Further 5 % where used for electricity production and 10% were burned. The main production sites of biogas were the regions of Stockholm and Gothenburg as well as the southern region of Skåne. The main sources for biogas production in Sweden are sewage sludge, food waste and waste from the food production industry. (Energimyndighet, 2010)

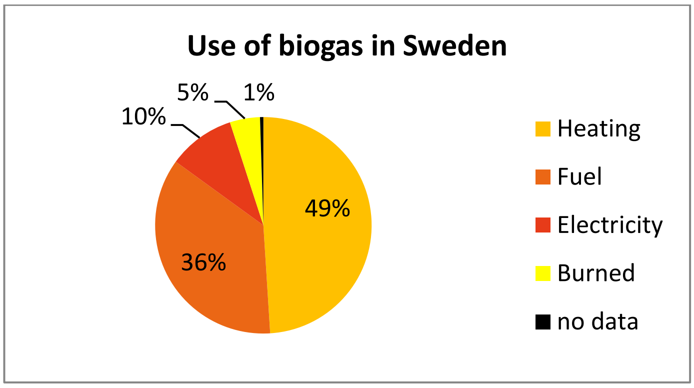

Figure 5. Use of Biogas in Sweden (biogasportalen.se, 2009)

Sweden expects the biogas production to grow rapidly within the next years. The goal for 2012 is a production amount of 3TWh/ year (Biogasportalen, 2011). In the town of Lidköping in West Sweden the first production plant for liquefied bio methane will begin its operations soon. Liquefied methane today is made out of natural gas delivered from Norway and other countries. With the new production site, driving with liquefied methane will become better for the environment as the CO^2 rate is lower.

The number of vehicles driving on gas in Sweden was 32.000 in 2010. 1400 of them were buses, 500 heavy trucks and the rest were private cars or cars used by companies and political institutions. Compared to 2009 this was an increase of 39% of the total amount of gas driven vehicles in Sweden. (Gasbilen.se, 2011)

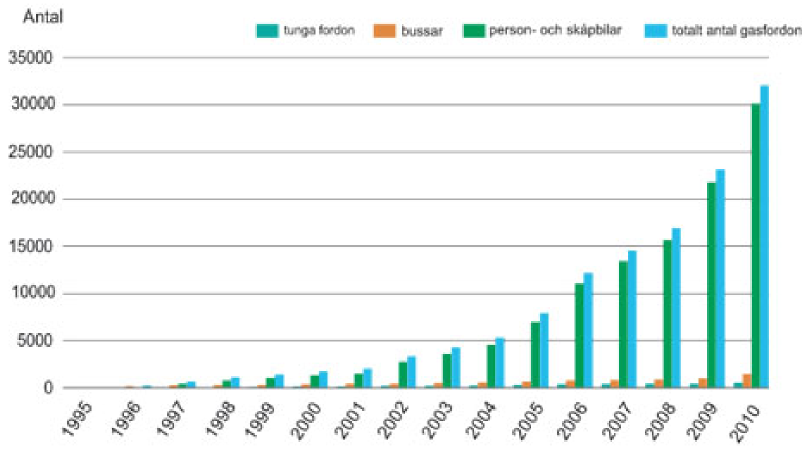

Figure 6. Number of gas-driven vehicles in Sweden (gasbilen.se, 2010)

With the growing number of gas-driven vehicles the number of gas filling stations has also increased during the last decade. An enormous increase can hereby be seen in the amount of public gas filling stations. Companies like Fordonsgas and EON regularly open new stations to provide a good infrastructure for gas driven vehicles.

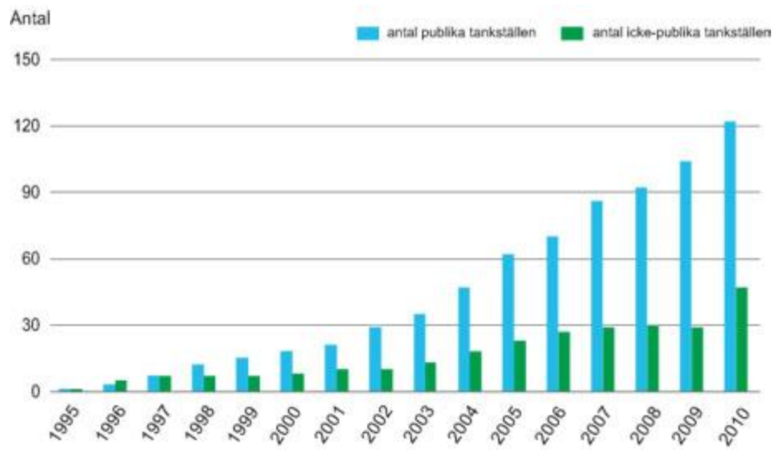

Figure 7. Number of public and non-public gas-filling stations in Sweden (gasbilen.se, 2010)

2.3 Volvo's Methane Diesel Engine

Figure 8, Volvo Methane Diesel Truck (picture: Sporer)

Volvo developed an engine that makes it possible to run a truck on both diesel and liquefied biogas. The engine is based on a modern EURO 5 standard diesel engine. After being converted for gas operation additional tanks are installed for either liquefied methane (LBG/LNG) or compressed gas (CNG/CBG). The engine can therefore be used with diesel as well as with gas which extends the cruising range of the truck. To start the engine a small amount of diesel is needed. The diesel tank makes the operator of the truck also less dependent on filling stations for liquefied methane as they are still quite rare. Diesel though is broadly available and makes the truck being a suitable solution for many industries even today. Due to the liquefied methane technology Volvo predicts that a truck can drive twice as far compared to the compressed gas technology.

Figure 9, Tank for liquefied methane (picture: Sporer)

With this new technique, Volvo expects a 25% lower energy consumption compared to a conventional gas operation which is good from an environmental but also from a financial point of view as gas is comparatively cheaper than diesel.

3. Methodology

The methodological part of this thesis shall make clear how the research on this topic is designed and which tools are used within the process. Furthermore the theoretical model used in this work, will be integrated into the Scandria project about sustainable transportation in Northern Europe. This leads to limitations concerning the geographical size of the study which concentrates on Sweden and Germany.

3.1 Qualitative approach

Qualitative research is a means to focus on a research problem from the understanding or the meaning of individuals or groups. It is based on qualitative information. Emerging questions and procedures are a main characteristic of qualitative research as well as a form of data analysis that inductively builds from particular to general themes. It is the task of the researcher to interpret the meaning of the data. (Creswell, 2009)

The researcher views the world in context to his study and to the applied theoretical model (Alvesson&Sköldberg, 2008). He tries to understand and interpret situations and relationships of life by getting in contact with the actors involved in those. It is thereby important that qualitative methods should start with the perspective of the subject under discussion and not from the ideas that the researcher combines with them (Alvesson&Sköldberg, 2005).

For this research project a qualitative approach is highly suitable as personal interviews and opinions are the main source for information about the development of coevolutionary relationships. The findings have to be analyzed by applying the theoretical model of organizational coevolution to a real world situation. Additionally, the number of the involved actors in the coevolutionary relationship under discussion is rather small and the actors operate in different fields of business and administration which has as a consequence that interpretation and evaluation of the arguments are necessary.

3.2 Data collection

The collection of the necessary data to cope with the research problem is an essential task in academic research. The outcome of the data collection process should be useful facts from the study's environment that help the researcher to understand, explain and elaborate the context of the research field (Blumberg, 2005). The collected data in combination with the theoretical model are the essence of the final analysis of the study. In this project the data which was collected in interviews, meetings and during observations will be used to describe and understand the relationship between the actors of the liquefied gas market. Representatives of the actors were directly contacted and further data from organizations with the purpose of providing information on energy issues and the gas market in particular are used to analyze the situation.

3.2.1 Primary and secondary data

Primary data includes the information that the researcher himself collects during the study (Blumberg, 2005). In this study, primary data includes mainly the interviews made with the actors in the development of the market for liquefied biogas in Sweden. An observation of the biogas facilities in Gothenburg gave further insight in the topic. Furthermore, the cooperation with Trafikverket and the environmental consultant company Ecoplan in Gothenburg led to primary data collected in discussions, meetings and further occasions in the planning process.

Figure 10, Study visit at biogas production site of Göteborg Energi (picture: Sporer)

Secondary data includes information that has already been collected and recorded by someone else, usually for other purposes (Blumberg, 2005). In the present study secondary data is mainly used to explain the theory of organizational co-evolution. But also empirical findings like studies from the German Energy Agency (Dena), Energimyndigheten and information networks concentrating on renewable energies and biogas as fuel alternative are included. They provide professional, large scale data that help to describe the current situation and the developments in the Swedish and German fuel market. In Germany those associations are namely Biogas e.V., gibgas and erdgas.com as well as the Agency for renewable resources (Fachagentur Nachwachsende Rohstoffe (FNR)). In Sweden Energigas Sverige, biogasportalen.se and gasbilen.se are the main information portals about methane as vehicle fuel. Additionally to those associations focused on gas as vehicle fuel, transport-associations like the Association of International Motor Vehicle Manufacturers (Verband der internationalen Kraftfahrzeughersteller VDIK), the Association of International Express- and Deliveryservices (Bundesverband Internationaler Express-und Kurrierdienste e.V.(BIEK)) and the Association of German Freight Forwarders and Logistics Operators (Deutscher Speditions- und Logistikerverband e.V. (DSLV) have been contacted in order to receive further insight into the topic under discussion. Many of the contacted associations and agencies appeared to be helpful sources to get information about the current conditions in the two markets. All governmental agencies and information associations have been contacted via mail and telephone to get the data needed for this study. Moreover the online services and the directly available data were used as well.

3.2.2 Types of data collection

Different data collection types are possible. Observations, interviews, documents and audio-visual materials are most common. In qualitative observations the researcher takes field notes on the activities and the behavior of the individuals at the research site in an unstructured or semi-structured way (Creswell, 2009). Interviews are a more formal and direct way of data collection that involves face-to-face communication and concrete questions to the individual at the research site. Further kinds of audio-visual materials like tone or video documents as well as photographs can contribute to a high reliability of the used data as it can be easily controlled for but also interviews and observations have to be documented in a reliable way.

3.2.3 Strengths and weaknesses of different data collection types

Those different types of data collection have advantages and contain limitations. Observations help to give the researcher first-hand experience. Furthermore he can discover unusual aspects of the study field that would have not been covered by questions formulated by an external researcher. The main limitation of observation is the limited possibility to report them. (Creswell, 2009)

Interviews are comparatively easier to document and the researcher has more control. It gives both the interviewer and the interviewee the possibility to prepare in advance and to provide suitable information. On the other hand, the view of the interviewee is influenced by his personal perception of the subject under discussion and the researcher does not get an objective opinion.

Documents and audio-visual materials have the advantage that they are accessible at any convenient time to the researcher. It could be thought that provided data in documents was created by participants paying attention and compiling the data, though no document should be seen as 100 percent authentic and accurate. A problem with documents is that not all information papers are available to the public and it can be tough to get the needed data. (Creswell, 2009)

3.2.4 Data collection types used for this study

To create a holistic view of the research problem this study uses a mixture of the types of data collection mentioned above. An observation of the biogas plants of Göteborg Energi was an important step for the researcher to understand the processes of the biogas production and distribution. Competent people contributed useful facts in direct conversations. Additionally to the biogas production the researcher upgraded his knowledge about the methane diesel technology of Volvo. This happened through direct contacts with engineers responsible for the development at Volvo. They explained the technology and its advantages as well as disadvantages directly at the study object. This was very important to get the full picture and to realize challenges and opportunities of that technology which were not obvious in the first place. A similar learning process was arranged with the gas provider Fordonsgas that is running the first gas station for liquefied gas in Sweden. During a visit questions could be asked and professional individuals could be won for further and deeper interviews which provided the whole project the necessary level of first hand data. Finally, Lars Thulin vehicle development coordinator of Renova provided the researcher with the opportunity to learn about the advantages of the methane diesel engine and to compare it with other technologies available on the market. Due to a combination of study visit and structured interview a realistic dataset could be collected including useful information about the view of a transport buyer on the situation of liquefied biogas in Sweden. Apart from the direct visits of the main locations concerning production and distribution of biogas in Gothenburg, further transport buyers were personally conducted and interviewed in a semi-structured way.

