The emergence of biogas infrastructures in The Netherlands

An assessment of the possible success factors for biogas infrastructures in The Netherlands

Frank Pijnenborg

ENEXIS

TU Delft

Project Details

The emergence of biogas infrastructures in The Netherlands

An assessment of possible success factors of biogas infrastructures in The Netherlands

Author: Frank Pijnenborg

Student number: 1264680

Email: f.pijnenborg@student.tudelft.nl

Date: 22nd of December 2011

This is the final product for the master thesis project for:

Study Program: Systems Engineering, Policy Analysis and Management (SEPAM)

Graduation section: Energy and Industry (E&I)

Faculty of Technology, Policy and Management

Delft University of Technology

This research is performed by order of:

Enexis NV, Rosmalen

Department: Asset Management – Innovation

Graduation Committee:

Chair: Prof. dr. ir. M.P.C. Weijnen, Section of Energy & Industry

1st Supervisor: Dr. ir. G.P.J. Dijkema, Section of Energy & Industry

2nd Supervisor: Dr. M.L.C. de Bruijne, Section of Policy, Organization, Law & Gaming

2nd Supervisor: Dr. A.F. Correljé, Section of Economics of Infrastructures

External Supervisor: ir**.** M.C. van Dam, Innovator at Enexis NV

Preface

This research report, on the emergence of biogas infrastructure in The Netherlands, is the result of my graduation internship at Enexis NV and also serves as the thesis report for the Master Systems Engineering, Policy Analysis and Management.

Even though I was drilled to cope with complex socio-technical systems during my education program at the Faculty of Technology, Policy and Management, in reality we will always face new challenges and problems. This applies to biogas infrastructures, what you will read more about in this report, but also to the Master Thesis Project itself. The final hurdle on the road to 'freedom', appeared to have its ups and downs from a social perspective- considering the quest towards the appropriate thesis subject- as well as from a technical perspective- by begging my computer to recover from another system crash. Every setback urges you to come up with strategies in preventing another setback. From a process perspective, preventing further setbacks by processing and implementing the comments that I received from my graduation committee. But also from an organizational perspective setbacks are to be prevented, by getting used to a strict backup schedule of my own work.

Looking back on my thesis project, I must admit that I have learned a lot. Naturally, I have learned a lot on the biogas industry, the anaerobic digestion, distribution network operators, green gas hubs, but most of all I learned to know who I am, what I can do and what I can achieve.

Now, at the concluding stage of my research I warmly thank my supervisors from the TU Delft for the provided guidance and assistance. Prof. Margot Weijnen for chairing the graduation committee, and her clear and straightforward criticism. Gerard Dijkema, for his inexhaustible enthusiasm in getting me on track and for keeping me excited about the subject. Mark de Bruijne, for his pleasant constructivism which gave me a bunch of new ideas after each meeting. Aad Correljé for his infinite knowledge on gas related issues.

Of course I also want to thank Michiel van Dam my external supervisor at Enexis NV for the pleasant meetings, tips, contacts and motivation. Together with his colleagues at the Innovation department they provided me with a very comfortable and stimulating environment to perform my thesis research project.

And last but not least I am very thankful to my parents, for giving me the possibility to live a wonderful life in Delft for the past 6,5 years. Those years were made unforgettable by my housemates, study mates and other friends.

With a heavy heart I am afraid this is my last achievement at the Faculty of Technology, Policy and Management.

I hope you all enjoy reading the results,

Frank Pijnenborg

Executive Summary

Motivation

Due to increasing energy dependencies, environmental concerns and European directives on sustainability, The Netherlands is increasing its share in renewable energy production. This has led to the definition of several energy ambitions. An example is related to green gas, with the ambition of green gas substituting 50% of the natural gas supply in 2050 in The Netherlands. At this moment in time, the most significant source of green gas in The Netherlands is biogas. This biogas is produced from biomass (e.g. cattle manure) by means of biological processes. Using an upgrading process step, biogas can be brought to the quality level of natural gas: green gas. However, these upgrading facilities are expensive, which results in it only being a viable option for those producers that handle significant volumes of biomass. Due to their relative low production volume, small-scale biogas producers cannot come to a solid business case for this upgrading of biogas.

Biogas hub

A biogas gathering infrastructure (biogas hub) seems to be a useful concept in approaching a cost-effective process. In this concept, several small-scale biogas producers are coupled using a stand-alone pipeline network which leads the gas of the different producers connect to one central upgrading facility. The upgrading costs are divided amongst all producers which increases the cost-effectiveness of the production process. Although several biogas infrastructures are initiated in The Netherlands, there is still no successful physical realization. However, this is not caused by a lack of enthusiasm amongst stakeholders; both private and public organizations have shown interest. Apparently there does not seem to be a successful environment in which it is able to realize a biogas infrastructure.

To tackle this situation the following research question is formulated:

Research Question

"What should stakeholders do to reach a situation in which a structured development is realized that makes biogas infrastructures in The Netherlands available at acceptable costs?"

System study

The first phase of the research focuses on the empirical description of the current system. As the biogas infrastructure is not yet realized in The Netherlands, a system study is performed to explore the main issues in the current situation. The question is if there are technological hurdles that need to be taken or if the main concerns are formed by the organizational aspects when a biogas infrastructure will be realized? Interviews and a literature review are used as input to a Multiple Perspective Approach, in which technological, sociological, organizational and ethical elements are combined resulting in a socio-technical system (STS) diagram. This STS is used in the remainder of the research to assess the applicability of the research findings. After the empirical phase of the research, two studies are performed in parallel. First, a comparison between biogas infrastructures and historical infrastructures from which possible success factors are identified and assessed on their applicability. Second, at the same time a theoretical analysis is executed using the Transition Management approach. The applicability of this approach is also assessed. In the eventual synthesis phase, the three components are combined which creates numeral insights to the causes of the current slow development of biogas infrastructures and also offers a set of solutions to this slow development.

Causes

Up till now market parties have been reluctant to participate in biogas infrastructure projects. According to the analysis this is caused by three main reasons.

First of all, the established regime in the energy sector is dominated by a couple of entities with big interests in the extraction, supply and use of fossil-based energy. With respect to the transition to a more sustainable energy supply, these powerful entities especially experience the costs and not the revenues of this energy transition. This situation is also enhanced by the Dutch government. In 2010 a total of 4.6 billion euro was spend to stimulate the end users of energy, a total share of 96.5% was assigned to fossil fuels and only 3.5% to renewable energy.

The second cause identified for the reluctance to participate in biogas infrastructures, is that the current initiators are facing unfeasible business-cases. The structure of the exploitation subsidy (SDE+) is a major contributor to this unfeasible business case. The application structure has the consequence that all available funding was divided amongst existing sustainable energy projects -other than biogas infrastructures- before the biogas infrastructures could apply for this funding. Due to this structure the subsidy pushes the most cost-effective production method to become operational. Even though the prices of biogas production facilities have already decreased biogas infrastructures are not yet one of these most cost-effective techniques. To overcome this valley of death investments are needed that can fund the phase of becoming a mature energy technology. Also the government could take an initiating role here and offer a subsidy that encourages technology development related to sustainable energy production.

The third cause identified for the reluctance of market parties is the institutional uncertainty. Institutions include among others regulations, contracts, subsidy arrangements and the 'rules of the game'. Biogas is not included in the Gas Act, therefore related activities are considered to be commercial activities. Currently the realization of a biogas pipeline can be executed by a construction company without it having any experience with gas pipelines. The realization of a biogas pipeline could result in serious issues for the safety and reliability of gas networks. In addition, possible regulations on cattle manure and stables create uncertainty for farmers. Overall, the ambitions that governmental taskforces have determined are not operationalized. A clearly defined governmental objective could create some regulatory certainty among stakeholders.

Solutions

When searching for solutions to break the impasse, four main categories can be distinguished.

The first being the policy-designing circumstances. Within the current political landscape decisions that have negative short-term effects (e.g. high-investments from the national treasury) and positive long-term effects (environmental gains) are unpopular. Politicians seem to seek for quick wins, a phenomenon that is inherent to our current democratic system. The incentive to focus on long-term policy seems to lack in this political environment. Yet there are possibilities to promote sustainable energy using the 'fourth branch of government', which has a major influence on the political agenda. Besides the national decision-making the process in Europe will take relatively more time and is subject to a broad consensus (27 member states). This is the political arena in which long-term visions and ambitions could be operationalized. European directives appear to be the main driver to most national legislation related to sustainable energy. The European Commission is able to start policy designs using their different (sustainable) energy related platforms. Moreover, also the European influence on gas legislation is significant. But since established entities have a major influence on this field it would be harder to achieve sustainability related changes.

The second solution opportunity is the framing of the renewable energy, and in particular: the biogas infrastructure. When the realization of renewable energy is framed as a chance for new markets, innovation and development -instead of an expensive problem needing significant amounts of tax money- it is easier to create support beyond the stakeholders. For example, in other countries the amount of people employed in the renewable energy sector is significant. As the Dutch government also succeeded to involve DSM during the transition from coal gas to natural gas, this could also account for the current established entities within the energy sector. The future role of these companies should be reconsidered in a further development phase of the transition.

The third alternative could be initiated by the government when they send out a production obligation concerning sustainable energy. In that case, energy producers will be obliged to produce a certain share using renewable energy sources. This would create an incentive for energy producers to become more innovative with respect to sustainable energy methods. At the same time the producer will be able to integrate the costs in their energy prices. With that, it will be the energy user that compensates the required investment instead of the tax payers.

The final solution strategy focuses on the integration and synergy that should be included in biogas infrastructure projects. By (re)using industrial flows and connecting demand and supply, an optimal integrative system can be created. All products from the production process like green gas, CO_2, heat and water should be used effectively. When this is achieved, it will lead to cost reductions and therefore to a more feasible business-case for private investors. It is therefore important to gather all the available support and where possible integrate them into biogas infrastructures. However, this possible solution is very complex and these possibilities for integration need to be explored further- which forms the main recommendation for further research.

Conclusion

Considering the scientific perspective this research and the accompanying scientific article sketch a guideline on how to approach ill-defined systems using a system approach. The resulting socio technical system enables the researcher to assess tactics and strategies from the historical and theoretical analysis. The scientific aim within this research was an attempt on gathering scientific evidence on the applicability of Transition Management on real-life cases. This appeared to be hard, due to the fact that the approach never fits a project exactly. Yet the inspiring character of the ideas could have a positive influence in the field and on the way people approach sustainability.

When reflecting on the main research question this research created an insight in the current situation regarding biogas infrastructures in The Netherlands, including both the opportunities and potential threats for such an infrastructure. If stakeholders succeed in overcoming the main barriers they should fulfill the available roles in the playing field. Especially the financier role and the activities concerning the overall operations needs attention, since responsibilities on this field are hardly described. The current attitude of distribution network operator Enexis fits in the overall playing field, which is in a slow development. Although they initiate in collaboration several biogas projects the 'you ask-we deliver'-attitude is leading. This seems as a proper attitude. Yet when Enexis is willing to accelerate the energy transition regarding biogas infrastructures it should focus on the role of stimulator. Since Enexis has an extensive network in the energy sector and academia, they are able to share and create knowledge which could bring initiatives together in order to evolve to new projects.

Although recommendations are offered to improve the situation for emerging biogas infrastructures in The Netherlands, it will always be important to consider the goal of an infrastructural realization. The growth of the share of sustainable energy in The Netherlands needs to be increased and the biogas infrastructure could function as a means to this end, never as a goal in itself.

Table of contents

List of Tables

1 Introduction to Green Gas Development

"To waste, to destroy our natural resources, to skin and exhaust the land instead of using it so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them amplified and developed."

Theodore Roosevelt, President United States of America

The essential role of energy within our society forces us to continuously search for energy (re)sources. Since fossil fuels are being depleted, sustainable alternatives are becoming popular (WRR, 2008). Unfortunately, the complete worldwide energy supply cannot be substituted by alternatives at once, creating our current dependency on fossil fuels. To ensure a sufficient energy supply in the future, a transition from fossil fuel -based production towards a more sustainable- based production of energy resources is needed. To achieve this, there is a need for transition resources. A 'transition resource' is considered less harmful to the environment compared to fossil fuels, but at the same time this transition resource does not meet the requirements of a 100% renewable energy resource. A transition resource is capable of contributing to a more sustainable energy supply until a fully sustainable energy supply can be operational. Nuclear energy, for example, is sometimes mentioned as a transition resource (Aarten, 2011). It is less harmful than traditional fuels, yet concerns about risks of nuclear waste cause that this energy resource is not unanimously considered as sustainable. A potential transition resource is green gas: an upgraded biogas, landfill gas, or synthetic natural gas (SNG). It has similar properties compared to natural gas and can be used for the same purposes. The advantage of green gas over natural gas is the fact that the total supply chain of green gas has a significantly lower greenhouse gas emission than that of natural gas. According to the Taskforce Green Gas, "a CO_2 reduction of 70% compared to natural gas could be accomplished if wise choices are made on the used commodities and production methods" (Dumont et al. p.7, 2008). In addition, since green gas can be used for similar purposes as natural gas, distribution could theoretically use the same, existing network. This creates a high degree of technological neutrality, something that is desirable due to its limitation of network-related investments. Especially during a transition period, where it is uncertain what energy resources will be used in the (near) future, independency of these network-related investments is an important advantage.

The Netherlands is performing poorly on the scale of sustainable energy consumption. Between 2009 and 2010 the share of renewable energy as part of the whole energy supply decreased 0,4% to a total share of 3.8%. This brings The Netherlands among the five worst performing countries of the 27 EU member states, with the average reaching up to a total of 9 %(PwC, 2009). Policy makers aim for a significant role for green gas in the Dutch energy supply; a 10% substitution of natural gas by 2020 and a 50% coverage by 2050. Before this can be achieved, several issues have to be overcome, ranging from technological, to organizational and institutional issues (Gigler et al., 2008; Dumont et al., 2008). As the green gas development is relatively new in The Netherlands, there is no complete overview of these issues available. Therefore this master thesis project starts with a strategic analysis on green gas development in The Netherlands, in order to enrich the contextual background of the study. By means of interviews at different departments within distribution network operator Enexis (see section 2.5.1)and studying literature, a collection of challenges is identified. As these issues occur in a wide variety of fields, the researcher will categorize them in the fields of technology, regulation, economics and organization. This categorization does not mean that a technical subject has no interfaces with organizational or economic aspects and vice versa. In the next section you will find the outcomes of this strategic analysis with the main challenges briefly discussed. The extensive version of the strategic analysis can be found in Appendix 1.

1.1 Results of the strategic analysis

Before the developments on the subject of green gas can be discussed, a short explanation on the concept of green gas is required.

Anaerobic digestion is a process successfully used for several applications. In it, process bacteria decompose organic material resulting in the production of biogas. Biogas producers in The Netherlands are increasingly using this decomposing ability to recycle biogenic waste such as manure, landfill and sludge. Besides anaerobic digestion another method is applied to produce biogas, namely gasification. In this case the organic material is combusted with a shortage of oxygen. This incomplete combustion results in a combustible gas, also called syngas. Biogas is often directly used in combined heat and power generators. But when we want to use the bio-, or syngas in the same applications as natural gas, there is a need for an additional upgrading step. The concentration of methane in the bio-, or syngas is insufficient compared to the methane concentration in natural gas; furthermore contaminants could be present. During the upgrading process these contaminants will be absorbed or scrubbed out, in addition the concentration of methane is increased- usually due to the extraction of CO_2. After this upgrading process step we consider it to be green gas, a 100% substitute for natural gas applications (Bekkering et al. 2010; Dumont et al., 2008).

1.2 Technological challenges of green gas

Supply biomass

When considering the subject from a technological upstream perspective, a continuous supply of significant biomass volumes is needed for the continuous production of green gas. This supply of biomass could become a major bottleneck for the successful implementation of green gas. The biomass available in The Netherlands is insufficient to achieve the 50% substitution rate that was proposed for 2050. Importing of biomass could fill this gap and is even stated as ‘required’ (Dumont et al., 2008), yet the overall sustainability and costs of the supply chain could worsen compared to conventional energy sources when long distance transport of biomass is required. Therefore the local characteristics of production location and biomass origins should always be considered before one decides on starting the anaerobic digestion of biomass (Bekkering et al. 2010). Due to the need for a continuous supply of relatively big volumes of biomass, transportation is also defined as a critical factor in the bio-energy chain (Boerrigter, 2006). When considering locally available biomass, it appears to be difficult for energy producers to agree on a multi-year contract with biomass suppliers. Waste processors and raw material suppliers do not want to bind themselves for long periods as they expect biomass prices to increase in the coming years. This price increase will be caused by a growth in the number of biogas producers, rising prices of fossil fuels and efficiency developments in the production facilities of biogas. Furthermore these biomass suppliers are considering initiating their own biogas production (DHV, 2010).

Capacity surplus

When considering the downstream element of the supply chain, there could be potential capacity issues. The balancing of gas supply and demand requires precision to be able to maintain the required pressure in the network. When gas is consumed at a specific location, production should inject a similar amount into the natural gas network to balance with the consumption. Flexibility of gas production is therefore of importance; production needs to be in line with consumption. Unfortunately, green gas production is less flexible than natural gas production. Due to the biological processes required for the production of biogas, it is not possible to stop the anaerobic digestion at once. As the production consists of living organisms, the biogas production will gradually decrease until the bacteria cannot survive due to a lack of biomass, temperature or the level of oxygen; a process that cannot be completed in a split-second. Furthermore, when gas demand is low the production of green gas will remain on the same level. In the same way that a producer was required when consumers extracted gas from the network, consumers are needed when a producers injects gas into the network (KEMA, 2010). This is especially the case during daytime in the summer periods when the demand for gas is very low (CBS, 2010). Producers of green gas in the Northern part of The Netherlands have already experienced that no demand was available, due to a lack of consumers. Because of the current network structure, gas that is injected in a local distribution network cannot flow towards the transmission network, which would offer a larger market for supply. In the current situation the surplus of green gas is flared, which is an undesired solution for the producer itself especially, but in essence the useless flaring of gas is not desirable for anyone (Enexis, 2010).

Network usage

In line with this previous point, another technological challenge is related to the fact that the existing natural gas network will have to be used differently if green gas is to become the transition technology. Instead of direct feed–in from small amounts of productive gas fields into the transmission network, a shift will have to be made towards injection of a wide variety of de-central production units within the local distribution network. The majority of production would be increasingly geographically decentralized and come from the branches of the distribution network instead of the core of the transmission network. This will bring more interfaces in the system, an increased number of entry points and a bi-directional flow of gas instead of a single direction.

Since the Dutch ambition for green gas would require a total of 1500 million m^3 green gas per year, ca. 1875 million m^3 biogas needs to be produced annually as the upgrading process causes a methane loss. Biogas producers will most likely reach an output of circa 300 m^3 biogas per hour (Van Tilburg et al., 2008). Due to the fact that the production process itself is rather simple, the usual assumption stated in literature on operating hours of a biogas digester is 8500 hours a year; a reliability percentage of 97%. Assuming a total of 8500 operating hours a year, in total 735 digesters would be needed in The Netherlands (Bekkering et al., 2009). It is questionable whether or not so many digesters are desirable in the country, especially when considering potential safety issues. Additionally questions rise on how to connect all these digesters to the grid. A commonly suggested option is the creation of hubs; a concept that could also lead to economies of scale as the costs of a single upgrading facility are considered high. When gathering raw biogas from different producers and transporting it to one central upgrading facility, these costs could be divided over the different producers. This could make the overall system commercially more attractive. The concept of biogas hubs is not new, however it is only from 2010 onwards that the first Biogas Hub initiative in The Netherlands started its initializing phase. Pipelines should connect 12 Frisian farmers and gather a significant amount of biogas. The biogas would be upgraded to natural gas quality and the network of GTS, the national transmission system operator, is planned for the transport purposes. Four other green gas hubs are planned in the near future, producing enough (green)gas to supply a total of 150.000 households (Rakhorst, 2010).

1.3 Regulatory challenges of green gas

Emerging legal status

When considering the topic of green gas from a legal perspective, activities and responsibilities related to biogas are defined insufficiently. An example is the fact that biogas is not considered as ‘gas’ according to the Gas Act. A distribution system operator is therefore not automatically responsible for the maintenance and implementation of biogas pipelines. At the same time the distribution network operator is also not obliged to realize a connection when it is requested by biogas producers. In the case the distribution network operator installs a connection pipeline, the costs that are made cannot be socialized in the connection tariffs (Van de Pas, 2011). Therefore the total implementation costs will be remunerated directly from the producer. Furthermore there is no legal agreement whether or not the production process of biogas could be seen as an agricultural activity, which could ease the process to acquire the needed permits.

Connection Obligation

Unlike in the case of biogas, green gas is considered a 'gas' by the Gas Act. Therefore green gas is also affected by the connectivity obligation that was introduced in April 2011. Because of this obligation the distribution network operators are obliged to connect every single household or industry when desired, to the gas network. This obligation is applied to both consumers and suppliers. This could lead to situations in which the realization of a connection is not cost-effective. The distribution network operator does not have the right to refuse a request until there is a legal confirmation about these not cost-effective cases. The combined distribution network operators proposed regulations that would prevent such a situation, however this proposal was found too complicated by the NMa. For this reason there is still no solution to overcome this situation (Van de Pas, 2011).

1.4 ORGANIZATIONAL CHALLENGES OF GREEN GAS

Certifi-cation

From an organizational perspective, the current certification process for green gas seems interesting. State-owned Gasunie is the full owner of the Dutch transmission network operator GTS. At the same time GTS has the full responsibility for the certifying authority, in this case Vertogas. This brings them in the position to set disproportionate requirements to the injected gas to protect their pipeline network. In addition, participating in the certification is not obligatory for producers. It is for this reason that just a small amount of producers participate in the certification process. This undermines the important role a certification authority could have in such a young market of renewables.

Capacity Balancing

Besides the technological challenge stated earlier on the production surplus, the capacity balancing also creates organizational challenges. As mentioned before, the distribution network operator cannot be confronted with a lower demand compared to the supplied green gas in its network. The gas needs to be distributed or stored. Production cannot be stopped at once due to the biological processes that are used in the production process. The distribution network operator has no options to drain the surplus of gas in their network. Therefore the agreements between producer and distribution network operator needs to be clear. In addition, most producers of green gas are located in low-density areas with a relative low gas demand. This enhances the need for a proper balancing regime. Compared to the current situation there is an information need from more individual suppliers. The responsibility to maintain the balance within the local distribution network needs to be appointed to stakeholders.

Gas demand

Innovations and trends like driving on electricity or green gas, decentralized electricity generation through solar panels on the roofs of consumer houses or newly-built residential areas without gas connections, all influence the gas demand. Uncertainty on these developments cause an investment risk, in particular on the long-term the market value of gas is not ensured. Companies that invest in green gas projects and that are depending on the revenues of the end-product, such as energy producing companies, will be most affected by this investment risk.

Industrial districts

The presence of highly specialized gas-related firms, located in close proximity of each other and embedded in local social structures that supports a mix of cooperation and competition, could lead to an 'industrial district' (Staber, 1999). According to literature, these industrial districts are credited with several sorts of benefits. This includes stimulation of innovation and the support of business adaptability (Amin et al., 1994). In the case of green gas, the collaboration between different sectors will be of great importance. Involvement of the agricultural sector is relatively new to the energy sector, while it will be especially the agricultural sector that could play a decisive role in achieving the 50% substitute in 2050. Furthermore green gas offers the possibility to invest in subordinated areas in the country. This also has economic advantages: the green gas industry could create job opportunities and on the long-term could substitute jobs that will disappear due to the depletion of the natural gas production in The Netherlands (RLI, 2011).

1.5 Economic challenges of green gas

Money allocation

When considering the economic side of green gas a number of challenges are clear. In line with the green gas regulation that is still in its infancy phase, agreements on financial allocation are also lacking or are poorly defined. This accounts to the costs and revenues that come with the exploitation of a biogas infrastructure. A distribution network operator will not automatically be compensated when it distributes biogas, while it is automatically compensated when distributing conventional natural gas. The overall allocation of costs and gains should be reconsidered; it should be clear who needs to bear the costs for specific elements of the system and who may claim the revenues of a certain service.