In general, the following companies have been directly contacted via mail or through direct visits to collect the data needed for this study:

Volvo Trucks, DHL, Renova, Schenker, Götene Kyltransporter, EON, Fordonsgas, AGA, Linde, Remondis.

To study and understand the preconditions for biofuel in Sweden in Germany laws and governmental regulations concerning the topic of renewable energy are reviewed and analyzed. Those can be introduced or proposed laws or information about the current situation concerning biogas as well as future prospects by governmental energy agencies specialized on future scenarios. The Swedish Skatteverket and the German Energy Agency (dena) was contacted to get information about tax rates and fuel prices in Sweden and Germany.

This kind of secondary data collection was complemented by a number of inquiries to Swedish and German agencies and networks dealing with the gas topic as well or being focused on the general development for the market of renewable energies. Furthermore, the homepages of the different actors involved in the co-evolutional process where studies to find background information about the work towards environment and sustainability. The specific actions plans of the different actors where afterwards checked for during the interviews with representatives of the companies and organizations. The mixture of those data sources and data collection types is an essential part of this qualitative study in order to get a suitable dataset.

3.3 Qualitative Interviews

Qualitative methods are used when the researcher is interested in experiences, feelings and general but personal opinions of the interviewed person. The goal can be, to find out about human experiences. Therefore it is common to use a set of interview questions of different areas that gives the interviewer as well as the interviewee the possibility to develop the discussed topic and discuss some aspects closer. (Svensson&Starrin, 1996)

Nevertheless, to be able to analyze the data gained through a personal interview, the interview itself has to follow detailed forms. The interview can be structured, semi-structure or unstructured. In a structured interview the researcher uses a detailed system like for instance a detailed questionnaire. The semi-structured interview approach is often constructed in a way that starts with rather specific questions but leaves space for the interviewee to present own thoughts and opinions in the end. Unstructured interviews on the opposite do not have a special set of questions to be answered but the interviewer has the possibility to lead the discussion into a direction that provides him with the needed information. (Blumberg et al., 2008)

The use of an interview type depends on the goal of the study. While structured interviews are useful for studies where the goal is to describe or explain a topic, the other two interview types are constructed to explore and develop the topic. Semi-structured and unstructured interview styles are useful as they help to identify the issues that are necessary to understanding the topic that is studied. (Blumberg et al., 2008)

3.3.1 Choice of interview type

To find out about the co-evolutionary relationships between the actors involved in establishing liquefied methane as a truck fuel in Sweden and Germany the conditions for this process had to be explored. Interviewees are obliged to have the possibility to talk about their experience in the process of cooperation and development of the biogas infrastructure. Only semi-structured and unstructured approaches can be a means to get useful data as unforeseeable events would not be covered otherwise. The interviewee was provided with the possibility to talk about advantages, disadvantages and challenges of the development process. Nevertheless, a broad framework for the interviews was developed to make the statements of the different actors comparable and suitable to each other. As the interviewed subjects come from different business areas like production, distribution and consumption a suitable framework was used to find out about similarities and differences of the several actors concerning the co-evolutionary process. It was due to the different backgrounds and business fields of the interviewees not possible to use the same set of questions and topics for every individual. This would have made the interview process untrustworthy and would have led to a low quality of data. Much more was it the focus to develop the answers of the interviewee during the session and to find out about facts that have not been considered by the interview initially.

3.4 Qualitative Reliability

Qualitative reliability indicates that the approach chosen by the researcher is consistent across different projects conducted by different researchers (Gibbs, 2007). Data collection therefore, has to be done consciously and accurate. Mistakes can always happen but it counts to avoid them. In interviews reliability could be reduced due to the interviewer or the interviewee. Concentration and a structured way of asking questions help to raise reliability. When compiling the transcripts of the interviews the researcher has to check if those contain obvious mistakes that occurred during the transcription (Creswell, 2009). The meaning of the answers must not be changed and the researcher has to guarantee a certain level of objectivity and should not interpret the data in this early stage of the research.

In socioeconomic qualitative research it is unlikely that two studies about the same topic will lead to the same results as individual opinions of the participants of the study and environmental conditions influence the data collection. Nevertheless the researcher has to work as accurate as possible and must always carry in mind that mistakes and inconsistencies can appear and might influence the result. Being conscious about that is an important fact of doing research.

The reliability in this study will be strengthened as the research field is narrowed down to experts directly taking part in the process of introducing liquefied biogas to the market, which reduces the risk of getting wrong information. The researcher though is conscious about the fact that some of the observations will be held in Swedish which is not the mother tongue of the researcher. Interviews though will be conducted in English, if the interviewee feels comfortable in doing so.

3.5 Qualitative Validity

It is the responsibility of the researcher to check for the accuracy of the findings (Gibbs, 2007). Creswell & Miller (2000) value it as one of the strengths of qualitative research as its findings are grounded on accurate information from the standpoint of the participants and of the researcher. Trustworthiness, authenticity and credibility are core characteristics of a valid study (Creswell&Miller, 2000).

The compliance between the theoretical model of co-evolution and the operational indicators of the study (Esaiasson et al,2007) is under control as the biological concept of coevolution is modified for the organizational context. The theoretical model therefore comes close to the situation that is observed in the study. The model is used to describe the constellation of the involved parties in the progress of establishing liquefied biogas. As the study shows the criteria of that model are fulfilled and suitable.

The overall threats of low external validity are considered to be low within this study as mainly first hand data will be used which is directly collected by the researcher during personal interviews. The interviewees are chosen in cooperation with Trafikverket which is the responsible institution for the Scandria project. Due to their experience, a well targeted field of partners was found and contacted. This selection is representative for the group that the researcher wanted to conduct and guaranteed that the measurements are closely connected to the subject under discussion (Esaiasson et al, 2007).

The results found in this study are based on a single co-evolutionary situation in Sweden. Nevertheless, it shows the similar development of different actors as they can be found in every industrial country. Even though single mechanisms might be different the basic concept remains the same. The findings of the Swedish situation are transferable to other markets with similar structures first and foremost Germany which is part of this study.

Though, it has to be considered that the market for biofuel and the economical as well as the political situation for renewable energies constantly change and develop. Results of older studies and experiments have to be used carefully or tested for under current conditions. The initiation factor of the co-evolutional situation, the general demand for sustainability, is not just a Swedish phenomenon, but can be seen in many western countries.

4. Theory

Cooperation and collaboration within the business sector have always been important to develop markets and to push boarders forward. Not just technological development but also the pure recognition of challenges and chances are drivers of innovation. In a globalized highly technical world new opportunities are arising constantly might it be due to political decisions, changes in consumer behavior or due to challenges caused by environmental circumstances.

The latter is the main driver of a constant change of business towards sustainability. The degrading situation of the natural environment forces many companies to find new ways to produce, transport and sell their products. Consumers have higher demands concerning products, when it comes to environmental friendliness and additionally the political demand for reducing CO^2-emissions puts pressure on companies to act and produce in a more sustainable way.

Several actors are at the same time changing their demands and way of acting due to changes in the environment. Though, they are not doing this independently from each other. There seems to be a mechanism that can explain why politics, business and consumers at the same time run towards a new more sustainable way of thinking and acting. All actors develop towards the same direction as the natural conditions are changing. This becomes especially obvious when new technologies, that are helping the several actors to reach their environmental goals, are available on the market.

To make new systems work several actors have to develop simultaneously towards the same goal. Organizations and business in general are thereby heavily affected by their environments. Companies and institutions though, have the possibility to act in concert with other organizations facing similar challenges and pressure towards sustainability. This can be a tool to counter, curb, circumvent or redefine these demands (Scott, 2008). Special circumstances can lead to simultaneous development of several actors in a market and even if the basic conditions exist for a development, one party has to initiate the process to cope with the challenges and demands.”Organizations are creatures of their institutional environments, but most modern organizations are constituted as active players, not passive pawns.”(Scott, 2008) Nevertheless, a development process of markets where many actors are involved is in need of active participation of all these actors.

The theory of co-evolution can be a suitable tool to study and understand the need of simultaneous actions. Originally developed as a biological model to explain simultaneous and dependent developments of animals and plants to adapt to changes in the natural environment, the theory of co-evolution can also help to explain the simultaneous development of organizations and further actors in the human world.

4.1 Co-evolution in biological sciences

The theory of co-evolution is highly connected with the ideas and mechanisms of evolution but describes the simultaneous development and adaptation of not just the environment itself but also of other living actors in the environment which go through the same process.

The concept of co-evolution was first mentioned in the work of Ehrlich and Raven (1964) describing evolutionary relationships in population biology even though Charles Darwin has mentioned similar concepts already in his famous "On the origin of species" (1859). Ehrlich and Raven studied the specific relationship of butterflies and their food plants and developed the theory of pure evolution talking especially about the dependency of the species to each other. They found out that there were several interspecific combinations between the butterflies and the plants they used as food sources. They draw the conclusion that those combinations and adaptations to each other "evolved in part in response to one another" (Ehrlich&Raven, 1964). This showed that the process of evolution is not just driven by competition of different species but also by adaptation of different organisms developing simultaneously due to each other's characteristics, creating a competitive advantage for all involved actors.

Another important definition is given by van Valen (1983) by focusing on mutualistic evolution which describes "the adaptive response of one species to genetic change in another species, which itself becomes genetic" (van Valen, 1983, p.2). It includes the important fact of genetic change which is a necessary part of every evolutionary development. Changes that are not genetic will not be passed on to the next generation and will therefore only be a temporarily advantage for an individual instead of a sustainable change of a species.

Ehrlich and Raven (1964) even argue that this mechanism of evolution in tandem, which describes the idea of co-evolution in an appropriate way, is one of the main drivers of the enormous organic diversity on earth. Co-evolution allows species to adapt to niches that they could not use for their own survival and progress without the simultaneous development of other directly involved species and external circumstances.

Furthermore it has to be mentioned that co-evolution in biology is a process that takes an enormous long period of time as new characteristics have to be passed on and spread from generation to generation. Large, complex ecosystems and extended time scales are necessary to see the effects and consequences of co-evolution. (Levin, 1983)

4.1.1 Fundamental criteria of biological co-evolution

To distinguish the theory of co-evolution from the traditional concept of evolution and other bio-adaptive relationships Futuyama and Slatkin (1983) provide three fundamental criteria:

1. Specificity: The evolution of one entity is due to the other
2. Reciprocity: Both entities co-evolve
3. Simultaneity: Both entities co-evolve concurrently

Due to these criteria a clear borderline can be drawn to the biological concepts of interaction, coadaptation, mimicry, symbiosis and parasitism. Co-evolution is the only concept among them which is based on a lasting, genetic change of both species (Porter, 2006). Genetics, securing a permanent change play therefore an important role in co-evolutionary mechanisms.