Subsidies

Furthermore the allocation of exploitation subsidies of the Ministry of Economic Affairs-which is currently based on the short-term- is a point of attention. Due to the current structure of the subsidy program, green gas initiatives barely get the chance to apply for the program as the cost price of green gas is too high per cubic meter.

Food Prices

Finally, in addition indirect consequences of green gas production form a concern. Since food sources can be used to generate energy, there is an increasing risk that these food sources (e.g. corn) will increase in price. Some prospects argue that food commodity prices will increase with 70-75% when they are used for green gas production. These developments could affect third world countries, the current fuel for food discussion.

1.6 Preliminary conclusion based on strategic analysis

Overall, it can be concluded that the topic of green gas and biogas is in an intensive phase of development. A wide variety of stakeholders is already involved and some major issues have already become apparent and developments occur on both in the technological and institutional side of the system. On an ad-hoc basis legal, economical and organizational arrangements are set by the Ministry of Economic Affairs, provinces, distribution network operators and energy producing companies. The practical developments progress faster compared to their institutional counterparts. A reason for this could be the fact that there is no long-term policy available on how subsidies, responsibilities, tariff structures and ownership should develop. This results in a reluctance of some stakeholders, since they face uncertainty. Furthermore the involved stakeholders serve different objectives and interests, which create difficulties in designing these institutional boundaries.

On the other hand this variety of stakeholders offers a variety of suitable research topics on the field of Systems Engineering, Policy Analysis and Management. The reason to start with this strategic analysis was to create a contextual background for the study, understand what the real underlying problems are and to come towards a suitable research subject for a master thesis study. After consulting with employees at Enexis and the graduation committee, the researcher decided to focus on the emergence of biogas infrastructures. Even though it is a known concept for some time now and the involved stakeholders show a positive attitude towards the concept, there currently appears to be an inability of realizing these gas infrastructures. In the next section the problem exploration is presented leading to the research topic of this thesis report, “The emergence of biogas infrastructures in The Netherlands”.

2 Research Definition

"To every complex problem there is an easy solution, and that is a wrong one."

Umberto Eco - Italian novelist (in Il Pendolo di Foucault, 1988)

➔ In this section the contextual background of this research is explored (2.1), resulting in a practical and scientific problem statement that forms the basis to research questions, research objectives (2.2), research approach (2.3) and methodologies (2.4). Information on key concepts within this thesis project is presented in 2.5.

2.1 *Problem Exploration*

Need for production

The Platform New Gas is a public-private taskforce appointed with the task to discover possibilities to increase the sustainability of the Dutch gas supply chain. The platform defined the ambition of The Netherlands related to green gas; in 2050 a 50% substitution of the natural gas supply by green gas should be achieved, with a 10% share being realized by 2010 (Dumont et al., 2008). To achieve these levels, a significant increase of green gas production is needed, as the current gas consumption in The Netherlands is 40 billion cubic meter a year. Current green gas facilities produce a total of 23 million cubic meter a year -equal to the gas demand of 16.000 households (Energy Valley, 2011).

Biogas major resource

As mentioned in section 1, green gas is an upgraded variant of biogas, landfill gas or Synthetic Natural Gas(SNG). Considering the circumstances in The Netherlands, biogas has the most potential to come to a significant production volume. There is an abundance of cattle that produces manure that is available for biomass digestion. Furthermore the possibility to convert human waste, including sewage sludge to biogas, can make a significant contribution to the total production volume (Dumont et al., 2008).

Expensive upgrading process

At this moment in time, the production of green gas in The Netherlands is limited to a few waste convertors, who use sludge to produce biogas before it is upgraded to green gas. The purchase of a green gas facility is a costly affair and therefore economically unattractive to most farmers, since they do not have the capacity to produce a sufficient amount of green gas that enables remuneration. From the 44.503 farmers owning cattle, approximately 80 have installed a biogas co-digester (Ministry of Economic Affairs, 2011; CBS, 2011). Their individual production level will not reach the amount required for a cost effective investment of a green gas upgrading facility. The concept of the so-called biogas hub seems promising in changing this situation (Braaksma, 2010).

Biogas hub

A biogas hub is an independent pipeline network connecting several biogas producers. The produced biogas is transported through the network to a central location, the so-called 'hub', where the biogas will be upgraded to green gas. The costs of the upgrading facility can be shared between the connected producers, which make it more likely that a financial feasible situation arises. Furthermore, when all the small volumes are brought together the produced volumes are significant. In the remainder of this report the biogas hub will be defined as biogas infrastructure.

Stake-holder support

Currently different stakeholders have shown a positive attitude towards the implementation of such a hub. Yet each of them operates from their own specific interests and objectives, e.g. their own agenda. The national government and the provinces want to increase the sustainability of energy supply and at the same time, decrease energy-related dependencies on foreign countries. Furthermore on the production side farmers and waste processors prefer to get revenues from their residuals. The public-owned distribution network operator has appointed themselves the objective to facilitate the energy transition. Public values like affordability and reliability are the underlying objectives to this policy. Despite the fact that all these objectives match the idea of biogas hubs, a concrete implementation has not yet been accomplished (Dumont et al., 2008; Eenkhoorn, 2011; Enexis, 2010).

Difference green vs. biogas

The similarities between green gas and biogas from a physical perspective is significant. However, when considering the organizational aspects the activities of green or biogas differ significantly. A clear difference between them is the status of regulation. Since green gas is legally recognized as gas in the Gas Act, responsibilities, obligations and remuneration agreements are defined. For biogas this is not yet the case. On the field of green gas an institutional framework was created during the last decade, since the green gas supply was growing, policy makers were urged to think about regulations. The lack of regulation and the poor distribution of roles and responsibilities make the situation of biogas an interesting topic from a systems engineering and policy analysis perspective.

Realization problem

Despite several biogas infrastructures being initiated in The Netherlands, no successful physical realizations can be reported as yet. Apparently there is currently no successful environment in which it is able to realize a biogas infrastructure. And it is questionable how the involved stakeholders could create an environment that can enable the realization of a biogas infrastructure.

Core of the research

There are several approaches available that could create insights related to the question of how such an environment could be created or influenced. In this research project, an empirical situation is taken as a starting point, since this offers a projection of the current situation. Scientists related to the transition management theory propagate that sustainable developments can be 'managed' by making use of their management ideology. Not everyone agrees on this, since criticism on transition management is widely available and therefore this approach is not yet considered as a guarantee to success or a best practice. It would be interesting to investigate whether or not transition management could contribute to the development of biogas infrastructures. Historical transitions have been executed without the help of the transition management approach. Therefore these historical cases offer insights in successful real-life experiences, which can be used to draw lessons about the development of infrastructures. By combining the theoretical approach with historical analogies, an insight can be created on whether or not transition management would have eased the historical transitions. This will indirectly assess the effect that the transition management method can have on infrastructural development. Furthermore, when the theoretical and historical perspectives are reflected on the empirically composed situation, recommendations can be proposed in order to create an environment that enables the realization of biogas infrastructures in The Netherlands.

Empirical approach

The biogas infrastructure includes the supply chain leading from biogas producers, converging their biogas to one central upgrading facility. When the conversion process of biogas to green gas is completed, the gas is ready to be injected in the transmission or distribution network. This latter action is not included in the biogas infrastructure system that is considered in this research. Since the period between initiation and realization of the biogas infrastructure faces difficulties, the scope of the research focuses on this specific period. Issues that were presented in section 1 as challenges to green gas and not related directly to biogas production like green gas certification, the connectivity obligation and capacity problems are left out of this scope due to the time constraints of this research. Yet to the overall success of green gas, these are of main importance and therefore subject to further research.

The framework that is used for this analysis is pragmatically composed for this specific case using the Multiple Perspective Approach (Ulrich, 1987). By means of interviews and literature studies an empirically obtained system description is presented in section 3.

Historical analogies

Meanwhile, infrastructural development is a widely covered subject in research. There is a wide variety of different infrastructures available in today's society. All of these started in a developing phase, just like biogas infrastructures do now. Historians have investigated the emergence of infrastructures throughout the world (among others Hughes, 1983; Kaijser et al., 2004; Van der Woud, 2006). These studies will be used to identify conditions that that turned out to be beneficial or successful during the emergence of a selection of today's infrastructures. In this case the emergence of an infrastructure covers the period from innovative technology until acceptance of the infrastructure to involved users. The findings and consequences to the field of biogas infrastructures can be found in section 4.

Theoretical approach

On the other hand there are also theoretical approaches that argue how infrastructures should be realized from the start. An example is the theory of Prof. dr. Wempe who raised the idea to start implementing an infrastructure before the producers are operating, instead of connecting already operating producers. This could probably solve the chicken or egg causality dilemma, since in the normal situation distribution network operators will wait for the producers before installing the infrastructure (Wempe, 2011). Another theory Rotmans suggests is the transition management approach. Here a transition pathway is presented that should be used when realizing transitions that are related to sustainable development (Rotmans, 2003). Whether or not these theories can be applied on biogas infrastructures in practice is questionable and will be discussed in section 5.

Enexis

Distribution network operator Enexis (see section 2.5.1) is involved in this thesis project. As distribution network operator, Enexis is strongly involved in developments related to energy infrastructures, both in gas and electricity. Since the company is willing to cooperate in facilitating the energy transition they are involved in pilot projects with renewable energy sources, like biogas. The company experiences the current pilots from inside the process and is curious about possible suggestions leading to improvement of the process. By combining the empirical, historical and theoretical elements of this study, a recommendation of the available roles (for Enexis) will be presented in section 7.

2.2 Research Definition

The practical and scientific problem statements are defined as:

Practical problem statement

> *There appears to be an inability among involved stakeholders to realize a biogas infrastructure in The Netherlands, given the current situation.*

Scientific problem statement

> *Evidence of the applicability of transition management theory to real-life cases of infrastructure development is not yet present.*

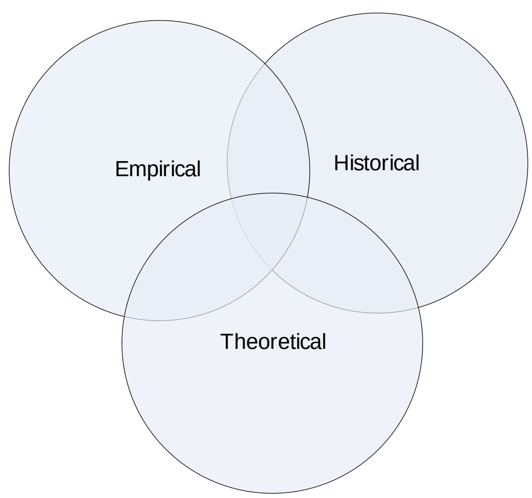
Based on these problem statements the research objective is formulated.

Research objective

To provide a framework of conditions, roles and strategies which could enable involved stakeholders to realize a biogas infrastructure in The Netherlands, reflecting an interdisciplinary perspective on the applicability of theoretical approaches to the realization of infrastructures as part of the energy transition.

This research assumes that a suitable starting point for realizing infrastructures related to the energy transition can be obtained by applying historical and theoretical lessons on an empirically constructed system (Figure 1). This specific interdisciplinary perspective -in which theory, history and empiricism are combined- is lacking in present scientific researches: a knowledge gap. The used research approach makes the research both problem and solution-driven, but also practice oriented. This can be considered to be a unique feature of this research method. Throughout the whole research special attention is given on the role or consequences to distribution network operator Enexis, as they are one of the initiators of this thesis project. The scientific relevance of the research is that it will assess the applicability of the transition management approach on the development of a real-life infrastructure. The practical aim is to offer an advice or guideline that supports involved stakeholders in the realization of a biogas infrastructure in The Netherlands.

Figure 1 - Research perspectives



Based on the research objectives and both problem statements, the following main research question will be answered within this research:

Research Question

What should stakeholders do to reach a situation in which a structured development is realized that makes biogas infrastructures in The Netherlands available at acceptable costs?

Two elements that need a short explanation are the 'structured development' and the 'acceptable costs'.

The structured development defines that the research focuses on the development of the infrastructure after it developed as a pilot. The term 'structured', points out that the infrastructure will have a set procedure from a physical, organizational and economical perspective.

The 'acceptable costs' ensures the research approaches the situation from a cost-effective perspective. Cost-effectiveness compares the costs and production revenues to assess the extent to which the production can be regarded as providing value for money. In this research we are not searching for the fastest way to realize a biogas infrastructure, but to a situation that enables a cost-effective performance of the system also in the future. Only in that case biogas infrastructures can bring a significant contribution to the energy transition.

The main research question will be answered using six sub-questions. Within the research framework these sub-questions are indicated using the abbreviation RQ1, RQ2, etc.

Sub-Questions

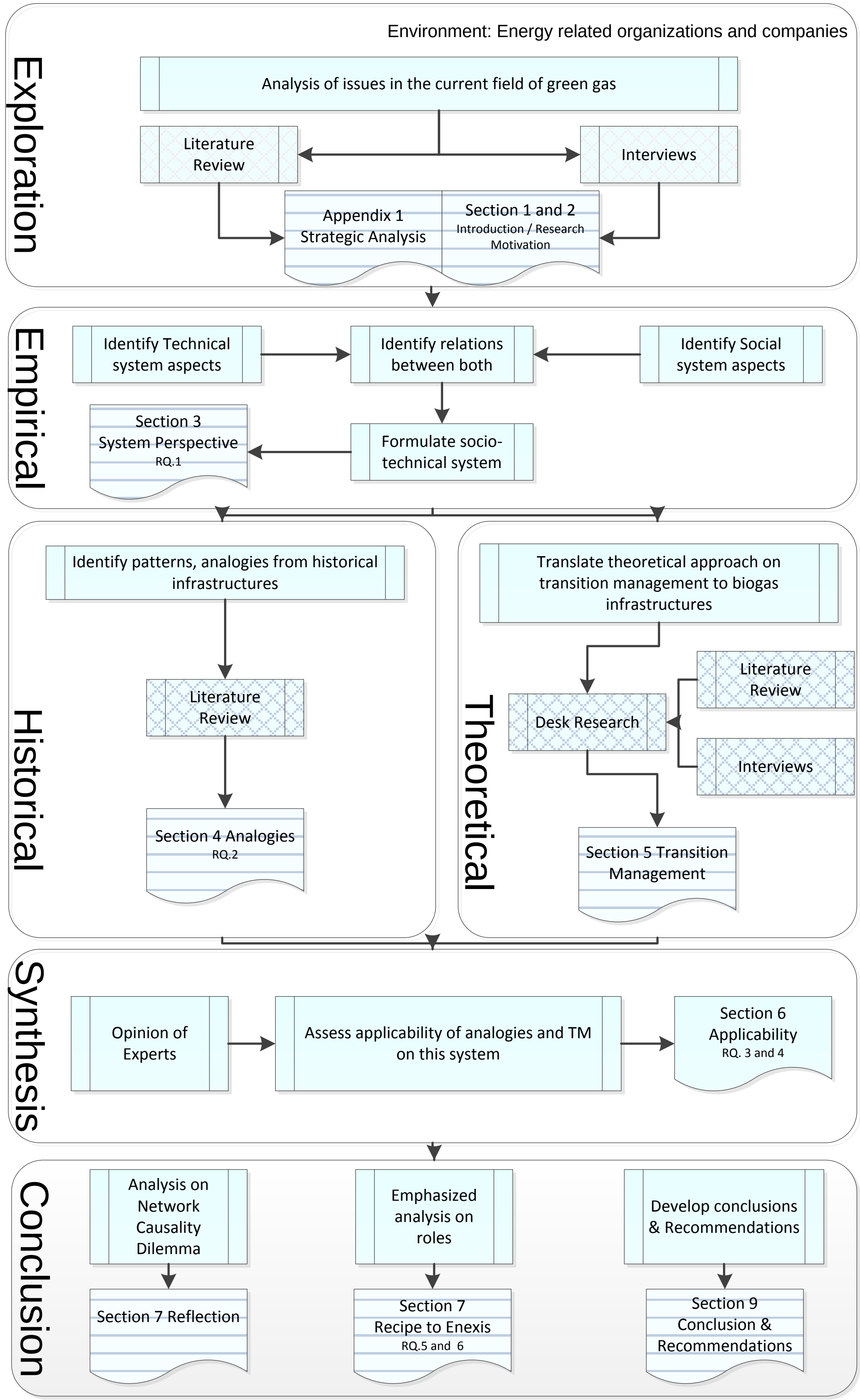
1. From a systems perspective, what are the most important (strategic) issues that influence the development of biogas infrastructures in The Netherlands?
2. What (pre)conditions made the roll out of (a selection of) today's infrastructures (un)successful?
3. To what extent could the (pre)conditions of RQ2 be translated to the case of biogas in The Netherlands?
4. To what extent could theoretical concepts from transition management be translated to the case of biogas in The Netherlands?
5. Which roles are (not yet) defined within the Dutch biogas playing field?
6. Which role(s) could distribution network operator Enexis fulfill within this playing field?

2.3 *Research Approach*

This research consists of several research steps. On the next page the research framework is presented (Figure 2), which explains the structure of these steps. Here also the empirical, historical and theoretical approaches as discussed in 2.2 are included. The research starts with an exploration in which an attempt is made to discuss all major issues related to green gas and biogas (Appendix 1). This leads to a better understanding of the complexity in which biogas currently develops in The Netherlands. Furthermore it aids realizing a focus for a relevant research topic. To answer the research questions there is a need for an insight on the current situation. Therefore a system study is performed. In this empirical research part an alternative research framework is used that enables the researcher to include multiple perspectives. The empirical study results in a socio-technical system(STS) description of the biogas infrastructure (Section 3).

The research then continues in two parallel research tracks, both linked to the STS of section 3. On the one hand, the exploration of the historical analogies that explores conditions that were beneficial to infrastructural developments throughout Dutch history (Section 4). On the other hand the theoretical concept of transition management is explored (Section 5). The combination with the STS will show whether or not both approaches could contribute in case of the biogas infrastructures. In the synthesis of section 6 the findings of section 3, 4 and 5 are combined. Firstly the relevance and utility of the parallel approaches in this specific case and furthermore issues that arise on a higher strategic aggregation level are discussed. In section 7 the roles that can be taken by the different stakeholders are investigated. Here special attention will be on the role of the distribution network operator, Enexis. Section 8 will give an overall conclusion of the research. The main barriers and solutions to them will be discussed, furthermore the recommendation to Enexis will be presented. Finally also a reflection on the results and used methodologies will be included in section 8.

Figure 2 - Research Framework



2.4 *Research methodologies*

The research framework also mentions several research methodologies: e.g. literature research, interviews and desk research. Since the biogas infrastructure is an innovative concept, that has not already been executed elsewhere, there is a lack of practical information about the composition of the infrastructure. As explained before, the technological system is not yet defined nor is the organizational or economic design of the infrastructure. Also the availability of experienced personnel is a problem in this case, this inexperience also touches the core of the research. The majority of the thesis project is based on desk research. Here literature research, observations and interviews are combined and synthesized in a logical argumentation line.

The first research phases, the exploration and the empirical description are supported by a *literature research* and *interviews*. Especially the empirical system perspective is majorly supported by *interviews* within the biogas infrastructure playing field, due to the lack of practical information. Additionally also biogas related meetings were attended, visits to a biogas production facility and discussion meetings created more insight on the subject. The scientific argumentation that leads to the research framework is based on scientific papers and books on system engineering.

In particular, the historical case studies are performed using *literature reviews* of authors focusing on infrastructures in society throughout history. Within this research field an extensive amount of research has been performed during the last decades, both within the Netherlands as internationally.

The synthesis research steps are mainly based on *desk research*, in which the combination of literature review, interviews, meetings and visits have been combined within an iterative process to produce the final conclusions and recommendations

The interviews were conducted face-to-face, with some exceptions that were done by telephone. During the interview mostly open questions were asked in a semi-structured way. Due to the fact that interviewees have different perspectives on the biogas infrastructures, inconsistency could arise in the understanding of concepts. The use of semi-structured interviews prevents this pitfall, since it offers the opportunity to focus or broaden a scope during an interview. The list of interviewees is included in Appendix 5, as is the description of the interview subjects. Summaries of these interviews can be obtained digitally by contacting the thesis' author.

2.5 *Basic concepts*

For a thorough understanding of this thesis project, additional explanation of the several concepts that will be used is required. First, we will focus on the position of distributed network operator, *Enexis*, within the gas supply chain (2.5.1). Furthermore the concept of *transitions* is explained in more detail (2.5.2). And finally in *2.5.3* the concept of *sustainable development* is discussed in more detail.

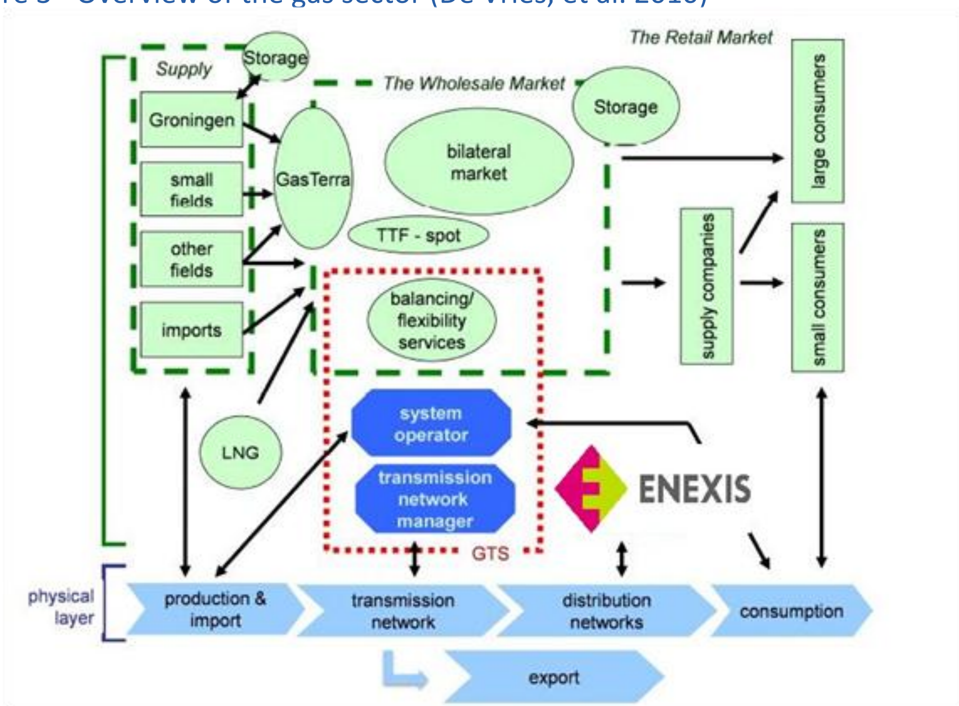
2.5.1 Enexis

Distribution network operator Enexis is one of the initiators of the thesis project. This section provides a short explanation of their activities and role within the gas supply chain.

According to the Electricity Act (1998) and Gas Act (2000) Enexis is responsible for the distribution of gas and electricity in their operating regions. Enexis is responsible for the design, construction, maintenance and control of the distribution networks that connect the customers to the electricity and gas transmission grid. Enexis is active in a large part of The Netherlands: Friesland, Groningen, Drenthe, Overijssel, Noord-Brabant and Limburg. Here it distributes electricity to 2.6 million consumers and distributes gas to 1.9 million consumers.

The role of Enexis in the gas supply chain can be deduced from figure 3; an overview of the Dutch gas sector. From a physical perspective the distinction is made between production, transport, distribution and consumption. Two European Gas Directives initiated a liberalization process and created a new landscape within the gas sector. More became responsible for different parts of the system. Before all stakeholders could properly act under the given responsibilities a time-consuming process of change was needed (De Vries, et al., 2010). The purpose of liberalization is that competition is introduced where possible; this under the assumption that competitive pressure will force market parties to become more efficient to the benefit of consumers. Not all stakeholders in the gas sector ended up in private ownership. The ownership of the physical networks for the most part remained in public ownership, which became the norm around most of the world. Currently, policy recommendations from the international economic institutions widely recommend the virtues of private ownership (Clifton et al., 2011). The public ownership of networks in created natural monopolies which offers the possibility to obtain an optimal quality of service, establish optimal tariffs and ensures equal access for all. The beneficiaries would be the consumers, who would obtain more options to choose for services at a better quality and a lower price (De Vries et al., 2010, Clifton et al., 2011).

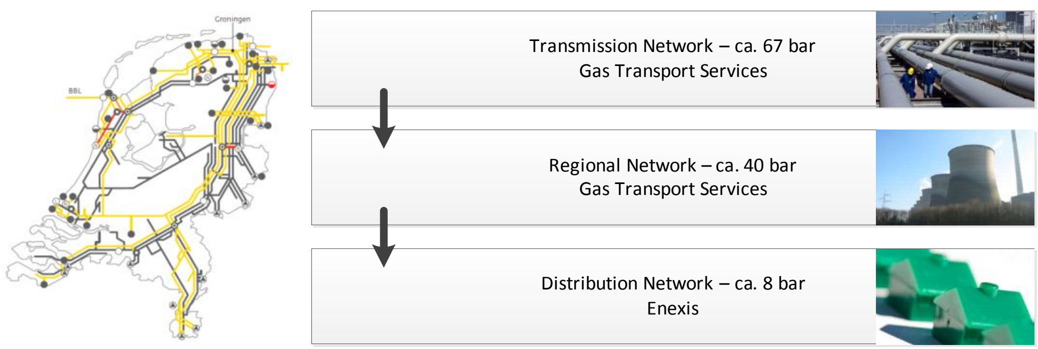
Figure 3 - Overview of the gas sector (De Vries, et al. 2010)



As is shown in figure 4 a distinction is made between transport and distribution of gas within the networks. The transport of gas is performed with high pressure pipelines and is concentrated in the transmission network. In The Netherlands this task is performed by the transmission network operator (TSO): Gas Transport Services (GTS), which is owned by Gasunie, which in turn is fully owned by the Dutch government. Distribution is considered to be the final phase in the logistical supply chain towards the end-consumer, this activity is concentrated in the distribution network. When in 2004 the Dutch government decided to unbundle the integrated energy companies to ensure the security of supply and increase the economic efficiency in the energy market, they obliged the energy companies to unbundle the production and distribution of gas. This led to the establishment of regulated distribution network operators (DNO's), like Enexis. Currently there are 11 of those DNO's active in The

Netherlands. These DNO's use pre-determined tariffs that are monitored by the Office of Energy Regulation (Energiekamer)(NMa, 2011). Activities related to trade, supply and production are covered by the commercial energy companies. Consumers can choose their own energy supplying company, while this is not the case for their DNO since this is determined by the location of a consumer.

Figure 4 - Layers in transport and distribution



Besides the core tasks of transport and distribution the gas regulation introduces additional responsibilities for the transmission system operator (TSO) and the distribution network operator (DNO). The TSO of the transmission network, GTS, is -according to gas regulation- responsible for supporting their customers in mixing gas to a desired quality (Gas Act, Article 10a.1.c). Furthermore, they are responsible for the balancing and flexibility regime. In this, they are supported by the DNO's who will provide information on their consumer demand. Another shared responsibility between the TSO and DNO is the construction of new networks and the registration of consumer connections (Energiekamer, 2005). Some industrial consumers are directly connected to the transmission network and do not have contractual relations with the DNO. Compared to the electricity regulation, the DNO has fewer obligations. They are for example not obliged to transport gas that is offered to their network. Furthermore consumers that are connected to distribution networks may not be discriminated against, based on the general terms and conditions of transport and tariffs, so equal consumers should be treated the same. The obligation to connect potential users is also at stake for gas since April 2011. This is discussed in further detail in Appendix 1 (Gas Act, 2011, Electricity Act, 1998).

2.5.2 What is a transition?

The dictionary describes a transition as, "a change from one form or type to another, or the process by which this happens" (Cambridge Dictionary, 2011). Moreover there appears to be a wide variety of definitions in literature on transitions within the last three decades. Table 1, which is adopted from Chappin (2011), presents a summarizing overview of these different definitions.

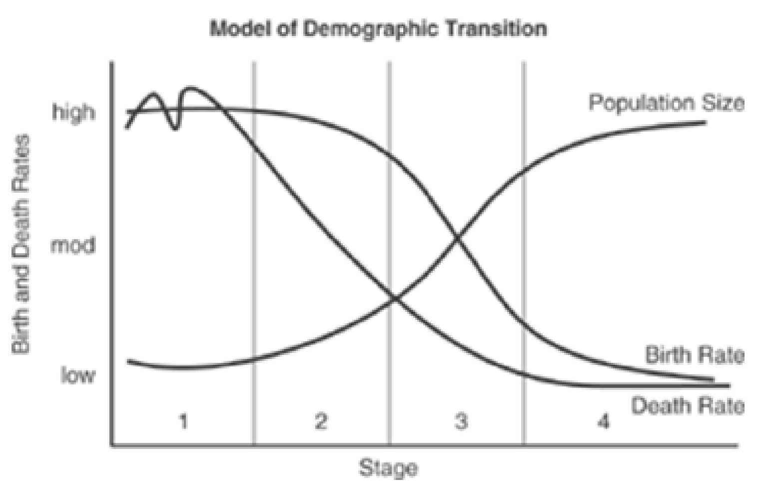
Table 1 - Components of transition definitions (Chappin, 2011)

Component	Variations
Type of system	Organization, socio-technical system, societal system, technological system, large complex technological system

Type of change	Irreversible, gradual, mode of operation, system state, structural, fundaments, major, socio-technical regime, system innovation, structural innovations, technological transformation, functioning.
Size of change	Substantial, major, fundamental, incremental, radical, profound
Speed of change	Radical, rapid, gradual
Before and after	Relatively stable
During	Relatively unstable
Reason	Wicked problem threatening development, demand for sustainability

Initially the term transition originates from biology and population dynamics (Davis, 1945). An interesting example is the demographic transition of industrialized countries in the twentieth century. The population evolved from a state characterized by high death- and birth rates towards a state with low death- and birth rates. This transition ends up with an ageing population and a decreasing number of youngsters, also the Dutch society is coping with this phenomenon. But this development will not end up in a static end point. Probably it will be the starting point of a new future development (see also Figure 5).

Figure 5 - Demographic transition (RAND, 2000)



Also in the field of economy the concept of transition plays a role. One of the main examples here is the development from a planned economy towards a market economy, the fact that this also brings new political and societal institutions makes it a transition instead of a normal change (Rotmans, 2003).

Within the field of systems engineering, transitions are defined as system changes. A system will change from a dynamic equilibrium state to an instable transition period, followed by a new dynamic equilibrium state. During a transition this equilibrium does not entail that nothing happens, like a status quo. There will be numerous influences but these do not affect the equilibrium, changes will often be under the surface which makes them not directly visible. The definition that is used by Rotmans is: “the shift from a relative stable system through a period of relatively rapid change during which the system reorganizes itself into a new (stable) system again” (Rotmans, 1994).

2.5.3 What is sustainable development?

A sustainable development is a development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). This is the most cited definition of 'sustainable development', launched in the UN report on the theme of 'Our common future' (year). Within this definition we can distinguish two elements, from the one side the needs and from the other side the limitations. The human 'needs' are basic and essential, examples can be found in food, water, health care or education. According to the UN report, the economic growth and also equity to share resources with the poor is required to sustain them. The limitations are mostly related to the environment, they are imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities (United Nations, 1987; Wikipedia.org, 2011).

Even though there is a wide variety in the definitions of 'Sustainable development', there are three specific characteristics that return in most descriptions according to Rotmans (2003).

- "Timespan of 25-50 years: Sustainable development is a phenomenon that goes over generations. So effort that is invested today will create benefits for a next generation over circa 25-50 years.
- Scale level: Sustainable development takes place on different levels. For example on national and regional scale level. Interesting point is that sustainable development on national scale could have a negative effect on the international sustainability level. This is caused by a shifting mechanism that transposes negative consequences for country or region A to country or region B.
- Plurality of domains: Development often has its influence on the economical, ecological and social-cultural domains. This combination is also known as people, profit and planet. The domains should be in balance, since when one of the domains is leading over the other domains, these will suffer from that (Rodriguez-Nikl, 2011; Rotmans, 2003). "

In the next section the system of biogas infrastructures is defined. This will also clarify whether or not the characteristics of biogas infrastructures can be stated to be a sustainable development. characteristics of biogas infrastructures can be stated to be a sustainable development.

3 Current situation of biogas infrastructures - a systems perspective

“"We can't solve problems by using the same kind of thinking we used when we created them."

Albert Einstein, German physician, 1879-1955

➔ This section covers the empirical approach of the system study, starting with an explanation of the used framework in 3.1. Hereafter, a socio-technical system will be composed using the system context (3.2), and the technological (3.3), sociological (3.4) and ethical system aspects (3.6). Overarching issues will be discussed in 3.5, while in 3.7 the first research question will be answered.

3.1 Multiple Perspective Approach framework explained

To be able to assess the findings of the historical analogies and theoretical approaches to biogas infrastructures later on in this report (section 4 and 5), first a status quo should be defined. There is a need for a detailed description of the system that is considered, in this case biogas infrastructure. Unfortunately this is a challenging task since there is no operational system available on which this description can be based. Furthermore, amongst the involved stakeholders there is no unambiguous agreement on what a potential biogas infrastructure should look like.

Socio-technical persp.

For this research the systems thinking theory (Checkland et al., 1990) is used as a starting point. Since a biogas infrastructure consists out of a combination of technological components and a variety of social elements as firms and organizations is involved, the infrastructure is suitable for the creation of a socio-technological system (Hughes, 1987). This approach originates from the systems theory in which the technical elements (like hard- and software) are combined with the stakeholders (these fulfil a role as sub function in the system). By using the socio-technical systems perspective a third element is introduced, namely the relations between these elements. These are considered as the social elements. Hughes (1987), Nelson and Sampat (2001) have already made this distinction: they described elements of a non-technical nature in systems. Where Hughes emphasized organizations and legislative artefacts, Nelson and Sampat considered institutions as ‘social technologies’ besides the physical technologies. Both stakeholders and technical elements are subject to the laws of nature, but social elements and the behaviour of stakeholders also refer to (individual) intentions and to more complex guiding principles (Ottens et al., 2006). The socio-technological perspective clarifies this interdependency since it, “points out that that change in social elements and technological elements cannot be fully separated: in order to understand how systems change (Chappin, 2011).”

Purpose of system persp.

To ensure that essential elements of the described system -in this case the biogas infrastructure- are included, a pragmatic approach is composed that combines different system perspective approaches. An exhaustive collection of system approaches is available, each with its own specific (dis)-advantages. For more information the scientific article ‘Method to study and explore ill-defined systems’, that is attached to this master thesis project, can be read. Whether or not an approach is suitable, depends on numerous factors, most importantly: the information the researcher is aiming to retrieve from the system. The goal of this specific system description is to cover the system's situation at the moment in which the execution of biogas gathering infrastructures has not yet started. Within this analysis both proposed technologies and institutions needs to be included.

Multiple Persp. Approach

The approach that is used to analyse the current system is the Multiple Perspective Approach (MPA) of Mitroff and Linstone (1993). In their book, "Unbound Systems Thinking", the authors argue that : "Multiple combinations of models and observations are more likely to lead to truth than any single model or set of observations." Consequently, they introduce an approach that 'sweeps in' as many perspectives as possible while analysing: the Multiple Perspective Approach (MPA) (Mittroff et al. p.97, 1993). The combination of models will contribute positively to the overall understanding, however how can one know which techniques are most suitable? Here arises the dilemma that is also known as Kant's problem: how do we choose a set of representations that are relevant for a particular problem? No answer is provided on this dilemma by the authors. Mittroff and Linstone argue that it can be considered like a jury arriving at a decision; in that case the prosecutor witnesses and integrates their perspectives to deliver a summary to the jury. All executives wrestle with such questions on a daily basis, often successfully, even though they often do it intuitively. It can be argued that the selection of the proper perspectives contributes to effective decision-making and implementation within organizations or systems (Mittroff et al., 1993).

In the article of Turpin, MPA is introduced as a general systems analysis framework that is useful for studying messy social problems in particular (Turpin, 2009). Two advantages of the method were identified. First of all, the underlying philosophy which is well expressed and satisfactory from a systems point of view. The essence of MPA is that it tries to be all-inclusive in its way of addressing a problem, this is a fairly idealistic idea. The MPA perspectives are classified into five categories, namely: technical (T), organizational (O), personal (P), ethical (E) and aesthetical (A).

Social Paradigms

The second advantage of the MPA is that it is able to address three of the sociological paradigms that were described by Burell and Morgan (1979):

- The functional paradigm (mainly using the T perspective): considered to be the primary paradigm for organizational study, assuming rational human action.
- The interpretive paradigm (covered by O and P): focused on the 'on-going-process' in better understanding the individual behaviour.
- The radical humanist (E): concerned with releasing social constraints that limit human potential. This paradigm is often used for justifying revolutionary change.

There is a belief that these different paradigms are incommensurable: when applying the functional paradigm one is essentially blind to aspects that are visible from the interpretive paradigm, and vice versa. An example: a civil engineer and a social worker at a road accident scene. The one will observe things that the other may be blind to. While the civil engineer will probably look at the traffic streams, traffic lights and accompanied risks, the social worker will put emphasis on the procedures of the emergency services (Turpin, 2011).

To sum up, the MPA seems to be a promising system analysis approach when applying a system study. However by applying the approach several authors determined that the approach lacks practical guidance. This also offers degrees of freedom to some own interpretation (Turpin, 2006, Meyer et al., 2007). Therefore an attempt is made to create a basic practical guidance for using the MPA in the next section.

A framework is designed(Figure 6) that covers the multiple perspectives of the MPA, namely T, O, P, E and A. Using a matrix structure the three sociological paradigms that were discussed in the previous section are added. As mentioned before, the one perspective will have more interfaces with a certain paradigm compared to another. But in order to get a thorough system, understanding a reflection of all combinations of perspectives and paradigms will be useful. In figure 6 the used techniques are visualized in red. The framework is supported by techniques that originate from proven system analysis methodologies. The selection of these techniques has been made pragmatically in order to satisfy the system study objective. In this case, this is to create a thorough system understanding to the technical and social elements of emerging biogas infrastructures in The Netherlands. In the scientific article that can be found in Appendix 6; "Method to study and explore ill-defined systems", more contextual background is provided on the available methodologies including their advantages and shortcomings.

Within this researches framework, two of Checkland's techniques have been used to complete the system definition-both originating from the so-called soft system methodology. The system definition is an effort to structure the current 'unstructured' situation (Checkland et al., 1990). In this case, the system definition starts with *root definitions*. These will sketch the philosophy and purpose of the system by distinguishing the functional, physical, economical, micro, meso and macro aspects. Furthermore the *rich picture* method is used; containing customers, stakeholders, transformation, worldview, owner and environment. This method is used to create the system context (Checkland, 2000). The cloud in figure 6 visualizes this system philosophy-which in combination with the root definitions-functions as a demarcation of the system.

Now the system boundaries are set, the input to the five perspectives can be generated (T,O,P, E and A). As a starting point the practitioner report of Turpin et al.(2009) is used. This includes four steps divided over the categories:

- T perspective, perform an analysis using influence diagrams or a hard systems method (from systems analysis, operations research or systems engineering).
- O and P perspectives include the perspectives of as many role-players as you can find.
- E perspective, use a critical systems approach to uncover some of the ethical issues.
- A perspective: state your interpretation of aesthetics.

These steps are elaborated as follows:

T perspective

Diagramming techniques will be used to identify the systems of interest and the underlying worldviews. This creates the opportunity to explore interconnection, identify emergent themes, system levels and subsystems according to key stakeholders (Collins et al., 2007). In this case the socio-technical subsystem of Chappin (2011) is taken as a starting point. This technical subsystem was originally designed for energy production, which is adapted for biogas infrastructures in this research. This step will focus mainly on the technical components, with a focus on the functional paradigm.

O and P perspectives

The sociological sub system will also be described using an adapted socio-technical subsystem of Chappin (2011). It considers current practices, interactions and participation related to biogas hubs. Furthermore, it describes the multiplicity of perspectives from different stakeholders. Each stakeholder that is involved in the process is discussed including their responsibilities and objectives. In addition, overall subjects will be discussed, that do not touch upon one certain stakeholder but on multiple. This perspective focuses on the interpretive paradigm.

E perspective

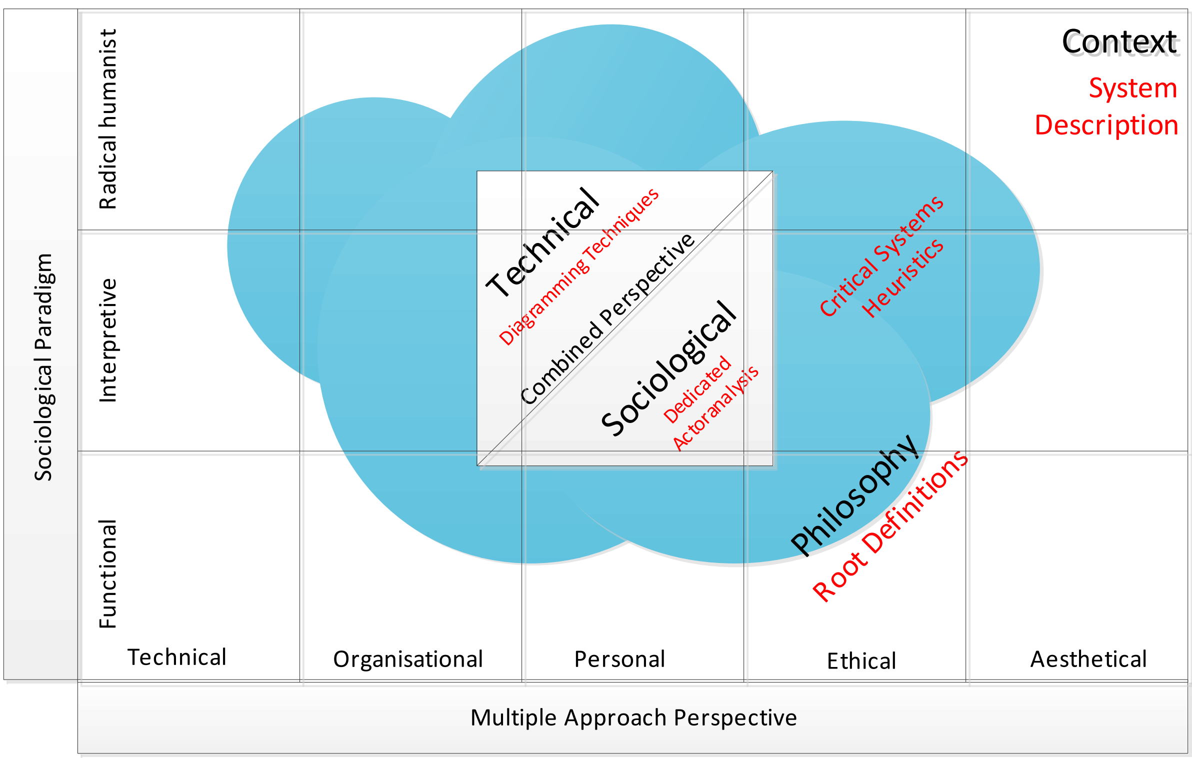
To cover the ethical perspectives, the Critical Systems Heuristics (Ulrich, 1983) is used to reflect upon the biogas infrastructure. This technique explores the difference between a desired situation and the current situation. A tension is revealed between the two situations in case of a problem. Within this perspective the radical humanist paradigm is leading.

A perspective

Within the MPA the aesthetical reflection is also included. Considering the system of biogas infrastructures in The Netherlands this seems to be an unimportant aspect. The system is located mainly under the surface, furthermore involved stakeholders do not have a specific attention on aesthetics in their objectives. As was mentioned in section 1, 735 digesters will be needed when the Dutch natural gas supply is substituted by 50% biogas. In that case a similar discussion could arise as is currently the case windmills. Are there maybe too many digesters 'polluting' the landscape? Since this situation is unlikely even in the middle-to-long term the aesthetical perspective is not elaborated further in this research.

The execution of these four steps is an iterative process, for example: issues from step 3 also could have consequences for the status of step 1. In figure 6 the used techniques are visualized in red, with the square in the middle representing socio-technical subsystems from both the T perspective and the O and P perspective. To finalize the MPA these subsystems are coupled as one general socio-technical system (STS). What the dis-/advantages of this approach are, will be discussed in section 8.3.

Figure 6 - Combined system perspective approach

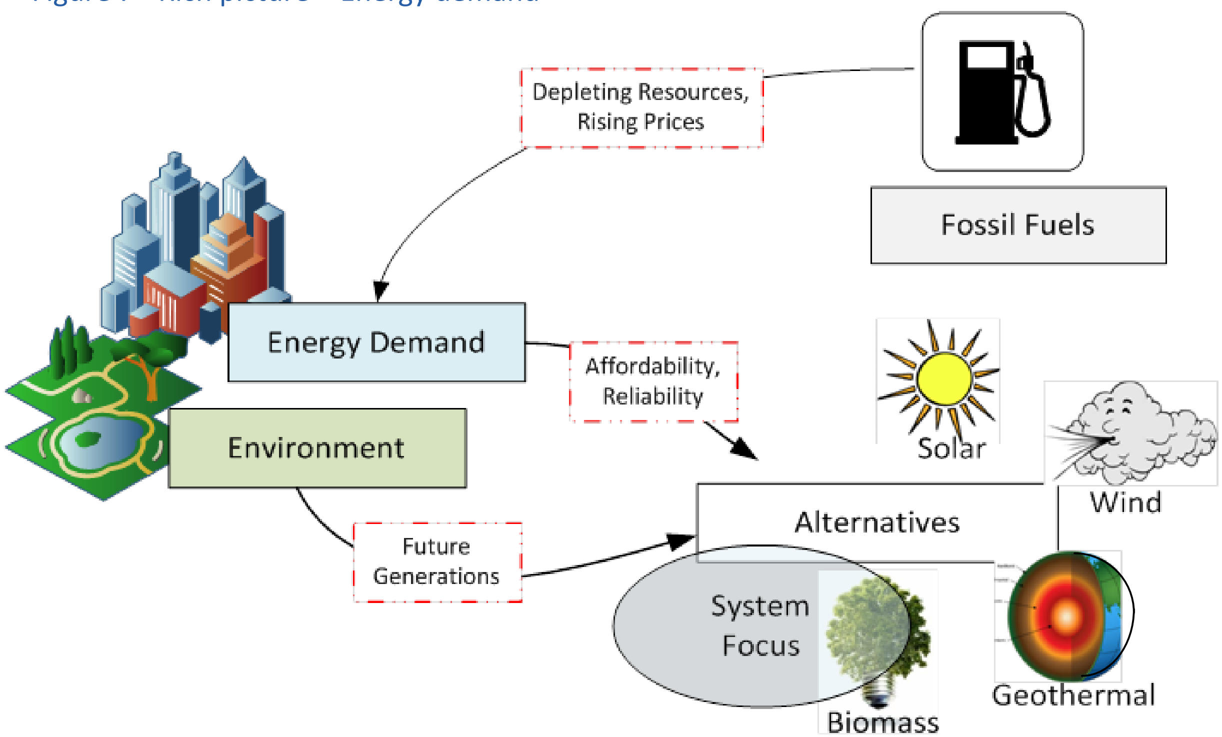


3.2 System Context – Describing the system background

In this first phase of the empirical system description, the system context will be explored using rich pictures (Checkland, 2000). Accompanied by a description these represent the underlying worldviews in which the considered system is defined. For a more extensive explanation on the technique please inform the methodological explanation on the bottom of this page.