Moreover, co-evolution is a boundary-crossing mechanism which leads to the fact that interspecific changes have to be involved in the process. This clearly expresses that at least two different species have to interact in the process. This process, finally, has to arise organically instead of being planned or worked on, as co-evolution in nature happens by coincidental mutation and adaptation rather than by conscious decisions of individuals. Changes and developments in a co-evolutionary context are adaptive and responsive. (Porter, 2006)

These additional facts presented by Porter (2006) lead to three further criteria of biological co-evolution that complete the three already mentioned criteria:

4. Genetic fixing: Change is permanent and replicated automatically
5. Boundary crossing: Involves two unlike, interacting species
6. Organically derived: Emergent and responsive, the outcomes of self-organization are unknowable in advance

4.2 The use of co-evolution-theory in an organizational context

Co-evolution is even in the context of biological sciences a rather young theory as it became a major research framework in biology in the 1980's (Futuyama&Slatkin, 1983). As a study of Porter (2006) shows, the topic of organizational co-evolution has entered scientific literature in the 1990 and is still relatively unknown but a steadily growing field of research while the number of publications in biological sciences since the 1980s is on a high level.

In a socioeconomic context, co-evolution was first applied by Norgaard (1994) in his work "*Development betrayed: The end of progress and a co-evolutionary revision of the future*". As highlighted by Porter (2006), Norgaard describes knowledge, values, organization, technology and the natural environment as " all permanently affected by the selection conditions provided by the others, as they themselves evolve" and makes thereby the point that systems influence each other constantly and do not exist separated from each other.

Lewin and Volberda (1999) define co-evolution "as the joint outcome of managerial intentionality, environmental and institutional effects". They add, that co-evolution "can be recursive and need to be an outcome of either managerial adaptation or environmental selection but rather the joint outcome of managerial intentionality and environmental effects". Environment in general plays a major role in the concept. It is though not just the natural environment making change necessary but also the protection of the natural environment that overall enables organizations and humans to act as they do. For Porter (2006) it is therefore obvious that co-evolutionary research in the field of organizations and natural environment " must somehow capture the idiosyncratic motivation for "going green".

Co-evolution in an organizational setting cannot only happen between organizations but also within organizations or within firms. To describe this phenomenon Lewin/ Volberda (1999) talk about multilevelness. McKelvey (1997) goes even further in his article "*Quasi-natural organization science*" where he distinguishes between co-evolution within the firm which he describes as micro-co-evolution and between firms and their niche, so called macroevolution.

The present work focuses on the latter concept as the relationship and the co-evolutionary tendencies between firms, organizations and institutions all being engaged in a common environmental project, shall be studied. Nevertheless, the theory of co-evolution "assumes that the co-evolution of organizations is an outcome of the interplay between forces internal and external to organizational environments" (Lewin et al, 1999). This makes it necessary to look inside organizations and companies to find out how they are organized internally to cope with environmental uncertainties. Organizations are able to learn how to handle volatile conditions and they develop enhanced capabilities for coping with higher levels of disorder (Brown&Eisenhardt, 1998). This characteristic is essential in co-evolution as it enables firms and organizations to adapt to new challenges and changes in the environment as governmental regulations or a shift in customer demand.

4.3 Aspects to be considered when applying biological co-evolution to organizations

Biological co-evolution is bound to the criteria of specificity, reciprocity and simultaneity. Furthermore the genetic fixation, the need of a boundary crossing situation and the organically derived source has to be given. Those criteria have to be fulfilled if the concept shall be applied. In an organizational context these criteria have to be interpreted and discussed to apply them to systems which were constructed by humans in a comparatively short time frame.

Specificity in organizational co-evolution means that the object to look on has to be sector specific and local (Porter, 2006). The actors have to be clearly defined and their business field has to be clear. Otherwise an analysis of the relationship to other co-evolving actors might be impossible.

The criteria of reciprocity which calls the need that both entities are changed can be fulfilled as organizational elements are permanently changing (Porter, 2006). A complex organization can be compared to a living organism that has to deal with several environmental changes and therefore changes itself and its partners constantly due to interaction.

Simultaneity requires that those changes happen at the same time. In an organizational context it has to be analyzed if the "change is mutual, in relation or response to other elements in a complex adaptive system" (Porter, 2006). The changes and decisions that have been taking by the different actors have to stand in relation to each other organization's changes. They moreover have to happen at the same time frame or at least as a response to the other's development to be a result of co-evolution.

To transfer co-evolution to organizational research Porter (2006) highlights the last three criteria. Boundary-crossing interrelationships as they often occur in business are important and essential to define. Also the "organically derived" criterion plays a role as it distinguishes the concept of co-evolution from intended or induced strategies. It has to be analyzed if changes and developments are emergent and adaptive. To see a co-evolutionary phenomenon, events leading to changes in all participating organizations have to be unplanned and unpredictable (Porter, 2006). Changes in the strategy or the philosophy of an organization produced by other mechanism than those cannot be ascribed to the phenomenon of co-evolution.

The last and highly important criterion of co-evolution in biological sciences is the genetic fixation. This is not less important in an organizational context but has to be applied to the circumstances that an organization is not built in the same way as a biological organism. Neither DNA nor the mechanisms of mutation or natural reproduction are to be found in organizations. Nevertheless, similar mechanism and systems can be seen to guarantee the fulfillment of this essential criterion. A development has to lead to long-term structural changes within the organization while mechanisms of fixation or permanency are identifiable (Porter, 2006). The general way of how challenges are dealt with after a co-evolutionary change is decisive. A single decision, taken as a consequence of a change where many organizations have been involved, does not state a long-term change but rather a strategic step. The human actors within the organizations have to change their way of thinking and acting to permanently fix co-evolutionary changes in the philosophy and the core strategy of an organization.

4.4 Differences between biological and organizational conditions concerning co-evolution

Applying a theory that is originally coming from biological sciences to a social science topic makes it necessary to be aware of some barriers that appear in such a transfer. In an organizational context, some additional factors have to be considered that might influence the model of co-evolution as it is used in a business context or might simply show that the model differs in the various contexts. One of those factors is communication (Porter, 2006). Within nature, co-evolution is a process that happens without communication. In an organizational context many developments that are made happen after consulting experts and also the organizations that are actors in the co-evolution process towards a permanent change.

Another major reason why biological co-evolution differs from organizational co-evolution is the human learning process (Porter, 2006). Changes can be made more rapidly compared to nature, where genetic fixations of changes normally take several generations and thousands of years. This comparatively faster adaptation of changes and the flexibility due to the human consciousness make the organizational co-evolutional process less accidental and can even steer the direction without breaking the rules of co-evolution. Human actors are just to be seen as conscious actors that can understand and influence processes without fully controlling them. This often leads to hybrid forms (Porter, 2006) as a result of co-evolution as the process might be stopped before the final, perfect condition is reached. New organizational forms can be the consequence of such a disrupted process, which is more common the new speciation in biology (Lewin et. Al., 1999). Similar facts are also reported by Kieser (1989) whose research shows that co-evolutionary processes lead to an increase of institution's functional specialization and to a reduction of social monopolies. Co-evolution in an organizational context can therefore lead to a broader specialization of organizations instead of just a better adaptation to the environment.

4.5 When co-evolution leads to a first mover advantage

Nevertheless, the theory of organizational co-evolution can just be a concept for describing and analyzing the environment and its actors. It can help to find the cornerstones of a special relationship leading to more competitive and more sustainable business models. A co-evolutionary situation between different actors in the market can lead to a competitive advantage for them. This advantage that was created by the simultaneous and dependent development of the actors might not be easy to catch up to for competitors who are not part of the co-evolution process.

4.5.1 First mover advantage

A first mover advantage is defined as "the ability of pioneering firms to earn positive economic profits" (Lieberman&Montgomery, 1987). Gaining such an advantage is considered to be a multi stage process. Firstly, there must be an asymmetry that is generated in the market. As a second step, the organization or firm has to be able to recognize this asymmetry in an early stage to be able to be faster than its rivals to make use of the situation. To be able to do so, the firms must possess some unique resources or foresight. Finally, there are a number of mechanisms that can give an organization the possibility to exploit its special position. (Lieberman&Montgomery, 1987)

Those mechanisms, leading to advantages, can arise from three primary sources as Lieberman&Montgomery (1987) name in their award winning work about first-mover advantage:

1. Technological leadership
2. Preemption of scarce assets
3. Buyer switching costs

In the case of the co-evolutionary situation of introducing liquefied biogas to the Swedish market, technological leadership can be clearly defined as the driving force. Without Volvo's technological development of the methane diesel engine the co-evolutional process might not have been initiated. This does not mean that only Volvo will enjoy a first-mover advantage. Transport buyers and the gas producers will have similar advantages when adapting to the new technologies in an early stage. Nevertheless the effect and the range for the other partners might be smaller than the ones of Volvo. For Volvo it is relatively easy to implement the trucks with the new technology in other growing markets and they included other markets from the beginning into their calculation to become profitable. The gas suppliers, and here mainly the local western Sweden company Fordonsgas cannot make use of their new competencies in other markets that fast. Even if they could sell their knowledge to companies in other countries which face similar situations there must be another advantage for them being part of the project. The network of truck manufacturers, gas suppliers and transport buyers plays an important role to find out about this advantage. The courage of all actors to be first movers and to work towards a system where every actor was dependent on the other ones created trust and reliability. The actors might profit from this and the factor trust is an important part that will be discussed from different perspectives.

Being a first mover can though also lead to disadvantages for the directly involved groups. Establishing a new system or technology is very costly and therefore time and resource consuming. Once established, competitors can easily follow the leaders without having as high investments as the first mover (Lieberman&Montgomery, 1987). Patents might be a protection against early followers. Nevertheless, if the infrastructure for liquefied biogas is once developed through the early co-evolutionary process between Volvo and the major gas suppliers, other truck manufacturers can make use of this. They still have the research and development costs (R&D costs) but their risk is decisively lower as they can be sure that the possible customers will have enough stations to refill their trucks with liquefied gas.

Another disadvantage of being a first mover is the phenomenon of "incumbent inertia" (Lieberman&Montgomery, 1987). The danger here is that the first mover does not continue to develop the technology that once created a competitive advantage for him. Competitors might overtake the former leader if they do not continue to develop their own technologies.

Exactly here the co-evolutionary process comes in again. Does this system protect the actors as they are developing similarly? Does the co-evolutional process in an organizational field prevent the actors of competitors outside the process or is it at least more difficult for them to adapt to the new environment? Or is co-evolution of some an advantage for all actors who will follow in a later stage of time?

The concept of first-mover advantages developed by Lieberman&Montgomery (1987) can be the link for finding out in how far the co-evolutionary process discussed in this work will lead to constant competitive advantages for the participating parties. Though, it has to be mentioned that such an advantage has not necessarily to be of direct economic rewards in from of profits. An organizational co-evolutionary process can further lead to factors like a high level of trust. This factor might not be traded on a market or will not lead to profits that can be seen in the books at the end of the business year. But to reach a sustainable development of business, non-tradable assets like trust have always to be considered and valued as they might be a competitive advantage in the future (Dierickx et al., 1989).

4.6 Organizational co-evolution and trust

The organizational co-evolutionary process is not just based on coincidences and unplanned situations it is influenced and driven by communication and cooperation (Porter, 2006). The actors are dependent on each other and it is therefore necessary for them to constantly exchange their state of development and to discuss new challenges and opportunities. High investments are taken by the manufacturer and the gas suppliers. To continue working on a big co-evolutionary project a certain level of trust is needed which has to be established and cultivated. "Successful alliances exhibit trust between the partners; unsuccessful alliances exhibit a lack of trust" (Koza et al., 1998).