Our current society is facing a rising energy demand, due to a growing population, emerging markets and growing wealth level. This leads to worldwide concerns on the availability of energy in the near future. Fossil fuels, which cover currently a significant majority of the energy production faces depleting sources and increased prices. Affordability and reliability, which are important public values of the energy supply, could be harmed by these circumstances. At the same time environmental concerns raise the belief that clean energy production needs to be realized. The search for alternative energy sources is therefore supported from several groups of interest.

Figure 7 - Rich picture – Energy demand



Biomass is one of the alternative energy sources that fulfil a role in the current energy supply. During 2010 biomass was responsible for 74% of the renewable energy production in The Netherlands (CBS, 2011). There is a wide variety of applications available to convert biomass into energy. Three major applications are the incineration installation, co-firing in power generators and the use of biomass as bio fuels in transportation. Furthermore biomass' organic waste can be used to produce biogas. Figure 7 sketches the context in a visual perspective.

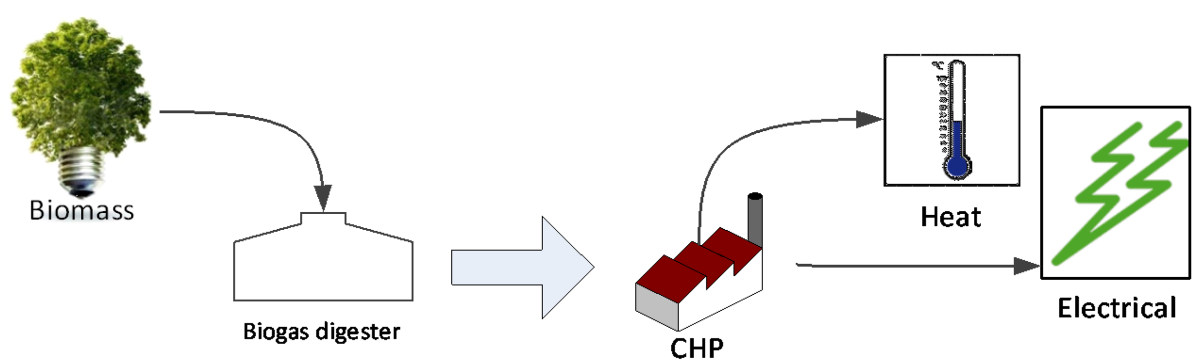
Methodological Explanation: Checkland´s Rich Picture

Rich pictures originate from Peter Checkland´s Soft Systems Methodology. It is a means to express a problem situation in a holistic sense. The ad hoc sketched pictures are used to explore and explain a situation or problem context. By using rich pictures people are encouraged to approach a situation using a holistic system thinking perspective rather than reductionist thinking. This allows a problem solver to consider a larger realm of issues as well as a larger number of solutions (Wigal, 2009; Checkland, 2000).

Currently biogas can be used in a combined heat and power generator (CHP), in which both electricity and heat are generated (Figure 8). CHP generators can meet a total efficiency between 60 and 85 percent considering the generation of heat. But the efficiency of the power generation is limited to only 33% (EPA,2010). In this perspective conventional power generators that rely on natural gas can reach efficiencies approaching 60%. However the volume of biogas decreases with almost 30% while it is upgraded to green gas, the overall energy efficiency that will be obtained over the whole process will end up at 44% (Agentschap NL, 2009). Therefore the added value of the upgrading process is present compared to the functioning of biogas in the CHP.

The concept of transporting biogas through pipelines is not new. In the case of farmers who connect their biogas digester to a CHP also a pipeline is used. Here it is short raw biogas pipelines on the terrain of the producer. But since potential producers are not located in each other's' direct neighbourhood, the biogas infrastructure will connect farmers on a longer-distance, probably using public terrain.

Figure 8 - Rich picture – Biogas to CHP

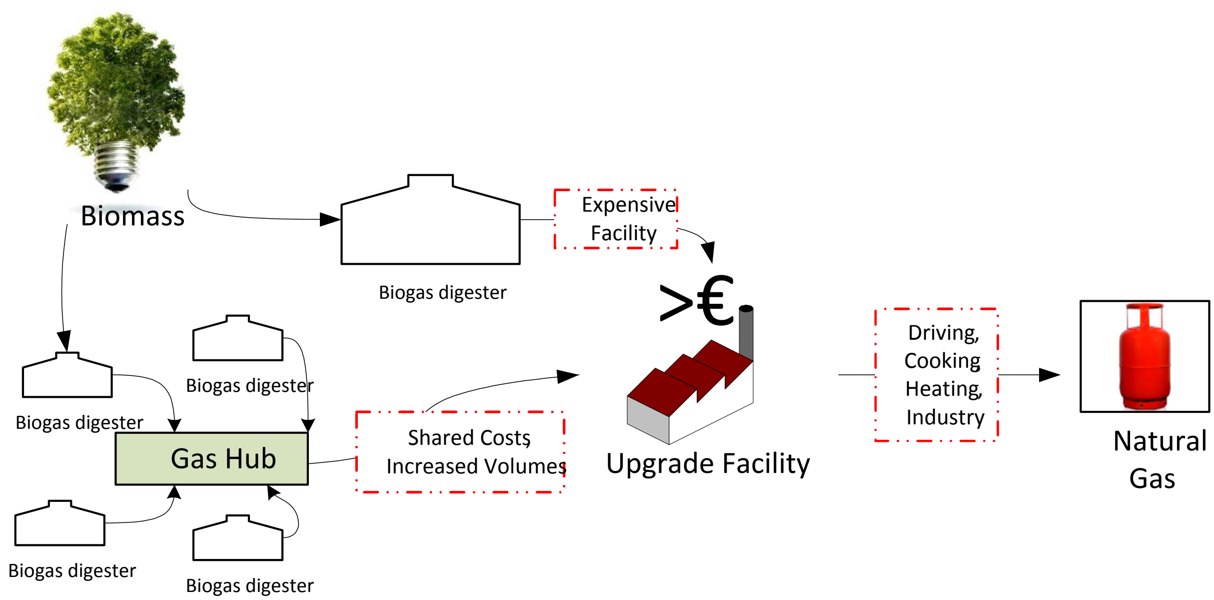


This raw biogas can be used for user appliances, such as cooking, lighting or fuel. Yet there is a need of adjustments to current appliances (Maramba, 1978). For example, simple stoves should be adjusted due to the contaminants that could harm the device. Additionally when the biogas is produced on a significant distance, no use can be made of the current natural gas network since also the biogas will mix with the natural gas and could cause damage to all kind of systems within the network, like the gas receiving station (Gas Ontvangst Station). Besides the injection of raw biogas would also bring safety issues, since biogas cannot always being odorized (KIWA TECH, 2009). This could cause dangerous situation when gas leakage occur.

Another application of biogas is the possibility to upgrade the biogas to natural gas quality. In that case the percentage of methane is increased, due to a washing step where the surplus of CO_2, H_2S, H_2O, NH_3(and some contaminants) are removed from the gas. This step will cause a heightened content of methane within the gas up to a >95% level. After this processing step the gas is referred to as 'green gas' (Reperrich et al., 2009). Green gas can be used in the conventional installations and can make use of the existing infrastructure. Currently there are already a few medium to large scale green gas producers active in The Netherlands. Examples can be found in Groningen (Waste processor, Attero), Eindhoven (Landfill gas, Carbiogas) and Spakenburg (Industrial waste, A v/d Groep en Zonen). Also individual farmers can use there cattle's manure or crops to produce biogas and upgrade this to natural gas quality.

A biogas hub will link independent biogas producers and will upgrade their biogas at one central location. In this case there is no need to invest in the relative expensive upgrading location at every location. Besides the shared costs, the overall volume of biogas that can be upgraded will increase. Some farmers will, including the shared costs concept, take the decision to start biogas production (Figure 9).

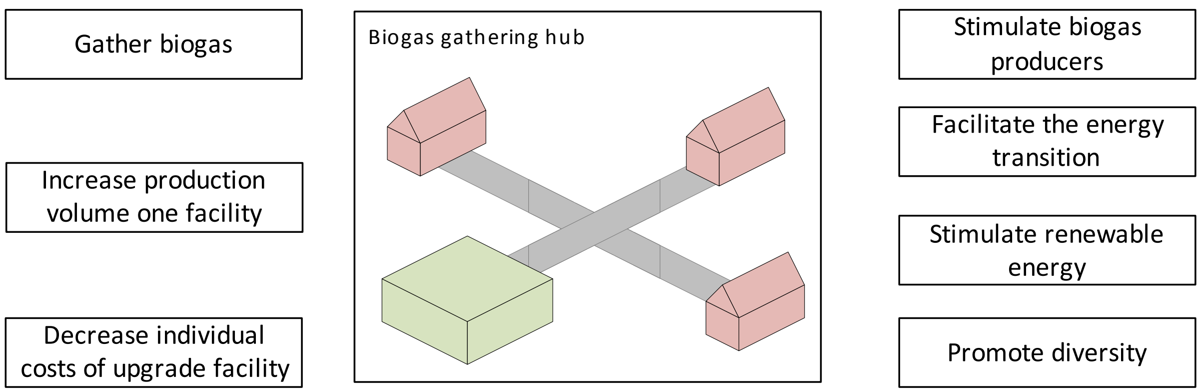
Figure 9 - Rich picture – Biogas Infrastructures



3.2.1 Root definitions – The philosophy behind the system

This research is focused on the realization of biogas infrastructure. Therefore the further description will be focused on this specific system, which should be defined first. In figure 10 we present a set of seven root definitions that are composed by the researcher and verified by stakeholders (Dumont, 2011; Wempe, 2011). This can therefore be considered as a common understanding of the system functions. Each function definition is accompanied with an explanation.

Figure 10 - Root definition - Biogas gathering hub



A biogas hub can be considered a system to...

- gather biogas

This covers the purely *physical* functionality of a gathering hub. The ability of connecting several biogas producers, leading to one central point that acts as the exit point of the system.

- increase the production volume of one upgrading facility

The definition approaches the consequence of the first *functional* definition, the gathering process increases the volume flow to the exit point.

- decrease individual costs of an upgrading facility of biogas

Due to the allocation of investment costs of one upgrading facility among several biogas producers, it will be more attractive to join a biogas hub. For small farmers this will make them a sound business case instead of a negative. Shortly this definition mentions the *economic* advantage of a biogas hub.

- stimulate biogas producers

The fact that a sound business case can be approached will stimulate more farmers to start producing biogas. This definition influences the system more on the economic *micro* level.

- stimulate green gas/ renewable energy

Since the system will generate more biogas, which is the main source to green gas, also the share of renewable energy could profit from the system. This definition has more impact on the economic *meso* level. Furthermore this can also be interpreted as fulfilling socio-political remits by funding political objectives (one of the motives on public funding according to Caracostas (2007))

- facilitate the energy transition

By promoting the share of renewable energy the system will also contribute to the energy transition as defined in section 2. The energy transition can be related to the economic *macro* level.

- promote diversity

Indirectly the emergence of new networks and infrastructures will create opportunities to other companies and knowledge institutes. Diversity is created, since initiated networks are open to all kind of companies and knowledge institutes. They can participate and generate advantage of these projects. This final definition on the promotion of diversity operates on a high aggregation level (Callon,1994).

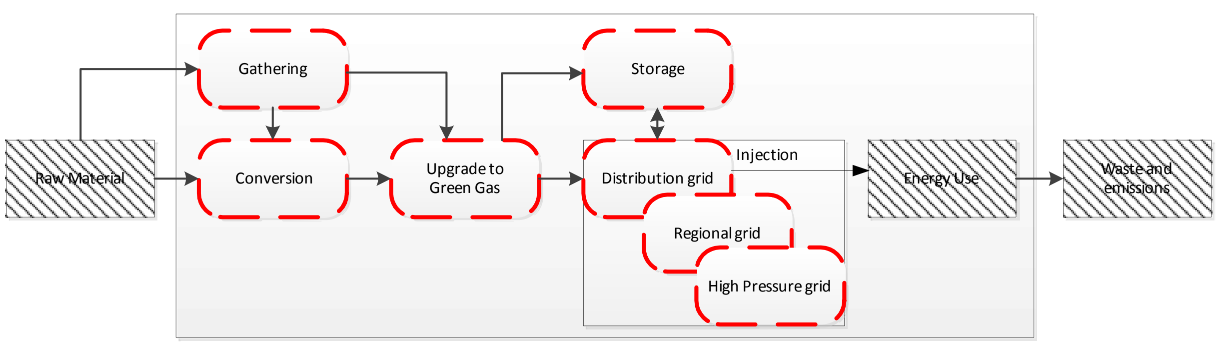
Methodological Explanation: Checkland´s Root Definitions

Root definitions are often linked to the rich picture methodology, as explained in 3.2. By using the root definitions several points of views can be incorporated which make a considered system meaningful. Furthermore it urges a researcher to observe a situation from reality avoiding them to end up in a hoped-for-analysis. Mind that root definitions could only obtain combined with a certain worldview. Some root definitions will not be agreed as important by all involved stakeholders. It is up to the analyst/researcher to propose final recommendations based on the selected views (Hanafizadeh, et al. 2011; Checkland, 2000).

3.3 Technical Overview – The Technological perspective

In the system diagram (Figure 11), which is based on Chappin (2011), a representation of the biogas infrastructure as part of a socio-technical system is defined. In this section the subsystems will be explained, starting with the technical subsystems. These explanations are descriptive and do not contain explicit analysis or conclusions. The red dotted activities can be seen as core activities of the biogas infrastructure.

Figure 11 - Technical subsystem



Raw Material

The raw material that can be used to produce biogas could have a varying background. In fact, all the material that could end up as compost is suitable for biogas production: organic materials such as vegetable, but also animal material, food and manure can be used for biogas production. The raw material could be directly converted to biogas at the location where the raw material is produced, e.g. a farm. On the other hand, it is also possible to gather the raw material and produce the biogas on a central location, e.g. waste processor. Depending on the scale of the production this could be beneficial.

When aiming on a significant production volume of biogas, the logistical process to bring biomass to the production process is complicated. This would be a major bottleneck for a successful implementation of biogas since import of biomass seems to be a precondition. The logistical processes are reported as a critical factor in the bio-energy chain (Boerrigter, 2006).

Gathering

The gathering process could act as gather process for the raw material. Yet when considering a biogas hub, the gathering process will cover the gathering of produced biogas to a central location. The conventional pipelines that are used for gas transport are made of poly-ethylene (PE), yet for biogas transport an additional facility seems necessary to guarantee a reliable distribution of gas. As was discussed in the Strategic Analysis the influences of e.g. contaminants on the pipelines are not clear yet. More specifically it appears that contaminants that are present in biogas like as hydrogen sulphide, benzene, limonene and ammonia have a higher concentration compared to the acceptable concentrations on health and reliability. The exact amount and origin of the pollution depends on the biomass.

- Hydrogen sulfide can harm the safety, health and environment.
- Sulfur compounds cause corrosion on plastics
- Ammonia can cause moderate corrosion on most plastics.
- All contaminants will practically cause corrosion when they are combined with water

The consequences of the contaminants presence is explained here in more detail:

In case of aromatic hydrocarbons (such as benzene and limonene) there is a risk that plastics (like PE-pipelines) lose their properties because of absorbed liquids or the extraction of essential plasticizers. This can cause embrittlement which harms the reliability of the pipelines dramatically. To prevent the pipeline to become weak, a water dew point temperature could be retained of 3°C (which is 10 °C lower compared to the average ground temperatures). However this will retain the strength in the pipeline, the costs of lowering the temperature of a pipeline network with 10°C will be significant. Which make it an unfeasible solution.

Besides the hydrocarbons it are the oil-like(higher hydrocarbons) components and sulfur compounds that could become sticky when they come in direct contact with each other. This can attach them to the inner-pipelines, causing constipation. This causes a high concentration, low vapor pressure and a low ground temperature, which then could cause undesired condensation. A low temperature would also prevent these risks (Van Gorkum, 2011).

Another important requirement in the gathering infrastructure will be the odorisation of biogas. Some literature argue that not all biogas can be odorized using the conventional THT addition (tetrahydrothiofene). When that is the case, people will not be aware of gas leakage. Additional safety measures needs to be taken, which increases the cost (Kiwa tech, 2009). Should be mentioned that the amount of THT that was used during this study was equal to the terms and conditions on connection and transport of regional system operators, a higher concentration could probably work out (Schoemakers, 2008). According to Mathieu Dumont, odorization will never be a problem since there will always be a technological solution available in any circumstance (Dumont, 2011).

Conversion to biogas

The most conventional method to produce biogas is by anaerobic digestion of organic feedstock. Here the raw material, like crop residues, municipal solid waste and animal waste is fermented to biogas. Bacteria are used to generate biogas by decomposing organic material. The residual gas consists of 50-75% methane, 25-45% carbon dioxide and traces of among others water, nitrogen, oxygen and hydrogen (Poeschl, et al, 2010). Another method that is applied to produce biogas is gasification. Here the decomposition of organic material takes place by combustion. Because the combustion is performed with a shortage of oxygen an incomplete combustion creates a combustible gas, also called syngas. The amount of produced biogas depends on the raw material that is used as input to the process and on the specific composition. Biomass consists out of carbon hydrates, proteins and fats. The more fat is included in the composition of the biomass the more biogas can be produced (FNR, 2009). Table 2 shows the costs of biogas producing facilities based on their production volume. This covers the conventional anaerobic digestion technology based on a ratio of 90% waste and 10% corn. These are indications of the costs, since the exact installation will depend always on location and the specific raw material used for conversion.

Table 2 - Costs of biogas production facility on M€ (Urban, 2008)

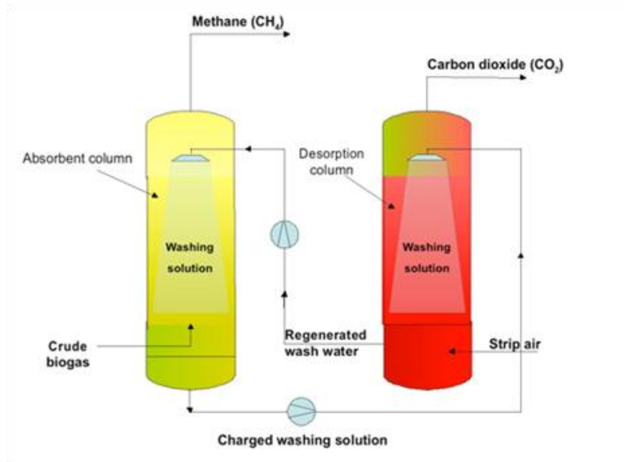
Volume (Nm^3/h)	100	250	500
Investment costs biogas (M€)	0,535	1,08	1,85
Operational costs biogas(M€/yr)	0,217	0,514	0,927

Upgrade to Green Gas

The additional processing step to convert biogas towards green gas can be done at the same location as the biogas is produced or at the central location the gather hub has brought the biogas. This upgrade is necessary to make the gas compliant with the quality standards in the Dutch natural gas transmission network. Removing contaminants and substances like carbon dioxide (CO2), hydrogen sulfide (H2S), water (H2O), ammonia (NH3) will cause a methane percentage of >95%. The technology that is used in the upgrading step nowadays could be biological, physical or chemical. However the biological process is only applied to remove H_2S from the biogas and not for the complete upgrade. The most conventional technologies that are used for the overall upgrading process are explained briefly:

- Pressurized water scrubbing: the difference on solubility characteristics between CO2, H2S and NH3 is used to separate them from CH4. Water is used as a scrubbing agent in a pressurized column to wash the components out of the biogas. Figure 12 gives a visual explanation. Considering the size of a regular biogas upgrading facility it will need the space of two transport containers.

Figure 12 - Pressurized water scrubbing



Source: MT-biomethane, 2011

- Pressurized swing adsorption: usually active carbon is used to separate carbon dioxide from the biogas by adsorption on a surface under elevated pressure. The active carbon is regenerated by a pressure swing that sequentially decreases pressure before the column is reloaded.
- Chemical scrubbing: due to the very selective reaction that carbon dioxide has with amine solutions only a methane loss of >0,1% takes place during the chemical scrubbing process.
- Membrane separation: dry membranes will be permeable to almost all raw biogas elements. Only nitrogen and methane will pass the membrane to a very low extend (Petersson et al., 2009).

Before the gas is in compliance with the Dutch natural gas grid there is also a need for odorization. In The Netherlands this is done using THT (tetrahydrothiofeen), this improves the safety in case of gas leakage. When the odorization process is finished the gas can be mentioned as 'green gas'.

In Table 3 the costs of the biogas upgrading process is presented. This covers the pressurized water scrubbing technology, which is the most regular technology, based on a ratio of 90% waste and 10% corn. These are indications of the costs, since the exact installation could depend on location. Considering the size of a biogas upgrading facility, most of them have a container serving as housing.

Table 3 - Costs biogas upgrading facility (Urban et al., 2008)

Volume (Nm^3/h)	100	250	500
Investment costs upgrader(M€)	1,145	1,323	1,699
Operational costs upgrader(M€/yr)	0,229	0,326	0,523

Now the costs are presented a brief business case can be sketched considering the current situation. When producing 300 Nm3/h a substantial biogas producer is considered. The current business case seems like this; The producer needs to invest approximately €1.200.000 for the biogas digester and €1.350.000 for the biogas upgrade installation. Furthermore the operational costs will be €600.000 for the digester and €350.000 a year for the operational costs of the upgrading facility (Urban et al., 2008). This makes a total initial investment costs of €2.550.000. The yearly operational cost will be €950.000. On a yearly basis this producer will produce 1.700.000 Nm^3 green gas a year. Which accounts for approximately €1.000.000 of revenues a year, based on a gas price of

€0.61 (DHV, 2010). It will take 51 years before the yearly revenue of €50.000 would cover all previous investments. This is not an economically solid business case.

Injection and Transmission

The injection into the network can be achieved on several levels, the distribution network, the regional network and the transmission network (see also Table 4). All require different pressure levels, respectively >0,8 MPa, 4,0 MPa and 6,7 MPa. Compressors fulfil this task. Gas can only be injected when there is a demand in the gas network, the balancing regime is of main importance to ensure a technical suitable system. When gas is injected without demand is at stake, the pressure level will be influenced which could have consequences to industries and customers connected to the network. The operators of distribution networks will therefore collaborate closely with the producers. They should know exactly what volumes of green gas can be injected in their distribution network. Furthermore concerns relating the gas quality create high awareness among stakeholders that are responsible for a reliable gas network on national or regional level. The reliability of their systems should not be harmed by the injection of green gas.

Table 4 - Characteristics of gas networks (based on Braaksma, 2010)

	Transmission Network	Regional Network	Distribution network
Pipeline material	Steel	Steel	PVC, steel, cast iron
Pressure	60-80 Pa	39 Pa	< 8 Pa
Diameter	48 “	16”	10”
Customers	Large industry, foreign markets	Industry	Households, horticulture, small industries

Energy usage / End users Demand

After the green gas is injected to the grid it can be transported to the end users. For the distribution network these will be local consumers (households, horticulture and small industries), the regional network could supply the industry while the transmission network could facilitate the cross-border connections and large industries.

Storage

Besides the supply to consumers another option is to store the gas temporarily. Seasonal fluctuations could cause a surplus in production, especially during summer periods when the gas consumption is relatively low. On the other hand, cold winters could increase the demand strongly. Storage capacity can be used to overcome these fluctuations by injecting gas into the storage when a surplus arises.

Green gas producers have a storage availability of their production of 30 min to 2 hours on average. This is far to less in coping with the seasonal fluctuations, since these can last for hours or even days. Also the pipeline network offers a storage buffer by itself, in combination with the producers storage availability this could cover a daily surplus (Dumont, 2011). But when a surplus is increasing, alternatives need to be found.