How can trust be defined? Kumar (1996) describes it as dependability of the partners where a leap of faith is made and where each actor is interested in the welfare of the other as everyone involved will take a profit out of it. To this definition the need of active work towards a situation where the actors can trust each other should be added. Otherwise, one could expect that trust is generated only through a dependability of the actors but it is an active process that needs time and direct contact of the partners.

In the present case it was not just necessary to build up trust between actors of different business fields but also between direct competitors of the Swedish gas market. This constellation and the courage of the actors to start the project made a certain level of trust necessary. All actors had the chance to proof that they are trustworthy and that they could even work on further projects. This is one of the major advantages of the co-evolutionary process for the gas providers. Volvo has its new technology as a competitive advantage but the gas suppliers had the possibility to get in direct contact with each other and with customers to create trust and loyalty.

Dierickx (1989) highlights that "Loyalty of one's dealers or the trust of one's customers cannot be bought. Dealer loyalty must be cultivated, and customers' trust must be earned through a history of honest dealings". The cooperation of the actors of the liquefied gas market was a possibility to show that it is in everyone's interest to deal honestly with each other and to develop a whole system together. Even if the system should not be accepted by the customers in the way the actors had hoped, they have created a network of trust and loyalty that will be an advantage for them for projects in the future. With the trust in each other they can create something very valuable that is "simply not traded on open markets" (Dierickx, 1989) but that is necessary for establishing sustainable business.

4.7 Summary

The major theoretical model of this study is the concept of organizational co-evolution which has earlier been transferred from biological sciences to the organizational and business field of research. The idea is to make use of the theoretical concept to describe and understand the development of the Swedish market for liquefied methane as truck fuel. The motivation of the several actors will be analyzed as well as the long-term prospects. Further it will be made clear why this co-evolutional situation is essential for the whole implementation of the new technology and in how far it leads to advantages for the actors involved in the process. After analyzing the Swedish market the focus will be put on the conditions for liquefied methane as truck fuel in Germany. The theory of co-evolution will here be used to find out if the conditions are promising to start a similar process as in Sweden or if the only way of introducing liquefied methane as fuel in Germany is to integrate the market into the co-evolutional process of Sweden.

Using the theory of organizational co-evolution in this way will both contribute to analyze the situation in the market as well as to the further development of the relatively young theory itself. The literature lacks practical examples of using the theory in business projects. Therefore this thesis shall contribute by using it as a means to describe mechanisms within the process and to find out how the different actors profit from a co-evolutional process. The originally from biological science resulting theory gives a new perspective on often slow bureaucratic processes in the real world of business and organizational projects.

5. Data Analysis

This part of the thesis contains two different sets of data collected and reviewed for this study. On the one hand data gained from interviews and knowledge accumulated throughout the process of the thesis shall be presented. On the other hand political regulations and standards are listed and explained as they are an important influential factor of the development of biogas and liquefied methane in general as fuel for trucks in Sweden. Those documents can also help to understand the development of the German market towards renewable energies and sustainable transportation approaches.

5.1 The actors of the development of the Swedish market for liquefied methane

During the learning process of gathering information about the situation for liquefied methane in Sweden it became clear who the main actors of that development are. It is important to know which actors are more passive and which are the initiators and early movers in the process. These key actors are named in figure 11 and afterwards their role in the process is described.

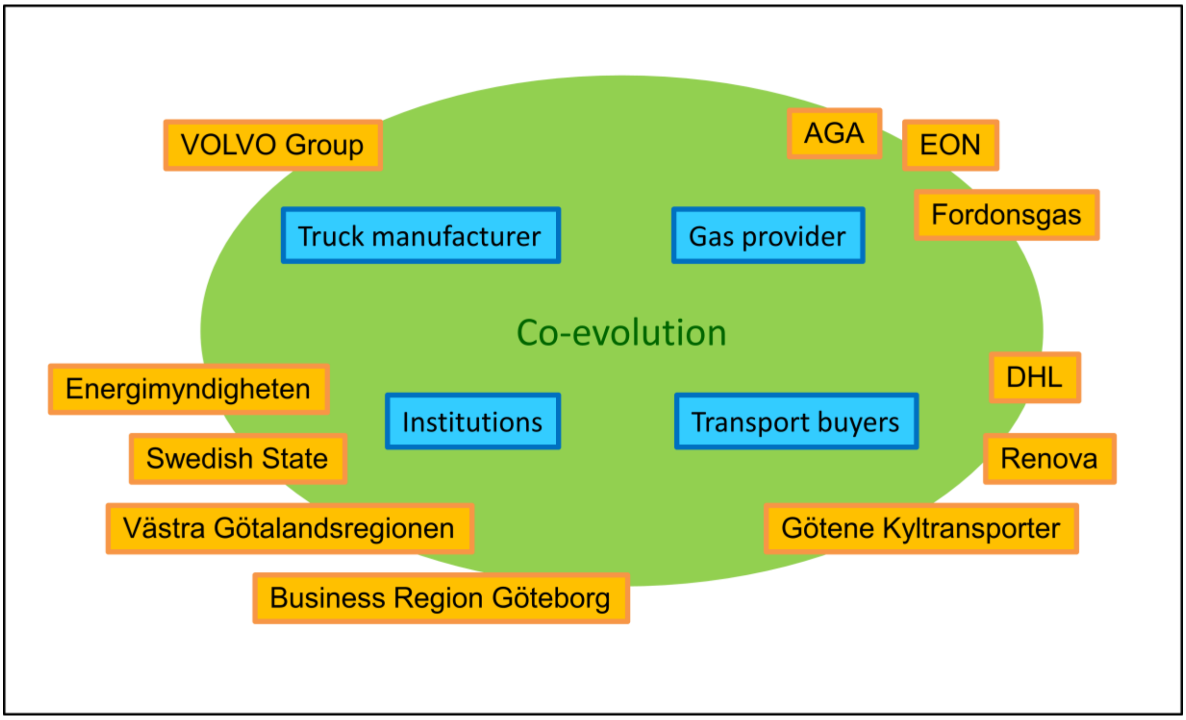

Figure 11. Actors involved in the development of the Swedish market for liquefied methane

Volvo Trucks and Fordonsgas have separately developed the vision of using liquefied biogas as truck fuel to create a more sustainable alternative to fossil Diesel. At an early stage of their projects they got in contact with each other and continued developing their idea well knowing that the other partner develops the same idea. Christina Eriksson, Business Manager Alternative Fuels and Hybrid Trucks at Volvo, attests that the development of the methane diesel technology would have never been initiated without a constant dialogue with Fordonsgas and the other Swedish gas-providers in the early stages of the process. Trust had to be built up so that each actor will do the necessary steps to make the new technology working in the market. During the development process DHL, Renova and Götene Kyltransporter could be won according to Eriksson to start field tests with the new trucks and to give advice about details that could be improved when driving with liquefied methane.

Roger Andersson of the gas supplier AGA highlights again the important role that Volvo trucks plays in the process. He says that without Volvo delivering a suitable engine that uses liquefied gas in an efficient way, his company would not have forced the development of the gas infrastructure as much as it does today. He and also Roland Nilsson of AGAs competitor EON underline Volvo's reputation in Sweden and he has always seen good possibilities that the importance of the company can influence Swedish legislation and authorities without creating a distortion of competition. The latter would of course help to implement the new technology in Sweden if governmental support in form of monetary funding could be provided. All involved actors could take a profit out of such a support. Andersson though, also mentions that AGA is dependent on the competencies of Volvo. If their trucks are not working properly than neither monetary support nor a well functioning gas supply system will help liquefied methane to succeed. If technology and infrastructure work properly Andersson is optimistic that transport buyers see it as a "natural step" to buy methane diesel trucks.

Nevertheless, representatives of all business actors within this co-evolutional process highlight the importance of the role that the state plays in the development of the Swedish gas market. Roger Nilsson (EON) interprets support from the state as "an indication of direction" and sees it as an accelerator for the implementation of a new technology. The advantage for the Swedish state by supporting the liquefied methane development is that the climate goals and the own Swedish Environmental Objectives, which are explained below, will be reached. Therefore the state is constantly searching for projects that lead to more environmental friendly actions.

Roger Andersson (AGA) becomes more specific and says that a number of 300 working trucks on the road and a competitive market price for LNG will lead to the success of the project. So far, Swedish governmental support is arranged for up to 100 trucks (BiMeTrucks, 2011). This support is partly financed by Energimyndigheten and Västra Götalandsregionen as will be explained together with the BiMeTrucks project later in the study. More work and further support from the state is therefore needed to implement the new technology successfully.

Volvo's Christina Eriksson sees the role of the state not just in providing monetary support but also in building up a legislation and standardization. This could for example be useful for fuel quality and filling stations in order to allow transnational passages of the new Volvo trucks. Common standards would make it much easier and cheaper to allow transnational carriers like DHL to transport goods on road with the new technology. Ulf Hammarberg, environmental affairs DHL, mentions further that for his company a gas filling station in northern Germany would be important to run the methane diesel trucks successfully. DHL transports goods, amongst other possibilities, via on-road transportation from Scandinavia to its distribution center in Lübeck. He says that a fuel system for long-haul transportation cannot be sufficient if it is only developed for the Swedish market under Swedish conditions.

All involved actors are first movers in their development part of the project. If they succeed, they will be ahead of their competitors. Volvo will be able to present a truck on the international markets that is unique concerning its environmental technology. This will give the Volvo group a good reputation within the environmental technology discussion. The gas providers and distributers can use their knowledge, gained in Sweden, to develop other markets for example in countries like India and Brazil, where gas in general is already more commonly used as fuel than in central Europe for example. The transport buyers Götene Kyltransporter, Renova and DHL can provide their customers with more environmental friendly transport solutions. A high demand can be seen in this field not just in the B2B field when it comes to sustainable delivery chains but also in the B2C field as DHL can prove with an increasing demand for its CO^2 neutral transport service "gogreen". The Swedish state participates finally in developing a possibility to reach its environmental objectives and reduce its CO² production. With Volvo, it furthermore supports a local company that can promote Swedish engineering all around the world pointing out the quality of Sweden as a research and development location. Environmental engineering is already an important part of Swedish industry. The project of establishing liquefied methane as truck fuel for long-haul road transportation is just another possibility to promote this.

5.2 The six criteria of organizational co-evolution applied to present case in Sweden

In the following part the criteria transferred from the biological model of co-evolution to the organizational model of co-evolution are applied to the process of establishing liquefied methane as truck fuel in Sweden. A short explanation of the various criteria will be given and the role of the several actors is analyzed. The focus is not set on finding out if each single criterion is completely fulfilled. This would restrict the analytical possibilities of the model to an unacceptable extend. The criteria are therefore used to analyze various factors of the collaboration of the actors. This will lead to a better understanding of the relations within the process at large.

5.2.1 Specificity: The evolution of one entity is due to the other

The involved actors develop their field of action due to the possibilities that are created by the actions of the other actors. This can be easily shown when one looks at the relationships between the actors.

Fordonsgas as the creator of the idea to use liquefied methane as fuel in Sweden and its investments in building up an infrastructure for it made it interesting for Volvo to develop a new form of engine that is able to use liquefied methane in an efficient way, without being completely dependent of that source. This was the first step towards the methane diesel technique which is now ready to be launched in the market.

This development of a new engine was only possible due to field tests with companies that became first movers of using this new innovative technology. DHL, Renova and Götene Kyltransporter were these early movers. For all of those companies transportation with heavy trucks is an essential part of their business and they were willing to try new paths to become more sustainable and to make use of a possible first mover advantage.

The transport companies were at the same time driven by a rising demand of their customers for more environmental friendly transportation.