In The Netherlands 4 large-scale gas storage facilities are operational (Norg, Grijpskerk, Alkmaar en Zuidwending). The last storage facility in Zuidwending opened in January 2011 and stores the gas in salt caverns (Cuiper, 2009). These storages are connected to the transmission grid of GTS. This means that the gas is not odorized, since some industrial appliances cannot cope with THT (VIAG,2011). Storage here would require a de-odorisation, which is technological complex (Dumont, 2011).

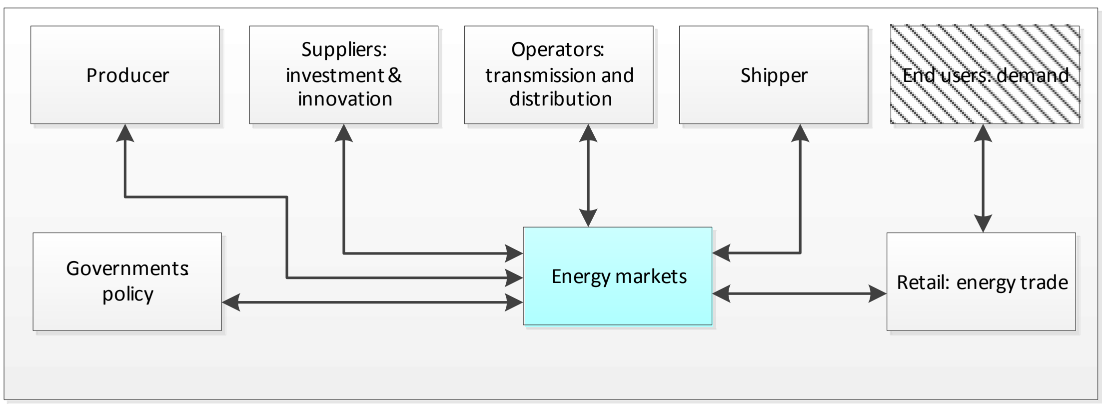
Waste and emission

When using biomass to produce green gas, waste and emission are unfortunately a by-product. Compared to conventional fuels, as diesel, bio-diesel and bio-ethanol, the emission of green gas is 80 till 90 percent lower (Kampman et al, 2010). For this reason green gas production is mentioned as a transition energy source.

3.4 Sociological system – The Organizational/Personal perspective

Now that the technical subsystem has been described, the social subsystem needs to be explained. The scheme of figure 13 is based on Chappin (2011), additionally it also includes the roles of producer and shipper. The social context is accompanied with some more background information, as the objectives and responsibilities of the stakeholders in the playing field are included.

Figure 13 - Social subsystem



Producers of biogas

The main element for biogas producers is the digester, the system element in which the biogas is actually produced. The producers of biogas are divided in two major categories. On the one hand the industrialized producers who convert e.g. waste on large scale, on the other hand the small scale producers. These are mostly farmers who digest the manure of their cattle. In the empirical biogas infrastructure system that is considered in this research the small scale producers are involved, however it is also possible to realize the biogas gathering infrastructure in the neighbourhood of a large-scale green gas producer. In that case the large-scale producer could become part of the system, since the biogas of both parties (large-scale and farmers) will be upgraded in the same upgrading facility. The farmers consider the possibility of producing biogas as a possibility to solve the manure problems, not yet as an additional business where they can earn money. Currently numerous farmers have an operational CHP, since the former SDE subsidy was applicable on the CHP this was financially attractive. The CHP is not included in the SDE anymore, which makes this kind of energy generation only attractive when also the heat can be used effectively. Yet this is in most cases difficult to accomplish due to geographic circumstances. For this reason these farmers are searching for economic attractive alternatives, such as biogas production. Especially the uncertainties related to legislation on stalls (2013) and the stop of the milk quotas (2015), increase the benevolence of cattle owners to start producing biogas (Saxion, 2010).

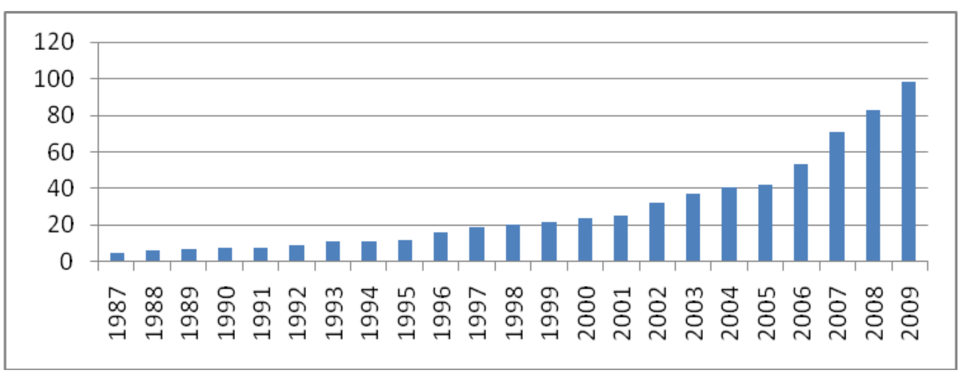
Producers of green gas

The production facility in which the biogas is upgraded to green gas will be managed by a producer. He is responsible for the gas quality that is produced, this also makes the producer responsible for all damage caused to individuals or the distribution network operator by the feed-in of his produced gas. Furthermore the producer is responsible for the demand of the gas. He guarantees the distribution network operator that sufficient demand will be available at the location of the network where the producer is connected to. There should be no negative allocation on an hourly basis, so the producers may not produce less than the proposed production. The producer will have contractual agreements with shippers and energy suppliers who will set the agreements with individual customers (Schoemakers, 2009).

	Action	Responsibility	Objective
Producer	Producing biogas	- gas quality - guarantees demand	Profit and continuity

Equipment Suppliers: Investment and innovations

Producers of biogas digesters or upgrading facilities are widely available. In 2009 there were 98 upgrading plants active in Europe. The market is growing and more are planned in the near future (Graph 1). In 2009 14 companies could provide upgrading plants in the European market. As was discussed in section 1 several stakeholders want to create a sustainable energy supply. Biogas and green gas are suitable energy sources in the transition period. Yet there are several other sustainable alternatives. Most of them are relatively new technologies and not yet developed to a cost-effective state. Also biogas digesters and upgrading facilities can increase in efficiency and decrease in costs. To deliver a competitive and economic attractive technology the developers of biogas equipment could make investments in the research and development. The price level of upgrading installations is already decreasing (Dumont, 2011).



Graph 1 - Number of biogas upgrading plants in Europe (eco.prospects.co.uk)

	Action	Responsibility	Objective
Equipment supplier	Producing equipment	- technological reliability	Profit and continuity

Network operators: transmission and distribution (Enexis, Stedin, Gasunie (GTS))

Currently biogas is not included in the Gas Act. For that reason the distributed network operators are not obliged to cooperate with the biogas projects. There are no regulated tariffs and the costs related to depth investments are cannot be socialized. In case of natural gas, the costs to cover the facilitation of the transport of gas from the distribution network towards the regional network can be socialized when the Energiekamer agrees on the fact that the investment has a general interest.

Since the network operators are responsible for the distribution and transport of the gas, they will have control over the distribution network. They will compose the requirements for injection and take care for related contracts. Distribution operators want to perform also the maintenance of all the gas pipelines in their service area, due to the safety and reliability concerns (Van Erp, 2010). In case of green gas, the distribution network operator measures the quality that enters their network. Furthermore they have the right to interrupt the injection when the required quality specifications are not met. The transmission network is owned by GTS, who has currently a conservative attitude to the injection of green gas in their network. Especially due to the technical uncertainties that arise (see section 3.3).

The need for gas production is directly linked to the energy demand. Especially in case of gas this relationship has a direct character, the gas that is injected in the network needs to get out of the network as well at the same time. Here an additional difficulty exists due to the fact the pressure needs to be constant in the network to maintain a reliable supply. Natural gas production can be easily adjusted, the Groningen gas field has a pressure that offers the possibility to vary the production. Biological production processes that are used to produce biogas cannot be stopped at once. This causes the circumstance that the produced green gas needs to be used directly, for consumption or in storage.

	Action	Responsibility	Objective
Network Operators	Transport and distribute gas	- network reliability - connect gas producers to network	Perform distribution and transport Facilitate energy transition

Shippers

The shipper is responsible for the balancing regime. They will take care that an entry point in the network gets sufficient volumes of gas to meet the demand of consumers in that specific part of the network. The gas will be purchased by the energy retailer (Energiegids, 2011).

	Action	Responsibility	Objective
Shippers	Trade gas	- proper balancing regime	Profit and continuity

Governmental authorities (Ministries, Municipalities and Provinces)

Many governmental organizations on supranational, national, regional and local level are responsible for the well-functioning of (some parts of) infrastructures. This makes them create policies, legislation and regulations in order to fulfill this task. In the case of biogas infrastructures in The Netherlands the Dutch government, provinces and municipalities are part of the system.

Encouraging renewable energy sources is one of the national governments objectives to participate in this social subsystem. The objectives originate from several targets where the national government agreed on from a global and European level. By creating legislation, regulation and subsidies incentives are created that could influence stakeholders behavior in realizing renewable energy projects. The government can manage the side-conditions of the system. Since the government has other responsibilities besides the encouragement of biogas and green gas infrastructures, there is no certainty about the policies priority.

On a local level the province and municipalities are involved in the system. The municipalities are for example involved with the issuing of permits. When installing a production facility a building permit is required, the municipality will assess whether or not a digester is in confirmation with the zoning. Additionally a coupling with the Environmental Act (Wet Milieubeheer) is needed (Greeve, 2009). So also an environmental permit is required.

The province can facilitate the process, at least this is the case in Overijssel and Friesland. The province investigates for example whether or not there are sufficient potential producers available who can be involved in a biogas infrastructure project. Indirectly this could also stimulate the local economies, as we will discuss in section 3.5.

	Action	Responsibility	Objective
National	Legislate Issuing subsidies	- fulfil sustainability targets - secure long term energy supply	Sustainability targets EU
Province	Facilitating the development process	- healthy economic region	Sustainability ambition Generation of jobs
Municipality	Issuing permits	- safe living environment	Creating optimal environment to live and work

Energy demand: end users

The need for gas production is directly coupled to the energy demand. But since there are alternative energy resources available and because appliances become more energy efficient the gas demand is decreased. Compared to 2011 Dutch households use almost half of the amount of gas that was used in 1981. Due to the wide-spread installation of the high efficiency boiler, improved isolation of houses and the purchase of energy efficient home appliances the gas usage decreased from 3000 cubic a year to 1600 cubic a year for a single household (NOS, 2011). There are also residential areas under construction that will not have a gas connection at all, like in Hoogezand-Sappermeer or Witmarsum.

An interesting notion is that the EU directive 2003/30/EC obliges The Netherlands to ensure at least 10% of the total transportation fuels to be substituted by biofuels. Also green gas can be used in this perspective, which could give an incentive to the green gas market. This substitution needs to be executed in collaboration with the oil companies, since their fuel stations are needed to achieve this 10% substitution. Furthermore car manufactures will be needed to make green gas cars attractive, with respect to driving performance, price and exterior. Currently the prices of these vehicles are high and not economically attractive to individual consumers.

According to research of Market Response service is the most important to consumers of energy suppliers. But besides the service the fact whether or not the energy is produced sustainable would be more important compared to the price level (Market Response, 2010). In this perspective producers should participate in biogas infrastructure projects to generate a sustainable image, and increase their amount of sustainable produced energy. Another research showed the most important reason to switch to another supplier, the research was held among 300 switchers. For these people the indicator 'price' was the most important reason to switch (Energiewereld, 2011). Therefore also the cost-effectiveness of the production needs to be monitored.

	Action	Responsibility	Objective
Energy users	Consuming gas	-	Low cost, high quality

Retail: energy trade (Essent)

Within the energy market the enthusiasm about green gas and biogas varies. Most energy companies do not participate in biogas related projects. Yet some energy retailers also contribute to energy production. An example is Essent NV, who also owns several power stations in The Netherlands. Essent is one of the initiators of the BioNOF project in Friesland, and currently the project owner. However the future estimations of the competitiveness of biogas and green gas are insecure Essent considers it as a new growing market. The company believes a solid business case can be created and therefore they are eager to become the first player on this market. This would probably involve them also in later stages (Dumont, 2011). Currently they are the only energy retailer involved in biogas infrastructure projects. The initiation of the BioNOF project has been agreed before the Dutch energy market was unbundled in 2008. At that moment Essent had public shareholders (Van Dam, 2011). Whether the same choice should be made under private ownership is uncertain. Fact is that no other biogas infrastructures have been initiated after the unbundling in 2009.

The energy retailer will purchase the produced gas and sell it to their customers. In contrast with the usual energy production of energy producing companies like Essent there is a dependency on the individual producers to achieve the desired volumes. Circumstances could arise in which a farmer is forced to stop his activities, for example because of a disease. The individual farmers are vulnerable to the business case of the retailer. Without the individual farmers no economic attractive volumes can be produced. This should be taken into account when an investment decision is made by the energy producing companies.

	Action	Responsibility	Objective
Essent	Investing in developing biogas hub	- corporate social responsibility	Exploring new market Sustainable image
Retailer	Buy and sell gas	- ensuring a sufficient amount of energy available	Profit continuity Image

Energy market

At the energy market APX-Gas NL suppliers and purchasers of gas are brought together to facilitate the financial settlement. The APX functions as a physical exchange with delivery on the Title Transfer Facility (TTF). The TTF is focused on the wholesale market, including long-term deliveries. Using virtual entry points suppliers sell the gas, while consumers take the gas from a virtual exit point. The TTF is actually administrating transactions.

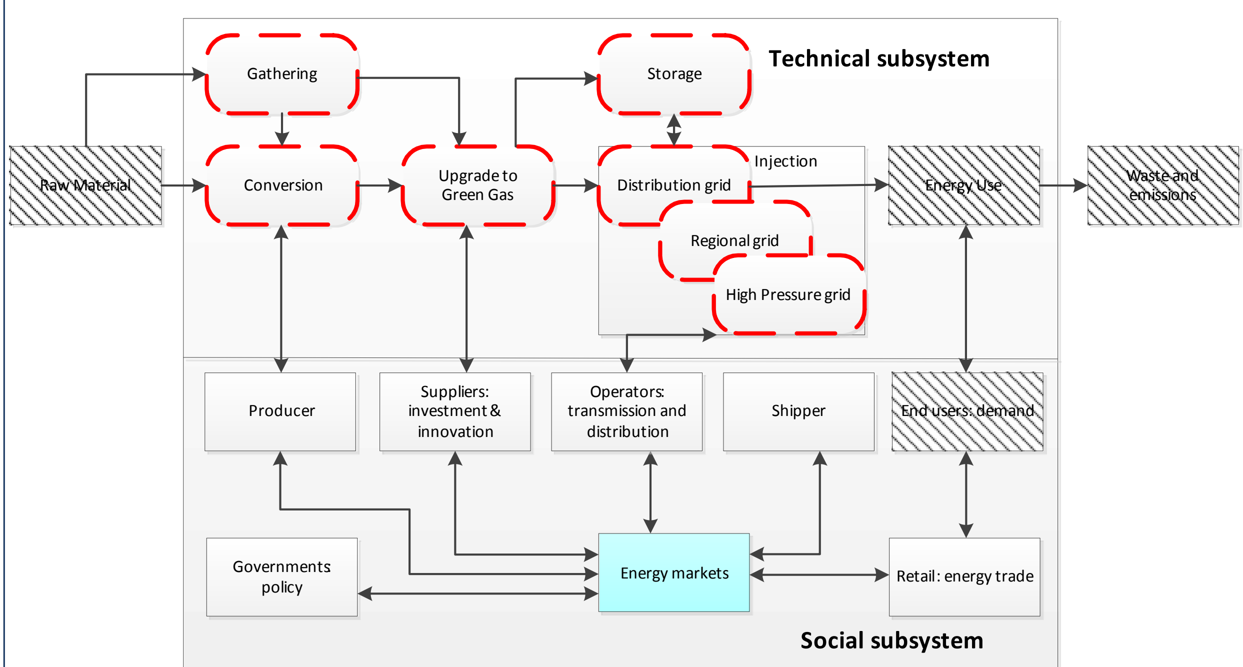
To a biogas infrastructure it is not exactly clear what kind of organizational model will be applied. One could think about one overarching organization that is responsible for the upgrading process and transactions with the market. This could also be the responsibility of the energy retailer, or perhaps the individual biogas producers themselves.

	Action	Responsibility	Objective
Energy market	Facilitating energy trade	- transparency	Efficient and transparent

3.5 Socio-technical system – the multiple perspective

By combining the technical and the social subsystem, the socio technical system (STS) can be created (Figure 14). In this section the subjects that have interrelations will be discussed. This interrelationship could be between entities in the social subsystem, entities in the technological subsystem or an interrelationship between both of them. These elements will be less descriptive and will contain more analysis. At the end of this section a more detailed STS can be presented, including the challenges and trends between the system components.

Figure 14 - Socio-Technical system



Involvement of stakeholders

First of all the involvement of the current stakeholders will be considered. Where in the technological subsystem every step is essential for proper functioning of the system, within the sociological subsystem the involvement of stakeholders is not equally important.

To get more feeling on the coherence of stakeholders in the playing field an overview is made after discussion interviews on stakeholder involvement in Figure 15 (Dumont, 2011, Wempe, 2011). This can be interpreted as a rather objective perspective on the system of emerging biogas infrastructures. A subdivision is made that between poorly and strongly involved stakeholders. The color represents the involvement to the considered system, red makes an stakeholder poor involved, whereas green makes an stakeholder strongly involved. It appears that the biogas infrastructure can be considered a system with a rather functional focus in the phase of emergence. For the development of the system, economic arrangements will mainly be made between the producing and facilitating subsystems. The purchase of gas by the energy retailers will be comparable with current arrangements e.g. solar-energy. The national government appoints to themselves a reluctant role in order to create possibilities for the market parties. With the SDE+ subsidy, on which we will elaborate in the remainder of this section, the Ministry of Economic Affairs, Agriculture and Innovation has the most direct influence according to the stakeholders. Only the local governmental organizations will have direct involvement and will therefore be key in the development phase of the biogas infrastructure.

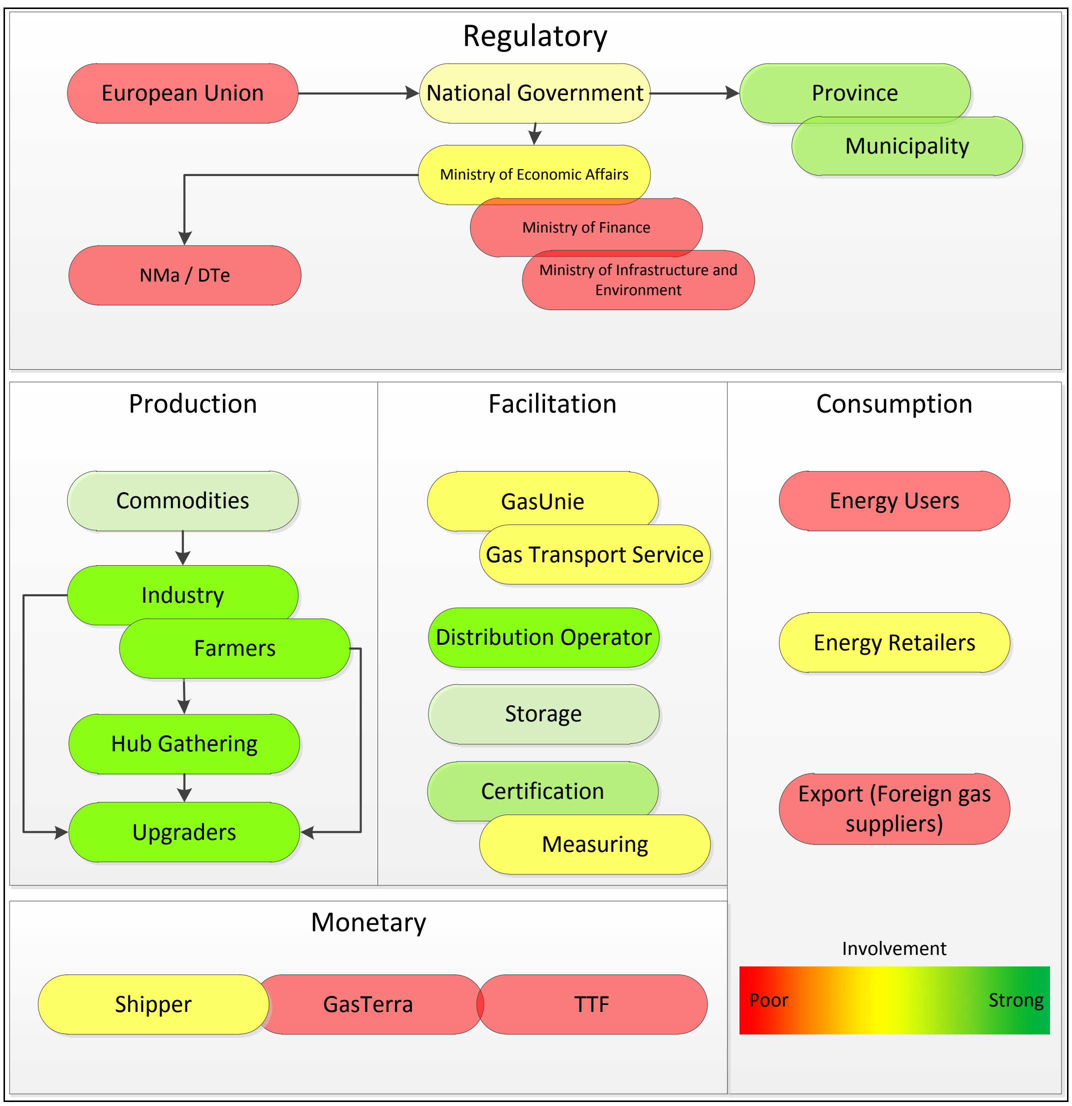


Figure 15 - Involvement stakeholder scheme

The problem with stakeholders within in a network is that their acts are not determined based on opinions, but they tend to behave strategically in order to consolidate a power position in the network (De Bruijn et al., 2008). In the case of the Dutch energy sector this is probably even more the case. The Dutch energy regime is dominated by a couple of parties with big interests in the extraction, supply and use of fossil-based energy. With respect to the transition to a more sustainable energy supply these powerful entities experience especially the costs not the revenues of the energy transition (RLI, 2011). At the same time the monetary support of the Ministry of Economic Affairs, Agriculture and Innovation has a remarkable emphasis on fossil energy. From the 4.6 billion euros used to stimulate the end users energy consumption, only 163 million euros (3.5%) was spend on renewable energy resources. The other 96,5% was assigned to conventional energy supply (Ecofys, 2011). Besides consumption also the production of conventional power is developing in The Netherlands, where several base load energy plants are realized currently. This negatively influences the possibilities of a suitable business-case for sustainable initiatives like biogas infrastructures. When all conventional power plants are realized as planned an overcapacity of 57 TWh or 12,8 GW installed capacity arises. The export capacity will be at a maximum of 7,2 GW in 2018, it is not likely that all capacity is available for export only. Neighboring countries would need power and the production cost needs to be competitive. This is currently not the case, since the Netherlands is still a net importer of energy caused by a slightly higher energy price than abroad (Boutkan, 2011). Therefore the gain of these base load power plants is not certain yet.

The dominance of established players is harming the development of the energy transition and therefore the development of biogas infrastructures (Van Soest, 2011).