Last but not least it was the Swedish state that closed the circle of the process. By supporting the liquefied methane project in form of the BiMe Trucks project subsidizing the first 100 trucks sold by Volvo the state took an active role in the process.

When the conditions were set for liquefied methane and even an own bio methane production site in West-Sweden, which is the business area of Fordonsgas two further gas providers discovered the potential of the system. Those two companies AGA and EON therefore took part in developing the southern part of the country and the Stockholm region.

The circle is closed and each actor moved one step forward due to the action of another one. No step would have happened without the development of all the other involved actors.

5.2.2 Reciprocity: Both entities co-evolve

This criterion shall secure that all involved actors take an advantage out of the process as co-evolution by definition has to lead to a development of all involved entities. Within the present case, co-evolutional tendencies and development can indeed be seen at all the actors. Volvo strengthens its market position by offering a unique product and by gaining knowledge in the field of liquefied methane and biogas. This knowledge derives from the co-evolutional process. Fordonsgas, AGA and EON, normally being competitors in the Swedish gas market, are capable to establish an environmental friendly alternative to fossil gas by concentrating on providing liquefied methane. The bio methane that can be used is even locally produced and creates jobs in Sweden itself. The facts of local production and environmental friendliness will lead to a better reputation and a more sustainable image for the gas suppliers involved in the process.

The transport buyers DHL, Renova and Götene Kyltransport do also take their advantages from being part of the co-evolutional process. As DHL faces a higher demand for CO^2 neutral deliveries as they can provide, experts of the company are constantly searching for new alternatives (Hammarberg, 2011). The methane diesel technology helps them to satisfy this demand and to reach the own climate protection goals. Their evolutional process to become a "green" transportation company is highly supported by the development of the other actors. Renova and Götene Kyltransporter face similar situations.

Furthermore they see the potential for cost savings after the acquisition costs have been covered.

The state finally has due to its innovative companies a possibility to provide financial incentives in a highly focused way in order to reach its own environmental goals. Furthermore it supports and promotes the own country as a location for research and business .The reputation and awareness of Sweden as suitable location and as a competent partner for environmental technology will rise and will probably create foreign investments which would refinance the own governmental investments in the field of liquefied methane. Foreign investments are also one of the main motivations for Business region Göteborg to promote the process as it helps to highlight the qualities of the Gothenburg region.

5.2.3 Simultaneity: Both entities co-evolve concurrently

To check if the actors co-evolve simultaneously a closer look at the whole situation has to be taken.

The public debate on sustainability and the business interest in environmental friendly solutions that began to rise within the last decade is one of the conditions that might have started the co-evolutional process around liquefied biogas. This made companies like Fordonsgas and Volvo thinking about alternative solutions to fossil diesel. Even though they knew that they cannot change the situation without other actors developing their business models and their way of thinking at the same time. Therefore they had to check early for interested companies that might want to become first movers within the field of sustainable transportation. With DHL, Renova and Götene Kyltransporter they found three early movers who were already searching for alternatives to the use of traditional diesel vehicles.

Also the actions of the Swedish state happened in the same time frame. The BiMe-trucks project which was supported by the Swedish region of Västra Götaland and the Swedish energy agency Energimyndigheten was established before Volvo launched its trucks on the market. The necessity of funding was obvious and the governmental actors took part in the process not after but during the development of the technology by Volvo and the gas providers. Nevertheless, it has to be mentioned that the monetary support of the Swedish state through its energy agency was not just an act to improve the environmental situation. It fell also in a time when the Swedish car and truck industry was hit hard by the financial crisis and the state saw the upcoming unemployment problem. It was therefore also a strategic decision to increase the demand for trucks when politics decided to provide support for the liquefied methane project.

Last but not least, it has to be mentioned that the movement towards renewable fuels was to a large extend supported by local initiatives and by municipalities as well as regions like Västra Götaland which took a lead in the development of sustainable mobility.

5.2.4 Genetic fixing: Change is permanent

Production, distribution and use of liquefied biogas are an attempt for the different companies to be more sustainable and to reach their environmental goals. As a CO^2 neutral alternative to fossil diesel, the use of liquefied biogas as truck fuel can make a decisive difference when it comes to the environmental footprint and even the use of non-biological methane leads to improvements. The topic could though also be used for a company to greenwash its image. If a large company in the long term plans to use one single methane diesel truck but is running the rest on fossil diesel, could allow them to advertise their efforts towards sustainability. It would though not change their ecological footprint dramatically. To check if the criterion of genetic fixing is fulfilled the corporate philosophies and especially the long run environmental strategies of the several companies have to be analyzed.

a) Fordonsgas

The vision of Fordonsgas is to participate in the process of establishing fuels that are environmental friendly. To work towards this goal, Fordonsgas is a company specialized on gas as vehicle fuel. It is not just a short term idea to do something good for the environment but it is a long-term goal to establish transportation mechanisms that are sustainable and not harmful for the environment (Fordonsgas, 2011). By initiating the process of using liquefied biogas as fuel for heavy trucks, Fordonsgas shows one more time that sustainability is not just a marketing idea but a concept for the future. With the investments in Sweden’s first production plant of liquefied biogas in Lidköping in Western Sweden, Fordonsgas takes an important step towards the long term development of a sustainable transport system in Scandinavia.

b) EON

The energy provider announces to treat the work towards a better environment as a central field of its business activities. Environmental questions are on top of the agenda and all business units of EON in Sweden are certified with the ISO 14001 environmental standards. Eon highlights four major fields of action concerning its environmental operations:

- Climate
- Renewable energy
- Energy and resource efficiency
- Sustainable development of society

Major investments have been taken to develop the own influence on the environment and to provide new forms of energy production to its customers. Nevertheless EON is also known for being an operator of nuclear power stations, coal-fired power plants and other less sustainable forms of energy production. In the market for liquefied methane in Sweden, EON can neither be seen as the initiator of the process, as it was Fordonsgas who started the process as gas deliverer. Nevertheless, a strong commitment towards renewable forms of energy production can be seen. According to Porter (2006) an idiosyncratic motivation for going green has to be identified to fulfill the criterion. This can be seen at EON as the investments into renewable energies are growing and the environment is seen as an important part of the business. The actual motivation for the development, might it be due to financial possibilities or due to an intrinsic believe, is not important for fulfilling the criteria. The role that sustainability plays when it comes to strategic decisions is important and in EON it can be seen as a core part of strategic decisions.

c) AGA

The gas provider AGA was, like EON, not the initiator of the process under dicussion. Nevertheless, it is an important actor within developing the infrastructure of the filling stations being responsible for the Stockholm area. Therefore AGA was still quite early involved in the process. The company sees huge potentials in the market for biogas and is as a member of the German Linde Group dedicated to the high environmental standards of that global actor. Therefore, AGA Sweden is certified with the ISO 14001 environmental standards and is aware of the advantages that environmental friendly industry solutions can provide for business and society.

d) VOLVO Group

The Volvo group sees environmental challenges not as problems but as chances (Volvotrucks.com, 2011). The field of action is thereby not limited to the development of new, more efficient trucks but also on the production facilities themselves. A company as big as Volvo, can see enormous potential in sustainable fields of business. With the development of the methane diesel technology, Volvo trucks proved that it has understood the needs for sustainable transportation. Its leading role in the co-evolutional process concerning liquefied methane makes the strong commitment towards sustainability obvious. The advantage for Volvo with its new truck engine is of course the one of being a first mover in a rapidly emerging market. The potential success will motivate the leaders of the company to invest even more in sustainability and into new technologies that reduce the environmental impact of the trucks as well as of the production sites. The methane diesel technology has set the foundation of long term success for Volvo and future developments towards sustainability will come both due to economical factors and due to a good reputation.

e) DHL

DHL as a global transport supplier sees its own responsibility in making transport solutions more environmentally friendly and has therefore developed a corporate environmental policy that has to be considered for all of DHL's projects and developments.

According to DHL environmental protection is integrated in the daily operations and shall be a value-creating factor in the long-term. Sustainability is seen as a concept that each employee has to live. Voluntary standards like the ISO 14001 and the UN Global Compact requirements have been fulfilled and are communicated to employees, customers and to the members of the whole supply chain. According to Ulf Hammarberg, responsible for environmental affairs, DHL has its global environmental standards but the different subdivisions have the authority to look for more sustainable alternatives within DHL's business activities. A country like Sweden offers a comparatively large variety of solutions when it comes to environmental protection and cost savings to more efficient technologies. This makes the Swedish division an important actor within the whole company and it is for sure a motivating factor for DHL's employees.

f) Götene Kyltransporter

As a provider of transportation for cooled and frozen goods Götene Kyltransporter deals with massive energy use both for driving and cooling. The company can therefore gain a lot by reducing its energy use. Ulf Johansson, owner of the company, has personally a strong interest in sustainability and environmental friendly transportation. As the leader of the company he can influence the development towards environmental friendliness of his truck fleet and he has the possibility to motivate his employees for this topic. Götene Kyltransporter became a first mover in the market when it comes to transportation based on liquefied methane and can therefore offer a lower CO^2 impact of his services than other companies might be able to. Moreover, drivers get a bonus payment if they drive in a fuel saving way which creates additional motivation for sustainable behavior. The company becomes a competitive part of the supply chain of his customers in this way as the demand for CO^2 friendly or even CO^2 neutral transportation rises rapidly. Sustainability is a business model for this company and the tools and measures are located in the core of the firm. The owner enforces the use of new technologies and sustainable development happens as a natural process.

g) Renova

Renova sees itself as a leading sustainable actor within the fields of waste collecting, sorting and recycling. Its environmental ambitions are focused on the business field of the company. As a local waste management actor, Renova implements new technologies of collecting and processing waste to reach a better outcome for the environment and for the customers. Renova is owned by several municipalities of Västra Götaland region. Therefore it has to follow the environmental guidelines of those municipalities as for example the ones of the City of Gothenburg. The local governments set high standards when it comes to sustainable development of the urban environment. Renova is due to this constellation highly involved in a number of projects to reduce energy consumption and to establish a more sustainable recycling environment (Thulin, 2011).

Nevertheless, the company has as a goal to offer sustainable solutions to their customers without losing sight on the economical parameters that have to be fulfilled. Environmental topics are part of every innovation that is assimilated by Renova. The waste business offers furthermore ideal conditions for sustainable energy production which can be easily implemented in the portfolio. Every single part from collecting the waste to recycling it is looked on from an environmental perspective. The observer gets the feeling that sustainability is a fixed component of the company's philosophy. This philosophy at the same time is the driver for Renova's first mover role within the liquefied biogas development in West-Sweden.

h) Swedish State - Swedish environmental objectives

The Swedish State, as one of the actors in the development of liquefied methane as fuel for trucks, has set itself a goal for the future state of its environment and has therefore created a common philosophy. 16 objectives for a better environment shall help to give orientation, advice and a roadmap for the most important actions towards a better environment and towards a more sustainable Sweden. Adopted by the parliament, the objectives shall help to solve Sweden's environmental problems by 2020. It has to be highlighted that those objectives are guidelines that state owned organizations have to follow. Furthermore they shall be a motivation for private people and companies. Nevertheless, companies, municipalities and institutions can have additional or own objectives how to reach their own environmental goals. The fact that general guidelines are existing is though an important sign of a conscious state that wants to provide everybody with support to create a healthier and better natural environment.

Concerning the present case about establishing liquefied methane and even bio methane, some of the objectives are more important than others. The most important shall be mentioned here:

Objective 1: Reduced Climate Impact

The reduction of the nationwide CO^2 production is a major goal of Sweden as it is also agreed upon on an international scale within the United Nations. The use of biogas as truck fuel can contribute massively to this development. So far long-haul road transportation with heavy trucks is totally based on fossil diesel producing a large amount of CO^2 emissions. The use of biogas on the other hand releases only the amount of CO^2 that the plants used for the production process have accumulated during their growth period. Biological fuels have a less harmful impact on the climate systems than fossil fuels and are therefore a helpful alternative to reach climate protection goals.

Objective 2: Clean Air

The clean air objective tries to highlight the problem of air pollution. Road traffic is a major polluter and solutions are welcome. Liquefied bio methane as fuel would help in this case to reduce the pollution and to improve the air quality. The major pollution problems can be seen in Sweden's large urban centers. Environmental friendly transport alternatives for goods and people will improve the air quality without reducing the comfort and speed of travelling.

Objective 9: Good-Quality Groundwater

Many fossil fuels can be harmful for the environment in cases of accidents where the fuel can pollute the groundwater. Gas-driven vehicles reduce this risk. If the fuel is even created on a biological bases less dangerous substances are contained in the fuel. Accidents in road traffic are just a small concern in governmental groundwater-safety considerations. But even small contributions are important to reach the environmental goals.

Objective 13: A Good Built Environment

This broad objective includes many factors. The quality of living in urban areas shall be improved with the considerations of this objective. Transportation and the fuel consumption as well as the emissions related to this topic play a major role here. The increasing use of locally produced biofuel can contribute to a healthier environment in cities. The liquefied bio methane project therefore offers a new possibility for Swedish towns apart from biodiesel. It is positive for the Swedish government to have different solutions to reach its goals to choose from. This is a motivation to support the biogas project from the beginning.

Future generations shall profit from these objectives and everyone in the Swedish society is motivated to participate and to play their part. Adapted to the present case authorities like Trafikverket and Energimyndigheten, businesses like Volvo, Fordonsgas and Renova and private consumers deciding to purchase environmental friendly ways of transportation have a responsibility to reach the goal. With this long-term concept the Swedish state as an actor in the biogas development fulfills the criteria of genetic fixation as many actors today but also future generations are motivated to participate in a sustainable development for a better environment.

5.2.5 Boundary crossing: Involves two unlike, interacting species

The boundary crossing criterion makes it necessary that at least two different species are involved in a co-evolutional process. In an organizational context this means, that at least two actors of two different business fields are involved (Porter, 2006).

In the present case it is obvious that many actors are involved and that they come from different fields. As already identified, Volvo represents the role of the manufacturing company that delivers the technical features for the trucks. Fordonsgas, AGA and EON on the other hand, are the gas providers which are responsible for building up a suitable infrastructure. This alone would fulfill the boundary crossing criterion but as this study has already shown there are more actors involved making the co-evolutional process more complex. The transport buyers and first movers DHL, Renova and Götene Kyltransport represent customers and users. All of them provide transports but they are no direct competitors as they offer different services. While Renova is a classical waste managing company, DHL and Götene Kyltransport offer delivery services. Götene Kyltransport is thereby specialized on transportation of cooled and frozen products in the southern parts of Sweden and Norway. DHL serves companies and private individuals with small or big scale goods delivery all around the globe with subdivisions in many countries, Sweden being one of them.

Apart from business it is again the state that shall be mentioned as an actor. The government and the governmental agencies are often waiting for climate smart investment projects. The developments towards liquefied bio methane as truck fuel, gave them the possibility to elaborate on scenarios how to support the participating companies and in how far it helps to reach the governmental climate goals.

5.2.6 Organically derived: Emergent and responsive, the outcomes of self- organization are unknowable in advance

According to Porter (2006), a co-evolutional process has to be unplanned and it has to have an unpredictable outcome. In an organizational context it is difficult to argue that something happened unplanned. The decisions taken by the leader of the involved companies have indeed checked the market situation for their products before they started to develop or launch them. The criterion though is not checking for single decisions that have been made in a company. The initiation of the development of the liquefied methane market itself was the unpredictable event. The search for alternative ways of producing energy or fuel is not that old. Even the big oil-crisis in the 1970's has not really changed the world's way of producing and consuming energy.

It was hard to believe that big companies will try to go completely new ways in the field of transportation and a co-evolutional situation as we see it today in Sweden has not been started. The climate problems that the world faces now in the early 21st century have other effects. The global discussion about alternative ways of energy production and the high demand for renewable energies was not predictable. Sustainability has become a hot topic in many fields, may it be in politics, business or society. Sweden is an early mover in this movement and has the knowledge and the will to provide new solutions. Recycling, alternative ways of energy production and a closer relation to nature have created a special environment that made the development of new techniques possible. This initiating process was the unpredictable factor that started the co-evolutional development of the involved actors of the present case as all of them strived for more sustainability and all of them followed the societal demand for products and services that cause less harm for the environment.

The process of building up an infrastructure for liquefied methane as truck fuel is, as good as it is, seems not automatically crowned with success. Other technologies might convince the consumers more or new developments will be even more efficient. Business has to take risks to harvest success but a co-evolutional process, as efficient as it might look like, is not automatically leading to the perfect outcome. It is much more a means to develop in order to be better and more efficient than the competitors. The success and the outcome of the liquefied methane project in Sweden is no exemption from that fact.

5.3 Sweden – conditions

The situation in Sweden can be seen as a role model for further developments in other markets. The co-evolution of the different actors is not just interesting from an academic point of view but it leads to advantages for the actors themselves. The important factors in the Swedish development are that actors from all fields within the transportation sector are working together. Truck manufacturers, gas suppliers, transport buyers and public authorities are involved. With one of them missing the project would have not come so far as it is today with the first gas station for liquefied truck gas being in use in Gothenburg and with Volvo successfully testing its new methane diesel technology in co-operation with the transport buyers. One of the factors that are a decisive support for the whole process is the BiMe Trucks project which creates a financial support for the transport buyers when operating the new trucks. To implement the idea of driving trucks with liquefied methane in other countries than Sweden such a support system financed by public authorities might be necessary to install as well.

Figure 12, Filling station for liquefied methane/ Stigs Center Gothenburg. (Picture: Sporer)

5.3.1 BiMe Trucks

BiMe Trucks is a project created as a support for implementing the technology of using liquefied methane as truck fuel in Sweden. On the one hand possible customers can be financially supported when purchasing trucks with the new methane diesel technique. On the other hand gas suppliers get financial incentives for building up the infrastructure in form of gas stations in strategically useful locations. The motivation for the project is to establish an economically competitive alternative to heavy goods on road transportation based on fossil diesel. The reduction of negative environmental influences is an additional driving force and serves also as a legitimacy reason for the institutions spending state money on the project.

The formal goal is to support the purchase of 100 methane diesel trucks in Sweden and to build an infrastructure including gas stations in Stockholm, Malmö and Jönköping while another one is already existing since October 2010 in Gothenburg.

The participators in this project are some of the actors of the co-evolutional process under discussion in this study. The leading gas suppliers E.ON, AGA and Fordonsgas as well as Volvo trucks and Energigas Sverige take part. The project leader is Business Region Gothenburg (BRG). Other actors, like the transport buyers, can be seen as direct profiteers, DHL and Götene Kyltransport have purchased trucks with the support of the project.

BiMe Trucks can be seen as a communication tool combining the several actors on an economical level. The business actors identified in the present co-evolutional situation are all involved in the project and so is the Swedish state. It is to say that the financial incentives provided by the project are provided by governmental organizations. The developments in the surrounding region of Gothenburg are supported by Västra Götalandsregionen. Purchases of trucks and building of gas supply station in other parts of the country are directly supported by Energimyndigheten, the Swedish governmental energy agency. The maximum financial support per truck is 175.000 SEK.

The support is organized in a way that not the manufacturer Volvo gets direct financial support but the purchasers of its products. Volvo itself therefore profits as the first 100 methane diesel trucks are subsidized by the state and might therefore be even more attractive for the customers. The customers, which have to cope with a new technology get the chance to save money in the short and in the long run and can improve their overall ecological footprint. Through BiMe Trucks the Swedish state directly supports the development of liquefied methane as fuel for heavy trucks. It participates in the co-evolutional process as an active member by creating a supportive environment for the involved companies.

5.3.2 Appraisal of the situation in Sweden

As a summary, it can be said that the development of the Swedish market for liquefied methane is heavily influenced and pushed forward by the co-evolutionary process between the different actors. Trust was created and the hope for being a first mover and to create a competitive advantage can be seen as an additional motivation apart from the fact that the new fuel technology is more sustainable and better for the environment.

From an economical point of view, the positive progress of the project is not a surprise as many preconditions were fulfilled in Sweden to start the co-evolutional process. Not only is the Volvo group a key actor in the Swedish market it is also important enough to make governmental organizations being interested in supporting single development projects. Energimyndigheten and Västra Götalandsregionen directly offer financial support to truck buyers via the BiMe Trucks project. Furthermore, the gas suppliers are cooperating to establish a good and growing infrastructure in the south of Sweden to make the new fuel available for logistics companies that drive long distances with their trucks.

The actors mentioned in this study created a suitable network and experimentation field for liquefied methane supported by the business network Business Region Göteborg. The region can now show visitors and engineers from all over the world how such a system can work and which challenges have to be faced. This is an advantage for the region itself and for its companies and organizations as successful engineering and sustainability can be presented and promoted. Due to a positive image within the sustainability topic, West Sweden might be able to attract more companies to create their permanent establishments in the region. From such a growth, not just the business region but also the actors of the early co-evolutional process would profit.

The interest of different actors in the same project creates the needed success and can lead to an advantage for their business models. Nevertheless, it has to be said that the Swedish market alone is not enough to establish the new technology of Volvo and the liquefied methane as truck fuel on a large scale. The Swedish market is simply said too small for such a project. The actors and mainly Volvo is therefore establishing and promoting its new technology on many other markets to really make a competitive advantage out of it. For logistics companies like DHL it would be interesting to be able to operate LNG trucks between countries. This would make it necessary to develop an LNG infrastructure in those markets as well. Especially the geographical position makes for example Germany an important site for such a development.

5.4 Germany – conditions

Sustainable transportation and renewable forms of energy and fuels are an often discussed topic in Germany and research and development follows several paths to find suitable solutions for the challenges of the next decades. Private business but also the government pushes this process forward. The renewable sources act from the year 2008 was an important step for Germany to develop and prioritize renewable forms of energies. This does not just positively influence renewable energy production but also supports the production of fuel out of biomass. An important step has been done with this law and it has set the corner stone of a more sustainable energy production.

5.4.1 Renewable Energy Sources Act, EEG (Oct, 2008)

In October 2008 the German government released the act on granting priority to renewable energy sources, known as the Renewable Energy Sources Act (EEG). It was from thereon the basis of governmental subsidies for investments in the field of sustainable energy production. Furthermore, this act was thought to raise attention to the climate and environmental protection issues and to create a sustainable supply with energy by reducing the use of fossil resources. It provides incentives to develop technologies that use renewable energy sources to produce electricity, heat and fuel. Therefore, the act is also a means to reduce the German impact on the climate and to become more independent from fossil, non-renewable energy carriers. It includes the following forms of producing energy from renewable sources: hydropower, landfill gas, sewage treatment gas, mine gas, biomass, geothermal energy, wind energy and solar radiation. As the focus of this thesis lies on the use of biogas, only the regulations for electricity from biogas are explained more in detail.