Governmental Motives

The essence of the national sustainability policies is majorly based on agreements made on an European and global level. A clear example is the Kyoto protocol, which brought countries reconsider their environmental policies and energy system. The European directive 2009/28/EC on the promotion of the use of energy from renewable sources, obliges The Netherlands to generate 14% of the total energy consumption out of renewable sources in 2020. In July 2010 every Member State needed to deliver an action plan describing the steps to reach the threshold. The Dutch government determined a top 3 list, with most promising renewable energy sources in The Netherlands. First co-firing of biomass was listed before wind on the mainland. Green gas came on the third position. This directly gave a boost to the position of green gas related to policy making. An example is the redefinition of the subsidy regulation (SDE+), after the release of the top 3 list also projects related to green gas have the possibility to apply for a SDE+ subsidy. The government is willing to fulfill the 14% renewable energy source as cost-efficient as possible. So innovation on the long term is not supported out of the SDE+ since the production costs are relatively high (Dumont, 2011). More information on the SDE+ can be found in the next section. It is important to mention that European directives are the incentive to the national legislator in order to design initiatives that contribute to long-term objectives like sustainability. In case of sustainable energy there are no examples of national legislation that came without the 'coercion' of Europe. The European Commission is of course involved with policy making in other policy fields besides sustainability. Think for example policies regarding gas and conventional energy production. Developments here would also affect the chances for biogas infrastructures.

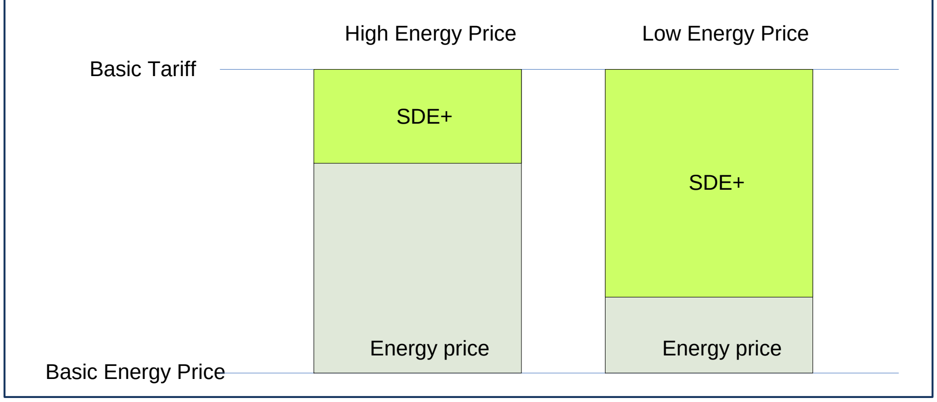
The current government is maintaining a reluctant role proclaiming that it is the 'market', who should take initiative regarding biogas and green gas. This is also the reason that no regulation is made on biogas. The Gas Act only applies on gas that meets natural gas qualities, which is not the case for biogas. This unregulated domain gives some degrees of freedom to the market parties. They could realize the biogas pipelines themselves. However this minimizes the role of the national government, this will not directly keep local and regional public authorities from incorporating in biogas projects. Currently the distribution network operators and municipal waste processing companies are closely involved with green gas projects. Provinces and municipalities are involved as well. Climate plans/energy ambitions are published on a national, regional and even local scale (Dumont, 2011). Following these energy ambitions the Province of Overijssel supports for example the Salland project. Basically they only facilitate the process by bringing companies and organizations together. Financially support will only be given in the form of a loan (Eenkhoorn, 2011). Local municipalities will be involved with permits of the realization of the pipelines and the installation of a production facility. It is remarkable that several decentral public organizations put forward higher ambitions compared to the national government, considering their acts. At the same time those 'lonely' ambitions are strengthened more and more by comparable ambitions of societal organizations and private entities (RLI, 2011). This creates a growing signal towards the national government, which combined these initiatives recently in the Green Deal. These combinations of 59 local sustainable initiatives are appointed by the Ministry of Economic Affairs, Agriculture and Innovation. The Ministry will support them with knowledge sharing, combining initiatives, changing regulations and additional funding (Rijksoverheid, 2011). According to critics the green deal does not stimulate innovation and does not show ambition. The Green Deal exists out of lots of independent initiatives and no structural improvement is created (Trouw, 2011). The green deal proved that bottom-up initiatives on sustainability like biogas producers, solar panels and recycling are developing. These initiatives are often well organized (Hawken, 2008). On the other hand the top-down support which is needed to facilitate these initiatives is lacking and the green deal related actions on knowledge sharing and changing regulations will not solve this. According to Van Soest this seems to have a lot in common with the neoliberalism; the energy transition is allowed for individuals and private entities, though when governmental action seems to be essential this government does not actively participate (Van Soest, 2011).

A possible motive for Ministry of Economic Affairs to actively participate in the energy transition can be found on the field of employment. The sector of renewable energy in The Netherlands is performing poorly. In comparable countries as Finland (13%), Denmark(11%), Germany(8%) or France(5%) a significant share of the population is employed in the renewable energy sector. In The Netherlands this is not even 1,5%, which accounts for 12.400 jobs(Eurostat, 2011). Renewable energy can be seen as a promising sector. Between 2008 and 2009 the market increased on average with 31% to a total of 179 billion euros in 2009 (WFF, 2011). A good example is Germany, where a significant share of the employers are active in the generation of renewable energy itself, but also in the development and production of renewable energy technology and related export. When other countries are becoming more and more sustainable also the demand for sustainable products and services will increase. Since Germany is the most important trading partner for The Netherlands, this will be increasingly important to the competitive position of The Netherlands (RLI, 2011).

Subsidies (SDE+)

The subsidy which is available to green gas projects is the SDE+ (stimulating regulation on sustainable energy). It is an exploitation subsidy, which compensates the difference between the current energy price and the production costs of the green gas. The subsidy has a term of 12 years and falls under the responsibility of the Ministry of Economic Affairs. . After this term the possibility exists that the ministry suggests a renewed agreement, applying a lower compensation since the highest costs are already made. Since the amount of SDE+ subsidy is limited the most cost efficient projects needs to get priority in meeting the government objective of 14% sustainable energy share in 2020. The SDE + has a tariff threshold varying from 62ct/Nm^3 till 104ct/Nm^3, based on the phase in which the producers are applying. To compare, the price of natural gas is currently ca. 55ct/Nm^3 (Gaslicht, 2011). The tariff threshold guarantees the minimum price a producer will get for every Nm^3 of green gas. Depending on the energy price, the SDE + will compensate the difference until the tariff threshold. When the energy price is low the SDE + will be high, and while the energy price is high, the SDE+ will decrease since the energy company will pay more per Nm^3. This mechanism is visualized in figure 16.

Figure 16 - SDE+ subsidy composition



To guarantee the most cost-effective producers will get priority the application of subsidies is divided in four shifts (see also Table 5). The first phase covers producers who are able to make a solid business case using the lowest tariff threshold of 62ct/Nm^3. In practice this is only possible to the larger waste processors, due to the fact their biomass is practically for free. The production of biomass originating from waste is already operational and compensated by municipalities. The only investments that are needed will be the biogas digester and upgrading facility. Producers who think they need at least 76 ct/$Nm^3$for their business case should wait until the second phase. When the available money is already spend in phase 1 appliers of phase 2 will not be eligible for subsidy. Last two years the first phase was already over-applied. This meant that also 1st phase subscribers did not have guarantee on subsidy and later subscribers did not have any possibility to get subsidy. Especially the more alternative technologies that are in a development phase will not have the chance to apply for subsidy on national level.

In 2010 around 1 billion euro on subsidies was spend on bio-energy. Around 90% was assigned to green gas projects (Dumont, 2011).

Table 5 - SDE schedule 2011

Phase	Period	Tariff threshold
1	1st July	62 ct/Nm^3
2	1st September	76 ct/Nm^3
3	1st November	90 ct/Nm^3
4	1st December	104 ct/Nm^3

Competiveness of sustainable energy

Consumers of renewable energy pay the same price compared to the conventional generated energy. However the cost price of renewable energy generation is higher, the difference is compensated currently with subsidies. The SDE+ subsidy is an example in this case. It is currently the governmental budget compensating the difference using the tax payer's money. Yet there are energy technologies available like biomass (codigestion) and wind power that are proven technologies, these can operate cost effective and need to be implemented in order to reach the sustainability targets of The Netherlands (Rooijers, 2010). An important policy measure that is suggested by the ministry is the obligation to energy producers to produce a certain share of sustainable energy. In this case the costs of the transition to sustainable energy will be covered by the users of the energy, the energy supplying companies will integrate the additional costs in their energy prices. Yet overall this will save the Dutch society 1,3 billion euro in the period between 2013-2020 (ECN, 2011). Unfortunately this will also cause organizational complications. For example there exists a difference between Essent, Nuon and Eneco, which are the main energy supplying companies in The Netherlands. All of them have a different portfolio. For example Eneco does not own coal plants. According to the Ministry of Economic Affairs the government cannot disproportionately create disadvantages to specific market parties. This would be discriminatory and not in confirmation with European Law (Dumont et al., 2010). However when such a regulation is advertised on a plausible term this will be considered acceptable, since the motives of the policy can be justified. Unfortunately 2020 is on such a short term that realization of renewable energy production facilities will be hard to realize. This operation needs a longer implementation period. Furthermore the differences between the energy supplying companies will probably ask for a solution that compensates the disadvantages of a company's portfolio by means of temporarily subsidies. Such a structure will activate energy producing companies to become more creative in the sustainable energy process. This could lead to cost-reductions and could make sustainable energy more competitive compared to conventional energy sources (Rooijers, 2010).

Attitude of market parties

Since the market parties are considered by the Ministry of Economic Affairs, Agriculture and Innovation as stakeholders that should take initiative realizing the biogas infrastructure, their benevolence is of main importance. Considering the energy companies, Essent was already discussed. They were active during the initiation of one of the pilot projects. Though it was questionable whether or not they should initiate such a project again in the renewed market situation, in which the energy companies do not have public shareholders anymore. The farmers have a growing economic interest when changing legislation on manure increases the importance of manure digestion. Yet also other private companies have shown some interest. These interests are limited to give support to the execution of a feasibility study on biogas digesters, not specifically a biogas infrastructure (Saxion, 2010). Overall there seems to exist a discrepancy between the attitude of market parties and the role the Ministry of Economic Affairs desires them to take, an initiating role.

Integration of activities

The production of biogas is dependent on biomass supply. Biomass will be converted to biogas before it is upgraded to green gas where the value chain ends. Within this value chain no pre-defined starting points are present. The same accounts of course for the end-product. By integrating different industries to the biogas infrastructure significant advantages can be achieved. An example is the planned upgrading facility in Rilland, Zeeland. Here integration between greenhouses, water purification and the processing of the digestate takes place. This partnership is actually the first biogas to green gas initiative that successfully applied for the SDE+ subsidy program. Indirectly this means that the developers have managed to create a solid business-case against low production costs (Dumont, 2011). Synergy advantages will enable such a solid business-case, when considering a biogas infrastructure project possibilities of providing direct demand, heat generation, processing of abundant biomass from other industrial process and green gas upgrading can be combined.

Realization of biogas pipelines by construction companies

The municipality of Leeuwarderadeel is the first to realize a biogas pipeline without any help of a DNO. The producer of the biogas put out a tender. Yet also Enexis applied to the tender to realize this pipeline between a biogas producer and the CHP of a public swimming pool. The eventual constructor, A. Hak, even suggested to make a combined offer together with Enexis. The client chooses the cheapest solution and therefore Enexis was not involved in the project. To the issued permit no additional requirements are defined related to safety or maintenance. This is an undesired spin-off caused by the unregulated jurisdiction of biogas. For example in case of a leakage the responsibility of repairing the pipeline is not defined (Van Gorkum, 2011; Leeuwarderadeel, 2011).

3.6 Critical Systems Heuristics – The Ethical perspective

In the previous sections the technical, organizational and personal aspects have been investigated, this resulted in a socio-technical system. To be able to complete the Multiple Perspective Approach an approach needs to be integrated that investigates the ethical issues of the system. For this, the critical system heuristics (CSH) (Ulrich, 1983) approach is applied. This approach uses systems thinking as a starting point, which is the reason that it connects properly with our previous analysis methods.

Methodological Explanation: Ulrich's Critical System Heuristics

The CSH is a rather structured method that enables not only well-trained professionals and decision-makers but also ordinary people to give a critical reflective systems view. Besides theoretical means, also heuristic support in the sense of questions and argumentation tools are provided. CSH claims that certain problem definitions, solutions or claims with practical intent are influenced by how we distinguish some facts and norms as from others. The reference system is decided by our boundary judgments, as soon as they are modified, relevant facts and norms are likely to change (Ulrich, 2005).

Our analysis starts with the system's 'anatomy of purposefulness', which is made up by combining the basis of motivation, power, knowledge and legitimacy (Ulrich, 1983, p.342). The scheme is created using the checklist of boundary questions (Ulrich, 2005). Every boundary category includes a desired 'ought-to-be'-situation and a perceived 'is'-situation. In

Table 6 the different boundary categories are listed. To use the first category as an example, this will bring us the next two questions: who ought to be the client or beneficiary of the system? And who is the client or beneficiary?

The answers to the questions are set up by the researcher after the technical and social system were described. Afterwards the results are brought to an expert validation (Wempe, 2011). It should be noted that the answers on the boundary questions are not covering all stakeholder perceptions. The answers are more or less an overall perspective of the situation. To most questions it is not possible to give single answers, like the guarantor and resources to success. Especially in this early phase of biogas infrastructure development, "success " is hard to define anyhow. The most significant answer according to the researcher are summarized in

Table 6. The difference between the 'ought-to-be-situation' and the perceived 'is-situation' sketches the tension that affects the system from an ethical perspective.

Table 6 - Boundary questions and answers to CSH

	Boundary categories	Who/what ought to be…	Who/what is…
1	Client	Society, Environment	Energy producers
2	Purpose	Improving the environmental state	Profit
3	Measure of Improvement	% of CO2 emission reduction	Profitability

4	Decision-maker	Energy producing companies	Government
5	Resources	Money	Regulatory power, money
6	Decision Environment	Benevolence of politics	Subsidy regulations
7	Professional	Distribution Network Operator	Municipalities
8	Expertise	Knowledge on gas grids, quality, balancing regime	Technical system knowledge local scale
9	Guarantor	Energy producing companies	Politics
10	Witness	Government, environmentalists	Government
11	Emancipation	Transparent level playing field	Elections
12	World view	Invest in sustainable energy, save money in the future by innovating now	Generate energy cost effectively Reconciled by: awaiting innovations on technology and rising fossil fuel prices

Now the boundary questions are answered the three basic applications of boundary critique will be discussed.

Ideal mapping (What is our vision?): Current energy production should not compromise the ability of future generations to meet their own needs. Energy producing companies will have the power to change the amount of emission per KWh/NM^3. A condition to success in the decision environment is the benevolence of politics, which cannot be controlled by the energy producing companies. Furthermore collaboration needs to be achieved with the distributed network operator who has expertise available to technically facilitate and complete the biogas infrastructure. A guarantor of success is the political support, without their mandate the subsidy program will not be adjusted. This appeared to be inevitable to come to a solid business case.

Evaluation (What is our assessment of the situation?): However the purpose of the biogas infrastructures can be traced back to the improvement of the environmental state, the parent purpose to the stakeholder in the position to change the environmental state is focused on profit. Here a discrepancy arises, which currently is slightly compensated by subsidies. Yet the amount of subsidies is decreasing and policy-makers are aiming on a self-sufficient market for biogas infrastructures. In other words, in the future the business case should be without any subsidies.

Reframing (What other context might be relevant?): Subsiding sustainable energy generation is often criticized. Prime Minister Mark Rutte once argued that wind-energy is not generated by using wind but by using subsidies (Visser, 2010). These kinds of statements create opposition against all kinds of sustainable energy. At the same time also conventional 'grey' energy is generated with subsidies, yet this is not often discussed in the public debate. According to Ecofys and CE Delft € 5.8 billion euro is invested versus € 1.5 billion euro in case of sustainable energy (Ecofys, 2011). So in terms of KWh, sustainable energy is still more expensive. Energy production in The Netherlands is supported by subsidies, also in the case of conventional sources. An important reason for these subsidies is the competitive environment that is created. In France energy is almost 30 % cheaper compared to The Netherlands. Multinationals should not be tempted to move out of The Netherlands because of the significant energy prices (Den Brinker, 2011).

In line with this, investments on sustainable energy projects should be framed as investments in the Dutch economy on the long-term. As already mentioned in section 3.5 the renewable energy sector has a lot of potential, especially since sustainability in neighboring countries is increasingly popular.

The Netherlands is currently one of Europe's main producers of gas. Yet considering sustainable energy, other European countries are further developed. Geographical characteristics can create good preconditions to solar, wind , biomass or hydro-energy, those of The Netherlands are not optimal in a European context. When Europe's energy supply is centralized, investments of sustainable energy could cross-border throughout Europe. Besides the Dutch natural gas production that will continue for some decades, sustainable energy investment could be made in other European countries. This will lead to a more efficient investments, however it could lead to an increased energy dependency when an unstable geopolitical situation in Europe arises.

Concluding notion on CSH

The tension between using the environment without compromising the ability of future generations to meet their own needs and our own current bank account seems to play a significant role in the development of biogas infrastructures. Where the government takes a reluctant role, the market does not fulfill the role that the government would expect from the market: a proactive role that initiates and realizes cost effective projects. Furthermore, there is a public aversion against sustainable energy, fed by the belief that these technologies are generated by governmental subsidies. This belief needs to be taken away in order to gain political support. When the energy supply is considered from a European perspective, instead of the national perspective, investments in foreign projects could be considered also in service of the Dutch energy supply. Foreign locations are often more cost-effective due to their local characteristics. The objective of the Dutch government to come up with cost-effective energy supply could then be met.

3.7 Research Question 1

In this section an answer was sought to the first research question, which was defined in section x as:

- From a systems perspective what are the most important issues that influence biogas infrastructures in The Netherlands?

Section 3 provided an extensive description of the technical and social system components. Using the Multiple Perspective Method the technical, organizational, personal and ethical perspective were projected on the defined biogas infrastructure. As there is no operational biogas infrastructure currently available, a disclaimer should be presented in the sense that the actual system could differ from this empirical composition.

By using literature and performing interviews it appears that a clear view of the end-situation is lacking to everyone, especially on the economic and responsibility aspects. The current system currently has a strong physical focus. The technological system is designed relatively easily, but less emphasis is put on the institutional environment of a biogas infrastructure; the 'social technologies' are not yet defined. As a result, a deadlock arises where it is not clear who shall financially compensate what components of the system, additionally this deadlock is also in place from a responsibility perspective. Who will take care for what physical components or organizational issues? (e.g. maintenance and exploitation). These uncertainties make stakeholders look towards each other, without significant progress as a result.

This could be caused by the current energy regime that is dominated by parties with a big interest in extraction, supply and use of fossil-based fuels. These fossil-based fuels are widely supported by taxes and subsidies compared to renewable energy.

The European directives seem to be an effective means to create incentives for the Dutch government in designing sustainable policies. These directives resulted for example in the formulation of a top 3 with the most promising renewable energy resources in order to achieve the 14% renewable energy share in 2020. Green gas was appointed as number 3 in this list which led to the inclusion in the SDE+ exploitation subsidy. Yet, this subsidy program appears to have a structure that becomes a barrier for biogas infrastructures. The business case of biogas infrastructures could not meet the lowest level in the SDE+. Therefore alternative projects seize the subsidy money since they can operate a cost-effective energy production.

The Dutch economy could have a major advantage of a healthy renewable energy sector. In comparable countries like Germany (8%), Finland (13%) and Denmark (11%) a major part of the population is employed in this sector. In

The Netherlands this is not even 1,5%. An effective policy measure that would strengthen the position of renewable energy in The Netherlands would be to set a sustainable energy obligation to producers. This would urge them for example to produce 15% of their total production sustainably. Yet this policy measures could face resistance from the current regime within the energy sector as well as European legislation.

On the next page the socio-technical system is presented (Figure 17) with the issues that arose from the multiple perspective approach. Considering the socio-technical-system and the position of the stakeholders, the government appeared to have a significant role. Using their regulatory power they could break through the impasse in which no projects start due to the lack of solid business cases. Except some examples in wind- and solar energy there is no economic attractive project related to green or biogas. Subsidies are essential to these projects, since the cost price of a cubic meter gas is higher compared to the market price. This difference needs to be compensated, otherwise the private stakeholders will not be activated.

The ethical perspective announced that the current economic considerations outweigh the future generations. Since no effective acting of currently involved stakeholders within the energy sector seems to be executed. Furthermore the political support seems averse to further investment in renewable energy, fed by the belief that these technologies are generated only by subsidies and should only be operational when they are driven by the market. Here the discrepancy arises between the government's reluctant attitude, expecting the liberal market to take the initiative, and the market parties who do not expect to achieve a solid business case.

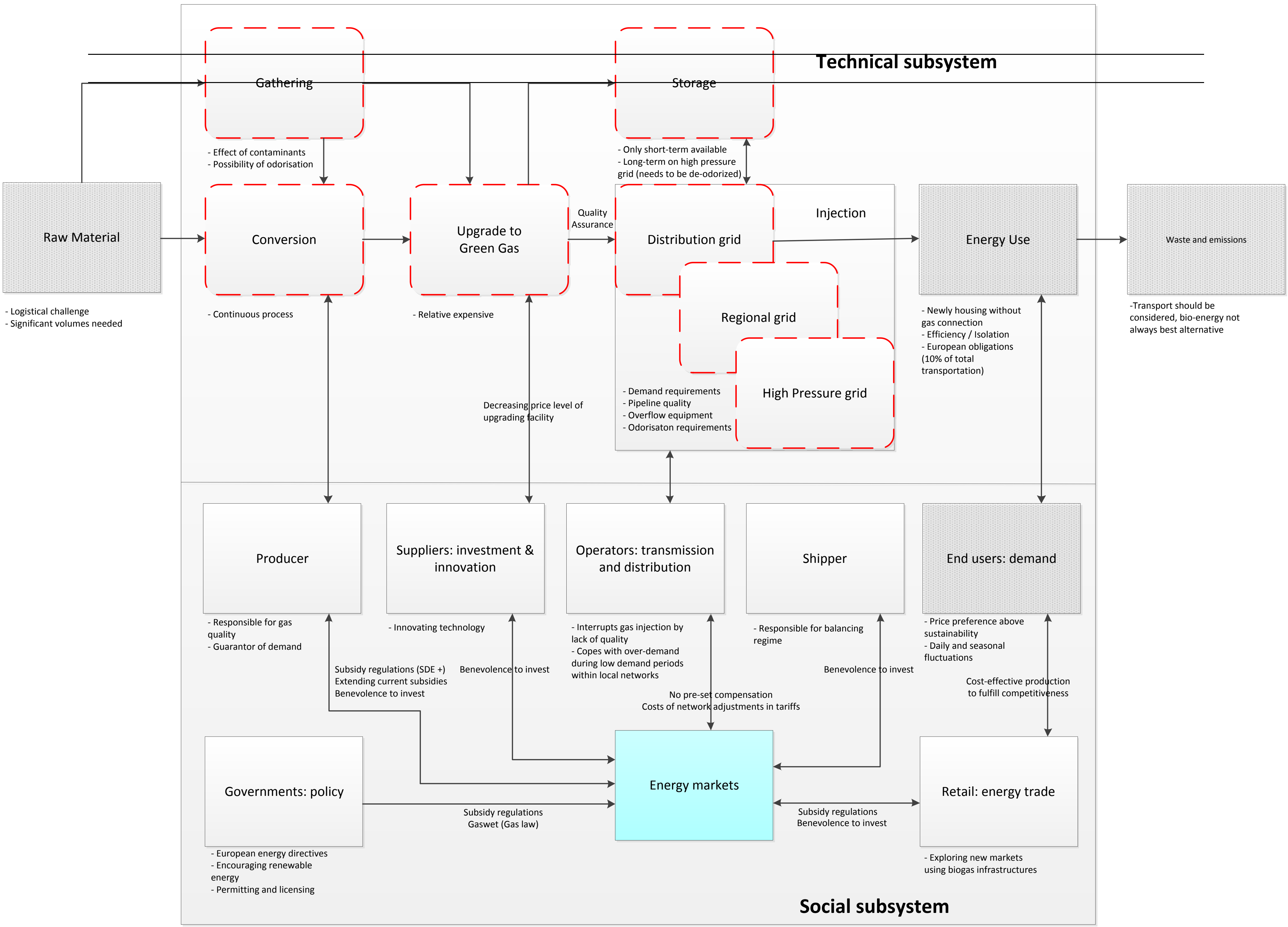


Figure 17 - Specified socio-technical system

4 Analogies from historical infrastructures

"Anybody can make history. Only a great man can write it."

Oscar Wilde – Irish writer (in The critic as artist - 1891)

➔ Section 4 presents the findings of 4 case studies on the historical emergence of today's infrastructures. In 4.1 the used approach will be explained. In section 4.2 the identified conditions will be presented and reflected upon the current situation (the empirical obtained system. Then in 4.3 the RQ 2 and 3 will be answered.

4.1 Historical analogies approach explained

Infrastructures are of essential importance to our current society. Highway roads, internet, mobile phone networks, all of these and many more fulfill vital functions in today's life. Significant amounts of infrastructures have been developed throughout history, all following their unique pathway. In this section analogies will be presented that resulted from the case studies analyzed in Appendix 2. In these case studies four major infrastructural developments in The Netherlands (canals, railways, telegraph/communication lines and the transition of coal and later natural gas network) are explored together with a more general exploration on innovation in The Netherlands throughout history. This latter is of importance as innovation covers the use of new methods or technologies, not the invention itself (Malerba et al., 2007). Therefore innovation is closely related to the emergence of new (concepts of) technological infrastructures, where it is not about the technological invention itself but about the use of a concept, in this case biogas infrastructures.

As the starting point of these analogies, the historical study of Auke van der Woud (2006) is used. Even though this historian has investigated numerous sources and studies, it is still likely that not all influencing factors are represented in his research. For this reason additional literature is consulted (including amongst others Van Vleuten (2006), Kaijser et al. (2000) and Hughes (1983)). But since Van der Woud sketches the roll out of infrastructures specifically in The Netherlands, taking into account underlying worldviews and setting some causal relationships, his work is used as fundament in this analysis. Since an analysis on historical work is actually an indirect analysis the conclusions needs to be drawn carefully. The interpretation of the historians combined with the interpretation of the researcher could lead to a lower validity of the results. The presented conditions should therefore not be considered to be the ultimate truth, only as a helpful direction.

The infrastructural systems all are assessed on five areas of interests, which are composed by the researcher: objectives, pre-conditions, drivers, barriers and advantageous policy measures. These areas of interest describe the initial state of society in which the infrastructure was able to emerge. And in addition the reasons of change and additional policy measures that the national government found necessary. By assessing the emergence of each infrastructure using these five areas of interest the possibility arises to compare the different case-studies. This comparison leads to ten conditions that positively influenced the emergence of infrastructures and probably therefore could be useful to future emerging infrastructures like the biogas infrastructure. When these conditions were present during the realization phase of the historical case studies it influenced the initial development of in a positive way. But what do we consider to be positive? A successful developed infrastructure operates properly from a technical and organizational perspective. The conditions that have a positive influence will not always have a direct effect, like growth and efficiency of the infrastructure. Recognized conditions could for example have negative short-term effects, but improve the infrastructure on the longer-term. This longer-term improvement will in this analysis be the criterion to obtain a positive influence. All conditions are presented from a positive perspective (see Table 7), in other words absence of a condition would influence an infrastructure negative. However when the involved stakeholders consciously choose to avoid a positively described pattern, this could lead to a negative influence on their infrastructure development. This will probably appear in higher costs, lower revenues, delays, etc.

4.2 Infrastructure conditions

The case studies from Appendix 2 create an insight in the emergence of different Dutch infrastructures, in this section we will describe the conditions that are recognized from those infrastructures. For this overview no order of importance is taken into account, also the sequence is random. In this section each condition will be introduced and their applicability with biogas infrastructures will be discussed.

Table 7 - Positive conditions to infrastructure realization

Availability of parallel infrastructures
Bringing available support together
Clearly formulated governmental objective
A niche as starting point
Being aware of high initial investments - lock-In effect
Being aware of profiteers
Have a thorough system perspective understanding

4.2.1 Availability of parallel infrastructures

It appears that the availability of other infrastructures could positively influence the implementation of another infrastructure. This could have three reasons, first of all a physical reason when making use of similar infrastructures or facilities. Secondly when infrastructures could be complementary to each other and finally when competition arises between substitutes and urge the infrastructure to innovate. First the physical cause will discussed. When infrastructures could make use of the same physical infrastructure synergy advantages can be achieved. An example can be found in the emergence of the telegraph lines. The lines were connected to the railway network, which was a 'shortest path' network between major cities in the country. This characteristic was also useful for the telegraph lines, since sufficient space was already available (Van der Woud, 2006, p.27). Furthermore the train stations that were used as a transfer location for passengers and freight could additionally be used as an exchange location for telegraph messages. This functional advantage led to a lower total investment costs during the initial realization of the infrastructure. However the advantage to the telegraph line is obvious, the advantage to the railways that were already operational is not directly clear. A difficult issue is therefore how to decide upon a reasonable compensation for the improvement of an infrastructure performance (Van der Woud, 2006, p.343). What is a reasonable price for the telegraph line company when making use of the physical entities of another infrastructure? In the case of the telegraph line this was not a real issue since both, the railway infrastructure and the telegraph infrastructure, were properties of the same company. In this specific case the interests and objectives of the infrastructure's initiator was equal. This would have eased this process even further.

The other advantages are based on the fact that infrastructures delivering a substitute strengthen the development of the 'competitive' infrastructure. This can be caused by infrastructures that are complementary towards each other or when competition arises that urges for innovative development. First the complementarity will be discussed. Infrastructures deliver a service (e.g. freight transport), the characteristics of a specific infrastructure will differ, which make the infrastructure more or less suitable to the required customer needs. When the differences are small the infrastructures could become complementary towards each other. As example the railways and the waterways can be considered. Where a railway network can deliver relatively fast transport services, the flexibility towards locations to deliver freight is relatively limited. Waterways exist, especially in The Netherlands, in a wide variety of types. Of course there are the wide and open canals that connect major harbors as Rotterdam and Amsterdam to the North Sea, these waters are deep and lack curves. Additionally also small water streams are available for transport. On the one hand the possibility to bring freight to a certain location over water in The Netherlands is more flexible compared to the railways. Yet this will certainly not account for every location (think about the Sahara, where waterways are not present at all). On the other hand the transport over water is slow and transfer facilities are needed to deliver freight to the mainland (Schotanus, 2005; Van der Woud, 2006, p.324). Yet both, the waterways and the railways infrastructures' characteristics, strengthen each other since freight is often delivered by a combination of water, railway, road and air traffic. A well-developed situation on modality A will improve the position of modality B. This is the case when the characteristics of the modalities differ to a certain extend. In the example of transport; costs, distance, speed and flexibility are the characteristics on which infrastructures differ. Heavy long distance freight will usually be transported by boat, before a transfer is made to trains (often industrial commodities) or road vehicles. The interfaces between those infrastructures, such as transfer harbors, are essential for the success of the others.

The third case in which infrastructures can benefit from other comparable infrastructures is linked to competition. Therefore it is in this case important that the service or product delivered is a substitute. An example here is the gas and electricity network. The introduction of light was based on gas in the early days, but soon people were able to generate light from electricity (Van der Woud, 2006, p.70). The distribution of electricity using electricity cables was easier to construct compared to the star gas pipelines. This caused a significant expansion of the electricity infrastructure (Van der Woud, 2006, p.73). After the gas engine was invented people were able to create electricity out of natural gas. Both fuels could already be used for heating purposes. So two products were able to fulfill about the same services, while using another infrastructure. This created a competitive environment, were innovation led to an increased efficiency, lower prices and better quality of services (Van Vleuten, 2006, p.297). An important notion about advantages due to infrastructure interaction is made by Kaijser. He argues that "interaction with other systems can cause system dynamics, on the one hand this could impose the position of both, but they could also compete on market share and decrease their joint success (Kaijser et al., 2000)".

➔ How does this condition relate to biogas infrastructures?

Parallel infrastructures

Now the advantageous effect of parallel infrastructures is explained the applicability on the current biogas infrastructure situation is assessed. And since three different perspectives were mentioned in the previous section, physical, complementarity and competitive efficiency, all of these will be treated separately.

Starting with making use of a similar physical infrastructure or facilities. The biogas infrastructure will be installed to distribute biogas. Due to the fact the biogas contains contaminants it is not likely that green gas (or natural gas) will be distributed by the similar pipelines. Possible synergy advantages could be created at the hardware installations of the biogas infrastructure that are located above the surface. For example by locating these on existing gas related industrial sites. Think about s gas receiving station (Gas Ontvangst Stations) or natural gas production areas. These areas, which have often enough space available can be used to install upgrade facilities. Furthermore safety measures and specialized knowledge on gas is already available. Concluding, the use of a physical infrastructure in parallel can be met partly.

The natural gas network, which is extensive in The Netherlands and connects almost every household and industry, can be considered as a complementary infrastructure to biogas infrastructures. A biogas hub and the natural gas network both offer the same service: transporting gas using pipelines. The 'end-product' of the biogas infrastructure, green gas, is even distributed by means of the natural gas network. Therefore the connection between both infrastructures increase the market range of the biogas infrastructure's end product. Vice versa this green gas gives the possibility to the natural gas network to deliver a more sustainable energy source. This appears to be a growing customer need which therefore also improves the market value of the natural gas network. On the other hand residual products of other infrastructures like a water treatment plant or waste processors could be the starting point of the biogas infrastructure. In this perspective the waste water infrastructure and the waste gathering infrastructure can be complementary as well. The condition of a complementary infrastructure is met with the presence of the natural gas network and could be expanded by integrating the residuals from the waste related infrastructures.

The growing popularity of sustainable energy causes an increase in solar panels and wind turbines. The so-called 'green' energy is increasingly popular, gets a lot of attention in the media and on the political agenda. This positively affects besides the green electricity also the attitude towards green gas, since both are considered a sustainable energy source. As was mentioned before, there are currently housing projects constructed that do not have a gas connection available. Since heating a living room and cooking can also be done using electricity, so all needs will be fulfilled. This development could be an additional driving force to biogas and green gas production, to become more efficient in order to increase the competiveness compared to electricity. Another emerging entity that provides a comparable service is the stand-alone green gas producer. Due to the fact they are also increasing in numbers the biogas infrastructure will be positively influenced. More producers could lead to a decrease in cost price of the production facilities and probably also in improving the organizational solutions that needs to be implemented. For example to overcome the capacity issue. There appears to be competitive infrastructures to the biogas infrastructure that can cause a positive influence to infrastructural development.

4.2.2 Bringing available support together

Another aspect is to unite the available support for an infrastructure. When support from societal layers, like citizens, industries and environmental organizations, can be brought together this will ease the acceptance of the infrastructure and accelerate its realization. As Hughes argues: "large technical systems needs strong economic and political stakeholders and a strong market demand as key drivers to expansion (Van Vleuten, 2006, p.301)". In most cases stakeholders should adapt their specific expectations and reach agreement on a common understanding. In this situation the majority of the stakeholders will be able to support the plans. A wide-spread support among all stakeholders is, especially for long-term transition processes, hard to achieve. Yet specific support to a certain project is not necessary from the very beginning. In this phase the commitment and benevolence (of some of the stakeholders) to the transition as a whole is of more importance. Using these stakeholders it is easier to achieve some kind of result (e.g. starting as a niche, see also 4.2.4), which will create the opportunity to convince other stakeholders from the use and benefits of the concept. This process of gathering the available support has been performed well at the rise of natural gas networks. Advantages of the infrastructure were communicated towards industries and citizens by means of a public campaign (Correlje, 2006).

When a transition is in a take-off phase, stakeholders will be present that have interests in the status quo situation, these will not be part of the supportive base . An example is the situation of the Dutch State Mines (DSM) who had a dominant position within the Dutch economy when the energy supply was majorly based on the coal industry. The discovery of the enormous volumes of natural gas put pressure on this position. DSM was likely to start acting strategically since their core product was threatened by the possible raise of natural gas. Though the Dutch government offered DSM an important position as negotiator on behalf of the state. The considerable size and experience of the firm in combination with their involvement in the (coal)gas production, made the government consider DSM a suitable negotiator. DSM started the negotiations with Shell and ExxonMobil, who were together with the Dutch state the owners of the discovered resources. The company managed to create an advantageous position to the Dutch state related to the natural gas production (Correlje et al., 2004). Furthermore DSM itself managed to transform their company in parallel with the rise of natural gas. A lot of the former mine workers found employment in the gas industry. The company itself converted to manufacturing of chemical products using natural gas (RLI, 2011). Apparently the future development was irreversible according to DSM. This is in contrast with their colleagues; another main stakeholder in the former situation was Hoogovens. They refused to stop their coke gas production and distribution, which eventually led to exclusion of the distribution sector by the national government (Schippers et al., 2000). The involvement of a stakeholder that in first instance was opposed towards the transition created a trustworthy relationship. After all a win-win situation could be reached since there was also taken a considerable amount of time to think about mitigation of the negative effects that this 'opposed stakeholder' would have.

As was mentioned by Hughes also an economic stakeholders is needed as a key driver when a large technological systems emerges (Van Vleuten, 2006, p.301). Infrastructures are bounded to high initial investment costs. Financial support is therefore necessary, these can be private or public. Several projects were severely delayed by reluctant investors. Especially to new innovative technologies the added value, specifically to public values, is difficult to estimate. This was for example the case when the state was asked to fund telephony lines. The telephone would be a minimal addition to the functionality of the telegraph lines, therefore the technology had minor potential since information transfer was more efficient without the use of the human voice (as was the case for the telegraph lines) (Van der Woud, 2006, p.343). Advantages of the proposed infrastructure needs to be clear, to private investors the commercial potential needs to be tangible.

➔ How does this condition relate to biogas infrastructures?

Bringing support together

When the process towards biogas infrastructures is considered it appeared that the playing field was explored step by step. Starting with gathering the main stakeholders of the energy sector in the Platform New Gas, during the period 2000-2006 (Dumont, 2011). This platform, which was mainly filled with public owned stakeholders, appeared to be the source of the current biogas pilot projects in The Netherlands. During the interview with Province Overijssel's Ronald Eenkhoorn the current stakeholder management was explained. In the pilot project Salland one of the most valuable criteria that made the province decide whether or not a region was suitable for biogas production, was the enthusiasm that managers of organizations within that region expressed to a project (Eenkhoorn, 2011). This was considered more important than the function of their organization in the biogas value chain. By selecting stakeholders using this criteria it is not guaranteed that the province will reach all supportive stakeholders. Especially since the province focuses especially on regional facilitating organizations, the support on other levels (like the national or international) is insufficiently ensured. A reason for this could be that the project is in the initializing phase. The province wants to clarify the physical potential of biogas production before an orientation is made on the regulatory and economical stakeholders. It is questionable whether or not this is the right sequence. Institutional uncertainty in the initiating phase can slow down the development of the biogas infrastructure.

'Negatively' affected stakeholders are present in the current energy field. The current energy regime is dominated by several powerful stakeholders who have big interests in the extraction, supply and use of fossil-based energy. With respect to the transition to a more sustainable energy supply these powerful entities experience especially the costs not the revenues of the energy transition (RLI, 2011). Yet these stakeholders are of importance when structural changes in the energy sector need to occur, since they own or operate essential functions or services in the market. The urgency of the transition towards a sustainable energy supply and the revenues of a biogas infrastructure needs to be clarified in order to involve these stakeholders. In the desired situation the stakeholders, who are negatively affected, will get a new role that restrain them from strategic behavior. This was also the case at DSM during the transition from coal to natural gas. The transition from the current situation towards a situation including a significant share of biogas is less radical, since the existing infrastructure will still be used.

The realization of biogas infrastructures will not really negatively affect a certain stakeholder; an extensive reform of stakeholders will not be necessary. Yet based on the information that was gathered in the strategic analysis of Appendix 1 it can be assumed that the national transmission system operator, GTS, has some resistance to the transport of green gas through their network. This due to the fear of technical problem that green gas could cause based on the presence of contaminants. Of course this does not mean that GTS does not encourage green gas developments, since these can also be initialized without a connection with the transmission network. For example when it is directly used for electricity generation. In this perspective the distribution network operator should have it concerns. This is the case, but since some DNO's are closely involved to the realization of green or biogas projects their resistance decreases. Probably the most important established regime players is EBN. The company encourages the exploration and extraction of natural gas and propagates the inclusion of natural gas in the energy supply, also in the longer term due to the fact fossil resources will conserve an important role also in the future. EBN participates in projects related to natural gas trade, transport and storage. Their policy is aiming on doubling the natural gas production from small gas fields in 2030 (EBN, 2011). The company has large sources for funding available, but it does not invest in green gas related projects. A prosperous development of green gas directly affects the competiveness of natural gas. This could also cause strategic behavior at companies as Shell and ExxonMobil. When benefits could be created to these companies this can give an incentive to the biogas infrastructural development.

For an emerging infrastructure also an economic key stakeholder is of importance. Therefore the added value of biogas infrastructures needs to be highlighted to investors. Yet in case of the private investors the foresights of the infrastructure needs to be economically attractive. The current business case for biogas infrastructures is not sufficiently solid to achieve this economically attractiveness. The exploitation subsidy SDE+ is designed in a way that the biogas infrastructures cannot benefit from it, despite the fact that green gas production on a medium sized scale highly depends on this subsidies. Financial compensation is hardly assigned to biogas gathering infrastructures. The unregulated status of biogas could create improved financial conditions since this will enable public investors by spreading the investment to the biogas network over 40 years. In the current situation the distribution network operator is obliged to spread the investment over 12 years, this results from the commercial character of the investment. A longer depreciation period will increase the willingness to invest and lower the net present value in the current business case. This condition to infrastructures is not sufficiently met in the case of biogas infrastructures.

4.2.3 Clear objective government

The political stakeholder is key to infrastructural development (Van Vleuten, 2006, p.301). Within all infrastructures that were discussed in Appendix 2 the government fulfilled an important role. This was rather positive or negative for the emerging infrastructure. Anyhow, it can be stated that the direction the government is likely to choose will have major influence on the infrastructure's development. Illustrating example is the moment that the government did not want to support the exploitation of the telegraph line in order to protect the investments that they made related to the postal services. The national government was anxious that the investments that were made already in the postal service would be harmed by a competitive infrastructure like the telegraph line (Van der Woud, 2006, p.343). The high investment costs that are related to the development of infrastructures bring significant risks. Ministers are anxious to lose political support when these investments appear to be useless because of the disappointing infrastructural project. A reluctant attitude is therefore understandable. Towards involved stakeholders it is of importance whether or not the governmental role is clear. What can the market expect from the government and even more important what can they not expect. Ambitions that are stated by governmental organizations are the first step towards clarity. However without any follow-up including a more operational interpretation including accountable targets, these ambitions have do not work out. In the strategic analysis of Appendix 1 it appeared that the translation of policies, subsidies, regulation and legislation on the field of green gas differed from the actual policy objective a government defined. This will cause uncertainty and confusion among involved stakeholders. Especially in case of infrastructures that are operational on several levels (e.g. local, regional, national) it is of main importance that policies are unambiguous (Van der Woud, 2006, p.175).

➔ How does this condition relate to biogas infrastructures?

Clear governmental objective

The energy transition which was introduced in the research motivation (section 2) has the objective to make the Dutch energy supply more sustainable. One could argue that effects of climate change are the main reason for policy makers to propagate sustainable development. Yet also concerns about security of supply due to depleting resources or geopolitical relations are important causes for the need of an energy transition. Rotmans argues that the energy transition has a pre-defined objective (Rotmans, 2004). The availability of a pre-defined objective for a transition is actually an unusual situation. Historical transitions often took place by coincidence or serendipity. Examples are the invention of artificial light, as incentive to create a gas infrastructure in industrialized city centres, or the discovery of the Slochteren gas in The Netherlands, which accelerated the Dutch energy supply in switching from a coal based to natural gas based energy generation. To have a pre-defined objective could be a big advantage since the end situation is already defined also the pathway towards the end could be defined. Though there should be awareness that no certainty is at stake that all stakeholders will agree on this end situation. Think for example about a radical example of a pre-defined objective: a 100% sustainable energy supply, without using fossil fuels (WWF, 2011). Others claim that this cannot be achieved without causing shortages on other resource, like rare earth metals that are used for solar cell production (Rhodes, 2010).

In the case of green gas several green gas platforms supported by the government defined targets that suggest an assertive attitude towards green gas development. Yet currently the government seems to be reactive instead of proactive with policies on green gas development, an attitude that not stimulates projects but causes confusion among involved stakeholders. When governmental actions are clarified, private parties will know exactly what they can expect from an economic perspective. Can they claim financial compensation, and under which terms? Furthermore lots of changes in legislation are expected in the future, when these regulations will be implemented instead of stay speculative this would also create more certainty to the initiators business cases. This will be a reason for investors to take a reluctant attitude.

When the focus is specifically on biogas the recommendation would be: the government needs to define a clear common objective related to biogas production and additionally some accountable targets.. This latter is currently one of the main issues. In most historical analogies the government took the leading role to facilitate a transition when it needed to be rolled out over the whole country. In the current 'neoliberalism' environment this role is getting vague. While on the one hand the market parties are appointed by the government to take initiative, on the other hand it is the government who has responsibility to some major terms and conditions. The government is coping with many objectives and interests, a cause for the fact that no rigid choices seemed to be made. Yet this could also stimulate the realization of biogas infrastructures, since there is time and space to gather support for the realization of the infrastructure. Furthermore also the institutional preconditions could be thoroughly considered since there is sufficient time available in the initial phase.

4.2.4 A niche as starting point

Economists of innovation indicate there exists a resistance to change (Hekkert, et al., 2007). An example is the lock-in on fossil fuels in the energy and transportation systems, something that implies a lock-out for more sustainable alternatives. In this case a strategy to overcome this situation could be a set up in a protected area or 'niche'. Here technologies can be developed and grow until they are able to compete with current systems. Niches will also include knowledge production structures and new alliances of energy companies, equipment manufacturers and users (Van Vleuten, 2006, p.302-303). Most technologies that formed the basis of infrastructures started as a niche. Besides the fact that this created the opportunity to test the viability of a technology, this is also a chance to generate additional investment funds that can be needed for further development. The project is then fulfilling the role of a showcase to investors.

A niche could also start institutional adaptations in management, organization and the institutional context which are important for the further development and diffusion of the technology. Starting as a niche could contribute to the support such a new technology needs, on the other hand could it also lead to the destruction of plans when due to unforeseen side-effects stakeholders take an opposing attitude. The organization and arrangements of such a niche is therefore also of vital importance. An example that can be mentioned is the telegraph line that started with an experiment of 19 km between Amsterdam and Haarlem in 1845 (Van der Woud, 2006, p.81). The connection was in the beginning only meant for railway service communications. But it soon attracted people who were interested in the exploitation of commercial telegraph services (Van der Woud, 2006, p.337). Furthermore this project created the opportunity to improve operational guidelines, which made continuation of the railways or telegraph lines smoothly.

➔ How does this condition relate to biogas infrastructures?

Start as a niche

As was argued in the previous section, most likely problems can be overcome by means of starting new developed technologies as a niche. On a small scale most relevant technical (but also organizational) problems will rise. A niche creates the opportunity to test solutions and protect future projects in facing similar issues. Furthermore the niche can be used as a showcase to generate funds. From a technical perspective especially the interaction of the biogas infrastructure with its environment will be interesting. So a niche project needs to include a connection with a distribution network, here arises challenges as appeared in the empirical analysis. Furthermore it will be interesting to consider the institutional barriers that arise. Currently the BioNOF project in Friesland is a relatively far developed project that can be considered a pilot/niche project. However the Salland project is in an orientating phase it could also be considered a niche activity.