The act names the formal goal that with the year 2020 renewable forms of energy production shall reach at least a share of 30% of the total electrical power supply (section 8(1)). Operators of public electricity networks have to buy electricity produced by using renewable energy prior to unsustainably produced energy (section 2). The act also defines the tariff paid for electricity produced with renewable sources. Section 27 exemplifies the tariffs for electricity from biomass as follows:

1. 11.67 cents per kilowatt-hour for the first 150 kilowatts of output,
2. 9.18 cents per kilowatt-hour for output between 150 and 500 kilowatts,
3. 8.25 cents per kilowatt-hour for output between 500 kilowatts and 5 megawatts, and
4. 7.79 cents per kilowatt-hour for output between 5 and 20 megawatts.

Those bonuses are valid for installations commissioned prior to first of January 2010. For installations in subsequent years the bonus will be reduced degressively each year (Section 20). The reduction rate for biomass is 1 per cent (Section 20 (2) 5.)

Additionally to these tariff payments the bonuses for electricity produced by biomass can increase due to three further factors. A technology bonus is paid for using innovative technology as in the case of producing biogas. The bonus for electricity from energy crops is paid for using renewable crops and liquid manure. Finally a bonus for combined heat and power generation is granted. Those bonuses are each 3,0 cents per kilowatt-hour (Section 27 (4)).

5.4.2 A lack of governmental support for using liquefied methane as truck fuel

The Renewable Energy Sources act of the German government was an important step to support und subsidize renewable forms of energy production. If the methane is produced from biomass this will push the development of the infrastructure forward. It has though to be mentioned that such an advantage does not help to introduce liquefied natural methane to the market. This is as fossil fuel not eligible for subsidies.

Nevertheless, the national production of biogas will be more attractive and the use of biomass will increase. The German government though, does not offer a direct support for biofuel. The only passive way of support is the total fuel tax exemption for biofuel until 2015. This can be seen as a support for liquefied biomethane but it is not an advantage for liquefied gas in general. If the production of LBG is not high enough LNG has to be used by truck operators. This natural gas is not exempted from the fuel tax. While in Sweden the truck operators are awarded for driving a truck on liquefied gas, the German truck operator or the Swedish truck operator in Germany only gets governmental support in the case of using biomethane which will not be broadly available in the beginning. From an environmental point of view this might make sense but it is one of the reasons why it will be hard to develop the German market for liquefied gas as fuel for trucks.

A reason why the German government does not explicitly support the use of gas is that 85% of the gas used in Germany is imported from other countries (BMWi, 2008). The main gas deliverer is Russia and a new gas pipeline from Russia to Germany is currently under construction in the Baltic Sea. Another reason for the lack of interest in LNG is that Germany does not have an own LNG terminal in one of its harbors. This would be essential for securing the gas delivery which is mainly done via vessels. Current deliveries are processed via Rotterdam in the Netherlands and Zeebrügge in Belgium. To become more independent and to make LNG more attractive for the German market an own LNG terminal would be necessary and might save costs compared to the delivery from Belgium and the Netherlands (Rempel, 2007). The delivery of LNG via vessels is though only more profitable compared to the gas delivery via pipeline if the transport distance is larger than 3000km (Rempel, 2006).

5.4.3 Appraisal of the situation in Germany

A similar co-evolutional situation as it can be seen in Sweden lacks the necessary actors in Germany. Throughout the study it became clear that the innovative system developed by Volvo and the gas suppliers in Sweden does not exist in a similar in the German market which has several reasons that shall be listed in the following.

Germany, as an important industrial country in the center of Europe has many actors working on a more sustainable transport system. As a country which is situated in the Scandria corridor for sustainable transport it plays an important role within this study.

While the Swedish state is supporting the methane diesel technology of Volvo in form of financial support for the first 100 truck buyers, there is no similar support for the German market. This is relatively easy to explain and became clear during interviews with the actors of the Swedish market. The Volvo group is a key company within the Swedish industry and state owned organizations are therefore more willing to support the technologies and concepts developed by this company. The variety of key industrial actors in Germany is much higher and similar support for project including "ideas" generated in Germany might be found put there is simply no reason for the German government to support the introduction of an engine technology that is not developed by one of the German truck manufacturers.

Furthermore, it has to be mentioned that German truck manufacturers like Mercedes-Benz and MAN concentrate on the development of technologies that use other fuels than liquefied gas. Compressed gas is much more common and a better infrastructure is provided for this kind of fuel.

Interviews with several German associations that work in the field of gas and transportation have tightened this skeptical view on the broad use of liquefied gas as truck fuel for long-haul transportation on German roads. Andrea Horbelt of the association for biogas (Fachverband für Biogas e.V.) mentioned that liquefied gas does not play an important role when it comes to fuel in Germany. There is so far only one gas station in Germany that provides liquefied methane. It is situated in the town of Jameln in Lower Saxony. So far, there is no large scale project planned to establish more gas stations or to convert more biogas to liquefied biofuel as Birgit Maria Wörber of "gibgas" states. Gibgas is another association specialized on promoting gas as fuel. She mentioned honestly in her own words that "liquefied gas as truck fuel does not exist in Germany" (Wörber, 2011). She adds though that the topic of biogas is well established in Germany. Therefore she highlights the activities of the local gas provider in the city of Munich where biogas is a steady component of the sold gas as up to a level of 50%. For the whole German market Wörber lists that 150 of the 883 CNG gas stations in Germany do already sell a mixture of biogas and natural gas. The result that one can draw out of his information is that gas as fuel is well discussed and even widely accepted in the German market and also the use of biogas is promoted and is under constant development. Nevertheless, experts make clear that the German actors focus on the solution of CNG instead of LNG. This difference and a general lack of standardization makes it hard for the Swedish actors to find and establish co-operations with actors on the German market but more difficulties can be found.

The production rate of biogas in Germany though is comparatively high and large private investments mainly of farmers have been made. Therefore the production rate of biogas in Germany is 2300 Megawatt produced in around 6000 biogas production sites (gibgas, 2011). The main obstacle for the fuel industry is that this gas is mainly used for energy production and heating instead of being upgraded to fuel. The subsidies paid by the state as they have been introduced by the Renewable Energy Sources Act, are not dependent on the different ways of using the biogas. The important factor for the financial support is the biogas production, not if it is used for heating, energy production or as fuel.

Market mechanisms steer the decisions of the farmers. The technology for upgrading biogas to fuel is available. If the farmers can realize a higher margin by producing fuel than by producing heat it can be assumed that many will change to produce the fuel. The current development of the German energy market though does not support such a theory. After the terrible accident in the nuclear power station Fukushima-Daiichi in Japan the public insurgence against nuclear power became strong again. The government decided to shut down the oldest nuclear power stations and to check for their security. It is expected that they will not be reactivated and that Germany will not produce any nuclear power after 2020. To reach this goal which is wanted by the majority of the German people, other energy sources have to fill the gap to avoid making Germany dependent on electricity imports from other countries like France that exports mainly electricity generated by nuclear power plants. Electricity produced from biomass will therefore be one of the renewable energies that will account for a sustainable energy mix. Energy prices in Germany are expected to rise within the next years due to this development and it could then remain more profitable for farmers to produce heat and electricity than producing fuel.

Another important factor to be considered when analyzing the situation of the German gas market is the prices for different kinds of available fuel. Not just the costs for Diesel, LPG and CNG but also the tax rates for those types of fuel vary between Germany and Sweden as the following chart makes clear.

	Germany			Sweden		
	Diesel	LPG	CNG	Diesel	LPG	CNG
Fuel costs	1,40 €/l	0,765 €/l	1,26€/kg	1,51€/l	1,05€/l	1,64€/Nm3
Fuel costs per kWh	0,14€/kWh	0,12€/kWh	0,10€/kWh	0,15€/kWh	0,16€/kWh	0,15€/ kWh
Taxation	0,47€/l	0,09 €/l	0,18€ /kg	0,55€/l	0,25€/ kg	0,18€ /kg
Taxation per kWh	0,05€/kWh	0,01€/kWh	0,01€/kWh	0,06€/kWh	0,02€ /kWh	0,01€/kwh

Figure 13: Fuel prices and fuel tax in Germany and Sweden (calculation/sources Appendix D)

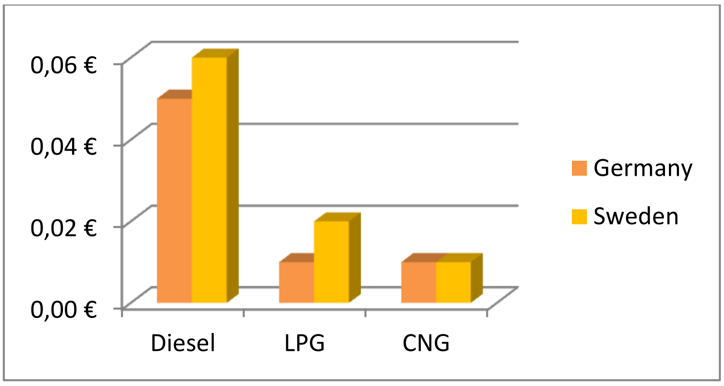

Figure 14: Fuel tax per kWh in Germany and Sweden

The figures show that fuel prices in Sweden are slightly higher than in Germany but the main focus of this chart lies on the fuel taxes. The diesel tax in Germany is lower than in Sweden which makes the need for an alternative in Sweden more urgent than in Sweden. But the charts can also show that the tax for LPG is double as high in Sweden as it is in Germany. The Swedish government restricts the use of LPG with a higher tax with the result that the total number of LPG driven vehicles in Sweden is low. LPG in Germany though is a very popular alternative for drivers as it is a cheap alternative to diesel. This gas does though not contribute to better environmental conditions as it is a fossil resource.

Nevertheless the existence and the broad availability of LPG can be an obstacle for the introduction of liquefied LNG on the German market. Today mainly used by car drivers the possibility of converting a truck engine from diesel to LPG use can become popular. Such a conversion costs around 7000€ (rrag, 2011) and is therefore cheaper than the additional costs that Volvo calculates for its methane diesel technology. Furthermore the advantage for transport buyers to convert their trucks instead of purchasing a new one might be an argument towards LPG use.

Many obstacles can be identified when the question if liquefied methane can be successful in Germany is discussed. The conditions are far away from being optimal and other fuel alternative make it hard for LNG to succeed. On the other hand it has to be said that so far there was no real attempt to implement liquefied methane as truck fuel in Germany. The Swedish project has therefore a chance to expand to the German market if suitable partners can be identified and motivated to participate.

5.4.3 Co-evolution in Germany

It already became clear that in the German market there is no comparable co-evolutional situation as it can be seen in Sweden when it comes to the development of the market for liquefied methane as truck fuel for long haul transportation. The basic conditions are different from those in Sweden and possible actors focus on other projects that in their eyes might be more efficient or realistic. Olof Källgren from Linde in Munich who is responsible for the gas market development in Germany calls the situation in Germany a "hen and egg" situation. Who will be first to make the necessary step? Linde itself seems to be interested but it has exactly the problem that the co-evolutional process in Sweden solved. At least one actor of every field (manufacturer, gas provider, transport buyer) has to be involved to develop the market for liquefied gas. For Linde it makes no sense to develop an infrastructure for liquefied gas as truck fuel if there are no users for it. Governmental support as available in Sweden in form of the BiMe Trucks projects cannot be expected from today's point of view as there are no actors cooperating to bring the process further.

Nevertheless, Germany can be seen as a possible actor within the co-evolutional process of the Swedish liquefied gas market. Interviews with representatives of large logistics companies like DHL and DB Schenker showed that long haul on road transportation between Sweden and the distribution centers in northern Germany is an important factor of their business fields. Operating trucks on LNG from Sweden to Germany would make it necessary for them to refill their trucks not just in Sweden but also in Germany. Therefore, a regional pilot project could be arranged in North Eastern Germany to strengthen the sustainable transport corridor between Scandinavia and central Europe.

The German legislation and the general conditions of the market do not seem to be optimal for LNG/LBG as truck fuel in Germany. But the demand of the actors of the Swedish market could be the beginning of a positive development of the German market for liquefied methane and would finally make the Swedish project also more successful and competitive. A close cooperation would therefore be necessary to make Germany part of the co-evolutional process. This could then be the starting point of further development towards using liquefied methane in Germany if this is wanted. Afterwards, a similar network of interested actors could come up to use and promote the technology and to develop the market with the help of the discussed co-evolutional mechanism. The main obstacle would though be to compete with other technologies that might be favored by the actors of the German market.

6. Conclusion

The process of establishing liquefied methane as truck fuel in Sweden - to contribute to a sustainable transport corridor - is highly influenced by the co-evolutional development of the actors. It becomes clear that each involved actor is dependent on the development and the will of the other actors to contribute their part to the whole project. The present work describes the situation of the participating actors with the help of the organizational co-evolution theory. The analysis by using the six criteria of organizational co-evolution shows the need and advantages of the collaboration of the actors.

Organizations, institutions, companies and all other actors have to be interested in not just short term goals that might help them to earn money, improve their reputation or solve problems in an unsustainable way. But they have to act according to their philosophy concerning sustainability to change their environment and to successfully cooperate with business partners and competitors. The situation on the Swedish market makes clear that all successful actors take advantage of their effort. It might just be a first mover advantage that Volvo Trucks has developed with the new methane diesel technology or it might be the gas producers and deliverers that helped to built up a better gas infrastructure and to generate new customers. Even though the project is still quite young and the long term success cannot be predicted today, trust has been built which will make it easier to co-operate in future projects and also with new partners.

The situation in Germany can be seen as the contrary of the constellation in Sweden and is therefore very helpful to fully understand the advantages of the co-evolutionary situation that makes it easier and more effective to establish new technologies on the market. In Germany, the possible actors and supporters do currently not agree on using liquefied methane as truck fuel. Major actors like Linde are interested in a development but lack suitable partners for a co-evolutional process. Notwithstanding the fact of being the leader in the gas market, a single company will not be able to establish a future technology on its own. For the future it should therefore be considered to integrate important actors from Germany into the Scandinavian process instead of starting an own co-evolutional development in Germany. This will be faster and could lead to harmony within the process. The danger of a lack of standardization when it comes to technology and filling stations will more likely be avoided. It is the task of the Swedish actors to motivate and integrate possible actors in the German market. Both the potential and the interest do already exist -

it is rather a separation in the way of thinking and a lack of contact that lead to the dilemma of not being able to integrate the German market in this project that is set to contribute to the mission of creating a sustainable transport corridor. The members of the Scandria project have to find a way to enlarge or to generate new co-evolutional connections with many different actors developing independently but simultaneously towards the same sustainable goals.

Liquefied methane as truck fuel is, from an environmental point of view, an excellent possibility to break the dominance of fossil diesel as truck fuel. Liquefied gas makes it possible to arrange long-haul transportation on road, as a larger amount of gas can be stored in the vehicle. Volvo's hybrid form of combining diesel and liquefied methane brings the necessary fuel security if no liquefied methane filling station is available. Truck operators will therefore always have the possibility to be independent of the gas infrastructure if necessary. Nonetheless, business and new forms of technology alone are not the solution for the environmental problems of the 21st century. National states and political institutions have to create the frameworks and guidelines towards a sustainable society. As authorities, they play an active role in every co-evolutional process and they have the power to steer large scale projects that are carried by many different actors. Push factors, like binding environmental laws and guidelines, as well as pull factors like subsidies for successfully sustainable projects have to be provided.

The author of this thesis analyzed the relations of the actors and the process of developing the infrastructure for liquefied methane as truck fuel. The importance of the collaboration between the different actors is highlighted and the current status of the Swedish as well as the German market infrastructure for liquefied methane is presented. While Sweden is ready to take this next step towards a more sustainable transport system, the German actors are hesitating to establish a similar system based on liquefied methane.

By adapting the theory of organizational co-evolution to the present case, the author was able to show the importance of suitable tools to analyze real life situations. The challenge of transferring a theoretical model that was originally generated by biological sciences to a strictly organizational topic made it necessary to understand both a biological and a human way of interaction. To find out about similarities and major differences of the two disciplines strengthens the theory for organizational use. Topics like conscious co-operation and communication had to be considered when analyzing business to business relationships even though they are not part of the biological co-evolution theory. The

transfer was done earlier by scientist like Porter (2006). Instead of using the criteria and on a practical example – like it is done in the paper at hand - his work concentrates on placing the co-evolution theory amongst other organizational theories. With the present study, the criteria developed by Porter were used to analyze a practical case, therefore became much clearer and their needs more understandable. Furthermore, a comparison of the two markets Sweden and Germany became possible. It can now be seen why liquefied methane is already an available kind of fuel in Sweden but not in Germany.
One example is though not enough to show the full potential of a theory like the one about organizational co-evolution. Raising attention of the advantages that results from a co-evolutional process have to be further highlighted. They might vary in different situations and can therefore not be generalized and transferred from one case to another.

Finally, further research should therefore concentrate on describing similar constellations as they can be found in the Swedish development of liquefied methane as truck fuel. Many different interdisciplinary situations are worth to look at. The organizational co-evolution theory is quite flexible when it comes to the topic that it is used for, but each additional example helps to fully understand the potential of co-operations and collaborations. Especially considering the recently booming environmental sector, in which the cooperation of actors of different organizational fields and institutions is an essential step towards successful implementation of new technologies, ideas and business models. Research that leads to a better understanding of this originally biological phenomenon, where actors evolve due to the change of one another, will have the potential to convince more actors to take the necessary steps and to start communicating with possible essential partners.
Liquefied methane and the future possibility of using bio methane as truck fuel for long long-haul transportation is an extremely important step towards more sustainability and environmental friendliness in the transportation sector. A true competitor for fossil diesel is found and the CO^2 production rate of long-haul on road transportation can be dramatically reduced.

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8. Appendix

A

Main Questions to vehicle manufacturer concerning the development of the liquefied methane infrastructure in Sweden

1. Would the development of the new methane diesel technique have been possible without the simultaneous development of the gas infrastructure in Sweden by Fordonsgas, EON and AGA?
2. In how far where possible customers (early movers like DHL, Renova, Götene) involved/ informed about the development process?
3. Did the global discussion about creating a more sustainable transport system influence the decision of constructing the new system?
4. Who in your opinion are the most important actors when it comes to prepare the market for liquefied methane and to be a real competitor for fossil Diesel?
5. The new engine system is a hybrid system between Diesel technology and liquefied methane technology. Are such hybrid forms necessary because the infrastructure environment is not changing fast enough?
6. What in your opinion should the state do to accelerating the success of more sustainable fuels?
7. Right now, there are only a few stations that offer liquefied methangas in Sweden. In how far do you consider the development of that infrastructure important and which demands do you post to the gas suppliers?
8. Is communication an important factor to coordinate the development of infrastructure, engines, state and customers or are the necessary developments happening naturally?

B

Main Questions to transport buyers concerning the development of the liquefied methane infrastructure in Sweden

1. What are the main environmental goals of your company?
2. Which advantages do you see by purchasing a truck running on liquefied methane gas?
3. How important is the customer demand for more ecological transportation/services in the decision process of purchasing new transportation vehicles?
4. Do you consider it to be a competitive advantage for your company to be a first mover when it comes to sustainable transportation on liquefied methane?
5. Right now, there are only a few stations that offer liquefied methane in Sweden. In how far do you consider the development of that infrastructure important and which demands do you post to the gas suppliers?
6. How should the support from the state look like? Should the state support the purchasing of the trucks? Should the state subsidize biofuel? Or should there be rewards for reaching climate goals?
7. Who in your opinion are the most important actors when it comes to prepare the market for liquefied methane and to be a real competitor for fossil Diesel?
8. Is communication an important factor to coordinate the development of infrastructure, engines, state and customers? In how far did your company communicate with Volvo and gas suppliers like Fordonsgas when you have considered using trucks running on liquefied biogas? Who did the first step towards this development cooperation?
9. Is it necessary for your company that also other countries like for instance Germany build up a good infrastructure for liquefied methane? Why, why not?
10. How should the support from the state look like? Should the state support the purchasing of the trucks? Should the state subsidize biofuel? Or should there be rewards for reaching climate goals?

C

Main Questions to gas providers concerning the development of the liquefied methane infrastructure in Sweden

1. In how far is the development of VOLVO's methane diesel engine important when it comes to the development of the Swedish market for liquefied methane?
2. Is it necessary to convince companies to use liquefied methane as a substitute for diesel or is this a natural process as the advantages are obvious?
3. Do possible monetary incentives from the state influence the development of liquefied methane and the infrastructure to sell it?
4. Does the development of the liquefied methane infrastructure in other countries like Germany play a role for your company when it comes to domestic methane infrastructure development?
5. What are the main advantages/ drivers for your company to develop the market for liquefied methane in Sweden?
6. Is communication an important factor to coordinate the development of infrastructure, engines, state and customers or are the necessary developments happening naturally?
7. Who in your opinion are the most important actors when it comes to prepare the market for liquefied biogas and to be a real competitor for fossil Diesel?
8. Was it Fordonsgas itself that initiated the development of a market for liquefied methane? If not who started the process and how was Fodonsgas involved? (Special question for Fordonsgas)

D

Calculation of gas prices and taxes in Sweden and Germany

	Germany			Sweden		
	Diesel	LPG	CNG	Diesel	LPG	CNG
Fuel costs	1,40 €/l₁	0,765 €/l₂	1,26€/kg₃	1,51€/l₄	1,05€/l₅	1,64€/Nm3₆
Fuel costs per kWh	0,14€/kWh	0,12€/kWh	0,10€/kWh	0,15€/kWh	0,16€/kWh	0,15€/ kWh
Taxation	0,47€/l₇	0,09 €/l₇	0,18€ /kg₇	0,55€/l₈	0,25€/ kg₉	0,18€ /kg₉
Taxation per kWh	0,05€/kWh	0,01€/kWh	0,01€/kWh	0,06€/kWh	0,02€ /kWh	0,01€/kwh

Exchange rate	SEK to €	1SEK = 0,11180€
19.April/ Oanda.de	€ to SEK	1€ = 8,93942 SEK

1l Diesel≙9,925kWh	dt. wasserstoff und brennstoffzellenverband e.V. Berlin (April, 7th 2011)
1l LPG≙6,57kWh	www.energieverbraucher.de (April, 7th 2011)
1kg CNG≙13kWh	www.greengear.de (April, 7th 2011)
1kg LPG≙12,87kWh	http://www.energieverbraucher.de/de/Energiebezug/Fluessiggas/Umrechnung__86/ (April, 7th 2011)
1Nm³ CNG≙11,28kWh	http://www.erdgasobersee.ch/fileadmin/media/dl/Begriffe_und_Umrechnungsfaktoren_1.03.pdf (April, 7th 2011

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6 fordonsgas.se
7 Energiesteuergesetz: http://www.bundesfinanzministerium.de/nn_67694/DE/BMF__Startseite/Service/Glossar/E/012__Energiesteuer.html
8 Svenska Petroleum Institutet: http://spi.se/statistik/priser/diesel
9 Skatteverket: http://www.skatteverket.se/download/18.6eb1f7eb12c507b23b7800010549/Skattesatser+2011.pdf