4.2.5 Being aware of high initial investments – Lock-in effect

Besides the public support that is needed in case of high infrastructural investments, the high investments also cause the risks on the lock-in effect. Due to developments in technology it is not unlikely that improved alternatives arise besides existing infrastructures or infrastructures that are in a parallel development. Especially this last situation could lead to difficult choices to investors, for example governmental organizations. In the case an implemented infrastructure is already embedded, innovations that will create a shift towards another infrastructure could have resistance from involved stakeholders. These may face financial consequences since significant amounts of money were already invested in the infrastructure. When a decision is made to stop such a project, the public opinion will probably blame the government for spending this money for nothing.

In the situation an infrastructure is already completed, the government could tend to protect these investments. An example can be found in the situation of the postal services. Significant investments in those services were made by the government, which needed some years to realize a reasonable remuneration (Stout et al., 2005). This would be hard when the alternative telecommunication line entered the market. Especially when the service would be driven out of the market, even a reasonable remuneration will be challenging to achieve. For this reason the government did not want to support the implementation of the telecommunication infrastructure. After all in this specific case there was no reason for a protective approach, both communication infrastructures could flourish and even strengthen each other. Communication became a new standard which was used by people increasingly using different modalities. But due to the fact that the added value and development of new technologies was uncertain the reluctant attitude can be explained (Rathenau, 1995, p.75).

There rises a tension between on the one hand a well-thought decision making process about high investments and on the other hand the urgency of this infrastructural development. These are inevitable since networks and infrastructures function as deep structures in society and to a large extend influence where people live, work and play (Hughes, 1983).

➔ How does this condition relate to biogas infrastructures?

Lock-in effect

Since the projects are currently developed as a niche no excessive investments are made at the moment. It is even questionable whether or not the government itself is contributing a major share to these projects that are initiated by local stakeholders, distribution network operators and energy companies. Of course the governmental participation is fulfilled indirectly due to the presence of distribution network operator and local authorities. The lock-in effect is currently not an issue to biogas infrastructures. Since the 'niche' projects are in an early development phase, the possibility on an overall cancellation even exists. This would not have deep impact consequences

4.2.6 Being aware of profiteers

According to the sources of literature that were used in this historical analysis the Dutch culture appears to have elements of suspicion and jealousy (Van der Woud, 2006, p.107). People from the normal population and industries appeared to seek for loopholes in the legislation that could cause advantageous situations for themselves. This behavior creates longer throughput times and higher costs to the project development. On the other hand the suspicion probably led to a more conscious process of implementation, since the added value needs to be thoroughly considered. An example can be found in the way the telegraph lines were implemented in America compared to the Dutch situation. In America the lines were realized in a high tempo due to their pragmatic culture, yet in The Netherlands the physical integration in the environment and by defining judicial preconditions (Van der Woud, 2006, p.40)

An example was the Wickevoort case where entrepreneurs invested in a piece of land. Their purchase was located exactly in the line between Delft and Rotterdam. The entrepreneurs were anticipating on the realization of a railway connection. This railway connection was indeed planned crossing the surface they had in ownership. The project developers wanted to buy the piece of land, but the entrepreneurs asked about 8 times the usual price, or they would require a train station on that location. The railway company did not agree on both proposals and realized a detour, just around the land that was in ownership. According to literature countries as England and France have less of these phenomena (Van der Woud, 2006, p.293). It is questionable whether or not France and England are suitable to compare with, these countries are significant larger. Yet from these countries information on this subject was available.

➔ How does this condition relate to biogas infrastructures?

Awareness to profiteers

Farmers with commercial instinct want to make the highest possible profits. Some of them choose to produce biogas on the one moment which is meant for green gas production, while when the variable electricity price increases a direct switch is made towards de-central electricity generation (using CHP technology). The producer will get an optimal price for its biogas. Since the upgrading facilities are often funded with a significant amount of subsidies this could cause a situation in which nearly no biogas is produced in return for the subsidy. Although the biogas producers are currently in small numbers, when these practices occur on large-scale an undesired situation takes place. Other involved stakeholders that are part of the biogas infrastructure are affected by this behavior as well, since economies of scale only arise when sufficient volumes are produced. The biogas infrastructure playing field needs to be aware of profiteers, yet this will be of more importance when the number of biogas producers increases.

4.2.7 Understanding the playing field

However all six conditions that we have discussed clearly have a different origin, all of them relate to one central and overarching aspect: a proper system understanding. One of the conditions contributes to the system understanding, whereas the other conditions need system understanding as a pre-condition that is required to work out properly.

Starting infrastructure development in a niche environment contributes to the system understanding, since this creates the opportunity to explore the technology and interfaces with stakeholders and technology. It explores the system from a functional perspective and creates therefore a practical oriented system understanding. Due to this overview most of the obvious problems related to infrastructural development could be overcome. Understanding specific technologies (in progress) could deliver helpful insights when they are put in a specific managerial and social environment. New technologies could cause specific managerial problems and new relationships within the playing field.

The other conditions require information from the ‘soft side’ of system understanding. Yet it would be too short-sighted when these aspects would not contribute to the system understanding, since every conscious reflection on the situation will clarify aspects of the playing field (yet it could also raise additional questions). To bring the support together from economic, political and market stakeholders, knowledge on the playing field is required. Especially when one is also willing to involve negative influenced stakeholders; what are their losses and where could gains to them arise. Furthermore the clear objective, formulated by the government, would need a system understanding. This since the effects and consequences of their policies needs to be well-considered. The same occurs to the awareness to profiteers. The (non)-existence of policies make people searching for loopholes to benefit. System understanding could reveal those shortcomings before policies are implemented.

A clear example of a lack of system understanding was at stake at the construction of the canals. Here the lack of geographical information, as for example the slope of a waterway or the volumes of water that will flow by, created a situation in which the developers of a canal were not able to estimate the effects on direct or indirectly linked waterways (Van der Woud, 2006, p.175). One could imagine that the construction of a canal on a certain location could cause a serious decrease of water volumes to other canals or rivers. This could cause problems to fishery or inland shipping, but also to responsibility issues. Since the different districts had their own responsible organizations considering the 'water management' and actions of one district influenced the situation of another (Calland, 1860).

➔ How does this condition relate to biogas infrastructures?

Understanding the playing field

To assess whether or not a thorough system perspective understanding is reached is difficult since this cannot be measured. Basic knowledge on gas networks is extensively available in The Netherlands. However green gas brings secondary conditions and as appeared in the strate gic analysis some effects of these conditions are not investigated sufficiently to ensure a proper operation of the distribution. Think for example of the effects of biogas compositions on pipelines or changes in the balancing regime and remuneration agreements of biogas producers. From a system perspective also indirect aspects will be of importance, an example for biogas is the food price that could be influenced when it becomes possible to generate energy from food sources (OECD,2008). It is not possible to investigate which elements are inevitable to a good system perspective understanding, since this assumes that all system elements are known. For this moment the issue list that is presented at the start of Appendix 1, the strategic analysis, gives quite a complete overview of the issues related to green gas. This since it is composed using interviewees from different stakeholders in the playing field and additional literature. In combination with the socio-technical system from section 3, the issues give a rather good system perspective understanding of the green gas field. It should be mentioned that when green gas is produced on a large scale this would probably bring new issues. Furthermore the knowledge on biogas infrastructures is developing, also this thesis could contribute to this process.

4.3 Research question 2 and 3

Now that the conditions have been discussed in the previous section, research question 2 can be answered:

- What (pre)conditions made the unroll of a selection of today's infrastructures (un)successful?

The emergence of canals, railways, communication and gas infrastructures have been explored in Appendix 2. This analysis delivered a collection of 7 conditions that had a positive influence on the former infrastructural developments. As Hughes already argued, the proper functioning of a technical system depends on the interaction of technical, organizational, economic, political, juridical and cultural components of the system. This is especially the case for the emerging phase, in which the institutional framework will be designed leading to the operational functioning of an infrastructure. The recognized conditions all have a direct link to one of Hughes components or the overall interaction between them, as can be seen in table 2.

Table 8 - Recognized conditions from historical analogies

Availability of parallel infrastructures (technical)
Bringing available support together (political, organizational)
Clearly formulated governmental objective (political)
A niche as starting point (technical, organizational)
Being aware of high initial investments - lock-In effect (economical)
Being aware of profiteers (juridical, cultural)
Having a thorough system perspective understanding (overall)

Whether or not the conditions were applicable on the specific case of biogas infrastructures was the main point of interest to be able to answer research question 3:

To what extent could the (pre)conditions of RQ2 be translated to the case of biogas in The Netherlands?

The conditions that were stated in section 4.1 were reflected on the current situation of biogas infrastructures in The Netherlands as was described in section 3.6. It appears that some of the conditions are met in the case of biogas infrastructure. Examples are the availability of parallel infrastructures, the start as a niche and the awareness to the lock-in effect. These conditions strengthen the position of biogas infrastructures in its emergence. However, when considering the complete set, most of the conditions are hardly met. Especially concerning the available support, an improvement is desired. There is a lack of investors willing to invest in the infrastructures. These are not yet present in private or public organizations. A window of opportunity can be found in the involvement of negatively affected stakeholders which are part of the current energy regime and have resistance to change. When they get involved in the transition process added value can be generated to them.

Besides this historical analysis, also the strategic analysis and the empirical analysis showed the importance of a clear governmental objective. In addition especially the strategic analysis showed that the relation between energy ambition and regulations is unbalanced. And from the empirical analysis it appeared that a gap arose between the current regulations and things to expect in the near future. Uncertainty on the direction of any governmental organization make stakeholders reluctant. Examples can be found in changing subsidy programs, potential changes in legislation, uncertain policy changes regarding manure. These uncertainties also create barriers for a proper system understanding since it will disturb rational decision making.

Overall it appears that currently the majority of conditions are performing poor in order for them to contribute positively to the development of the biogas infrastructure. Too many issues are still present and need to be solved, mitigated or managed to make biogas infrastructures a success.

5 Transition Management - possibilities for application to biogas infrastructures

"Life is pleasant. Death is peaceful. It's the transition that's troublesome."

Isaac Asimov, Russian writer (1920-1992)

➔ Section 5 explores whether or not the emergence of a biogas infrastructure can be 'managed' using the Transition Management theory. Firstly an explanation will be given on the theory itself (5.1) and the different roles that arise in the playing field according to this theory (5.2). In 5.3 the criteria will be checked that will indicate biogas infrastructures as a suitable subject for application of transition management. The application itself is discussed in 5.4 resulting in answering RQ 4 in 5.5.

5.1 Transition Management Approach

Inter-disciplinary

The concept of 'transition' was already discussed in section 2, here the more conventional applications were discussed. But recently this concept is also used to bring structure in a variety of complex societal phenomena. In this case there is no leading field of science, but a combination of economy, social sciences, innovation sciences, policy analysis and (integral) systems engineering are applicable. This interdisciplinary approach, which is called transition management, could offer us a better understanding of the complexity of societal dynamics (Rotmans, 2004).

Societal change

A transition is in this case a structural societal change resulting from several developments, like economy, culture, politics, technology, institutions and the environment (Rotmans et.al., 2000). These developments could also strengthen each other to end up with societal transformation that normally will cost quite some time. Usually transition terms will take about 25-50 years in total. The fact that existing barriers, institutions and relations needs to be opened up and possibly renewed is the main reason here. Within this period the changes seem to occur gently, but on the short term severe changes will be part of the process. All major and minor changes together will, when they will point in the same direction, in the end lead to one transition (Rotmans, 2004).

Innovation variety

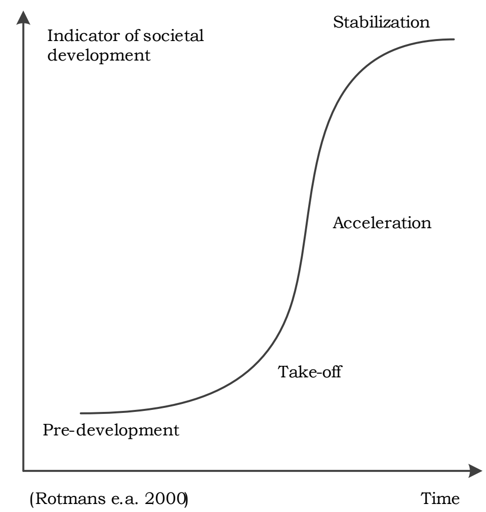
A precondition to a transition is that innovation needs to be at stake on different levels of a system. System innovations occur as an umbrella over a situation in which individuals, companies and organisations are located. These innovations will besides the 'hard' technological innovations also concern 'soft' innovations as regulations or within organizational structures. The more complex an innovation becomes, the more important the 'soft' innovations will be (NRLO, 1999). The difference between normal innovations and system innovations is that the system innovations will need a much longer time span. Transition management is concerned with uncertainties and is not focused primarily on market demand but also on the development of public goods and services that do not have a well-functioning market already. A system innovation aims on the prevention of market failure and system failures. Here the market failure may indicate a dysfunctional market system where too little is invested in research and development. The system failures consider structural defects in the societal systems, like the economic, the political or innovation systems (Rotmans, 2004).

According to Rotmans, transitions can be considered in three dimensions: time, scale and nature. In this section these different perspectives will be explained.

Time dimension

Firstly the time dimension, as already mentioned transitions could cover a serious timespan of over 25 years. In the very beginning the status quo will hardly be influenced, this can be considered the pre-development phase. Thereafter the transition will come in the take-off phase directly followed by the acceleration phase in which the societal change will really have their impact. In the end of the transition a stabilizing pattern will converge to a kind of equilibrium in the stabilization phase. An important notion is that this stabilization phase will be temporarily until a new transitional movement will take place. The phases are visualized in figure 18.

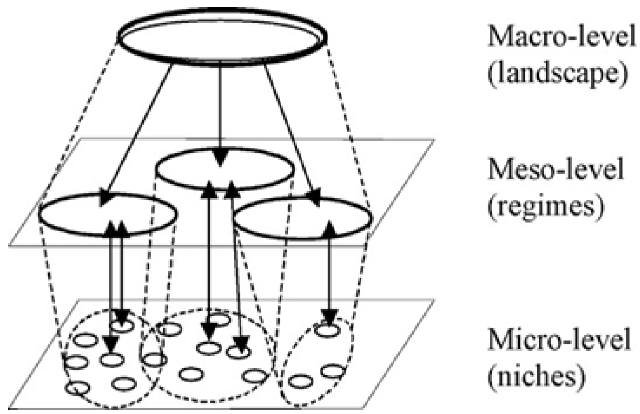
Figure 18 - Different phases of transition



Scale dimension

The scale dimension of a transition can be illustrated by the layer model of Geels and Kemp (2000) (Figure 19). Transitions arise on different scale levels starting on the macro level were politics, culture and paradigms are changing relatively slow. These have their effect on the meso level were objectives, rules and regimes arise. Within this level resistance to innovation is likely present. Organizations, institutes and networks often prefer to preserve the existing rules and interests. The problem with stakeholders within in a network is that their acts are not determined based on opinions, but they tend to behave strategically in order to consolidate a power position in the network (De Bruijn et al., 2008).This meso level is in interaction with the micro level which deals with the daily action. Here the radical innovation and experimentation can arise.

Figure 19 - Scale levels of transition



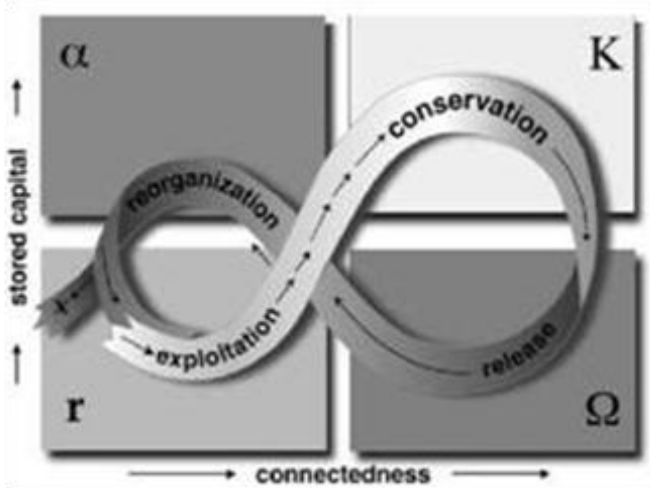
Source: Geels and Kemp, 2000

Nature dimension

The third dimension that is distinguished by Rotmans is the nature of the transition. Holling's adaptive cycle can be used as a guideline here. According to Holling the transition of complex systems contains fast periods of construction and rise versus slow periods of decrease and demolition. Interacting dimensions

shows the adaptive cycle, which consists out of 4 phases: exploitation, conservation, release and reorganization. The American automotive industry is often used to illustrate this mechanism. One could imagine the inventors of the first car, these people were just crafting in their garage before they came up with an end product, for which no existing market was available for. After testing and 'reorganizing' the process these people found out that there was a market for automobiles and started 'exploiting' them. More and more companies started producing cars, some companies failed, others got the chance to grow. Growth was often fed by mergers and acquisitions until a few large American companies consolidated on the market and came into the 'conservation' phase. These companies were large and inefficient, until the Japanese car manufacturers entered their markets, with better cars, a higher quality and against low prices. This brought the American automotive industry into the 'release' phase, with disappointing sales and profits. To come back on track, these companies were forced to start reorganization. New policies and strategies will bring the companies in the exploitation phase again, producing innovative products that approached the wishes of customers better. These innovations brought the industry some success again (conservation phase), thereafter companies as GM came into huge problems again due to the increased competition and inefficiencies within the company (release phase), something that 'closes' the adaptive cycle (Nikolic, 2010).

Figure 20 - The adaptive cycle



Source: Gunderson et al., 2002

Interacting dimensions

All three dimensions will have interactions during a transition. This starts with the pre-development phase, here the establishment often slows down the process since they want to preserve the current norms and values but want to improve technology and policies. When within the three levels of the micro, meso and macro model changes occur, the take-off phase of the transition will start. Internal and external disturbances could cause this take off, with elements within the micro, meso and macro level that will strengthen each other. Technological innovations (eg. eye-security technology) could for example being enforced by worldwide cultural changes (eg. worldwide push towards safety and security). These interactions could work both ways. The micro-level can enforce the macro-level, but also the other way around. After the take-off phase the acceleration phase will start due to a series of irreversible and unstoppable developments all moving in the same direction. The establishment will take a facilitating role here. The situation changes due to pressure from the micro level, pressure from the macro level and self-reflection. Within the acceleration phase changes take place that have a major impact on the established situation and cannot made undone. This can be considered as an instable phase in which the current norms and values will be substituted by the new ones. The transition will then come in a dynamic equilibrium, like the conservation phase of Holling's diagram. This situation will continue until new influence will create incentives towards a following period of transition (Rotmans, 2004).

5.2 Roles in the playing field according to TM

The previous section explained the underlying philosophy, structure and dynamics of transition management. The transition management method as it is explained by Rotmans is more than a philosophy since it also hands more practical guidelines to accomplish a transition. In this section the suggested main activities will be explained in combination with the most important roles according to the theory.

The effect of conventional management methods (imperative, responsive and network) would not be sufficient in the complex societal situations as described in the previous section. Transition management is an unconventional management method that is, "not based on command and control but an evolutionary method that adjusts, influences and corrects. In practice this leads to terms and conditions creating space for innovation using the initiatives on the right moment."(Rotmans, 2004, pg. 51)

Transition management is not suitable to fit in a roadmap since it has an evolutionary character. Yet we could define four main activities, these are not sequentially fixed. Transition Management is an iterative process (Rotmans, 2004).

- Design a transition arena: A variety of stakeholders are brought together in an 'innovation network' on a central innovation theme. The stakeholders include the 'societal pentagon': government, private sector, knowledge institute, societal organizations and intermediaries (project organizations, consultancy firms). Demarcate sub themes and create a relation between transitions and system innovations.
- Develop long-term vision and transition pathways: Investigate the different perspectives and motives and converge them towards agreement. These could lead to long-term visions, including innovative, inspiring and ambitious elements leading to an end situation. This end situation will be most likely evolve during the transition process. This should not be confused with back-casting, since in that case one final situation is considered as a starting point to reverse engineer to a desired state. Due to the changing end situation this reverse engineering is not an option.
- Steer on learning and knowledge: By means of experiments and pilots, or discussing scenarios among stakeholders the learning-by-doing and doing-by-learning concepts will create insights and make the transition proceed step-by-step.
- Monitor and evaluate the process: There is a need to check upon the progress of a transition and continuously monitor and evaluate the activities between stakeholders.

For a more extensive explanation of those activities, please check Appendix 3 on Transition Management.

Rotmans defines a combination of five stakeholder groups. Most of them operate in another arena and is judged on a different output (objective) which can be found in Table 9 (Rotmans, 2004). The roles of stakeholders will differ depending on the phase within the transition.

Table 9- Overview of stakeholders, arena and objective

Stakeholder	Arena	Objective
Government	Political	Political power
Private sector	Free market	Profits
Knowledge institutes	National-, or international scientific	Scientific acknowledgement
Societal organizations	Societal	Societal support
Intermediairy	All arena's and in between	Power and robustness of stakeholder network

Govern-ment

To the government an important role is appointed in the initial phase of the transition. Here the government could take a supporting role in the exploration of the transition arena. As co-developer they could sketch terms and conditions that create an environment of innovation. After this initial phase transition developers need some degrees of freedom, therefore the government needs to make a step backwards. From that moment a more or less facilitating role will be taken. Again terms and conditions need to be sketched due to a further development of the transition. When a broad societal agreement is achieved and the project progresses the government needs to monitor the gains of innovation. The political arena will be confronted on a regular basis with activities within the transition process. Governmental organizations can offer support when needed e.g. in legislation, new institutional structures or economic incentives. Hereafter the stabilization phase comes in, the government should consolidate, monitor and maintain the new situation.

Private sector

The private sector needs to develop long term visions, this will make them aware of sustainability. Considering the balance between people, profit and planet could help to apply the concept of responsible entrepreneurship. However this integrated approach needs a fundamental change in culture, processes and the strategy of a company. Due to the fact that the free market is the operating arena to the private sector this change will be hard to achieve. Profitability on the short term outweighs the sustainability on the long term.

Knowledge institutes

The knowledge institutes should invest in inter-trans disciplinary research. Within this kind of research the confrontation with practice is essential. This should be achieved by the participation in innovation creating networks with societal stakeholders. In this case the knowledge development serves the practice and vice versa. In this perspective the knowledge institutes should take the role of co-innovator and co-producer of knowledge. The knowledge will be generated in collaboration with the practice.

Societal Organiza-tions

Within the transition process the role of societal organizations needs to transform from a defendant of interests towards a creative 'pleaser'. In other words a re-active and defensive oriented attitude should become a more constructive and pro-active attitude within the stakeholder playing field. This will enable stakeholders to approach solutions instead of problems. It is preferable that societal organizations change the 'one-issue' attitude and become 'multiple-issue' attitude by merging their issues with other societal organizations in alliances. To these organizations the advantage will be that their strength in the stakeholder playing field will increase by forming these multiple issue combination.

Intermediary

The intermediary is operating between the different arenas and could fulfil several roles here. It is actually a sort of broker who brings parties together (*facilitating* role), executes the sale (*executive* role), takes care for the contract issues (*content/knowledge* role) and finally an *initiating* role. This combination needs an intermediary that has another kind of authority. Instead of mainly facilitating and executive, the focus should be shifted to a more initiating organization that interacts within the whole spectrum. Overall the intermediary should stimulate other stakeholders and search for new players in the playing field.

Users

Within the transition process the actual users fulfil the role of co-innovator. By interacting on a regular basis with reality, innovation has the opportunity to reach a final development.

5.3 Applicability of Transition Management to biogas infrastructures

After the theoretical concept of transition management is clarified and a brief introduction to the main activities was presented, the approach needs to be translated to the case of biogas infrastructures in The Netherlands. First of all, the position of biogas infrastructures needs to be investigated with respect to a transition. Can we consider an implementation of biogas infrastructures as a transition? This is a requirement before transition management can be applied. The same accounts for the link between sustainable development and biogas infrastructures.

Part of transition

As stated in the 'Research Motivation', the energy transition is in progress. Biogas infrastructures were suggested to be part of this energy transition since it is a means of producing green gas. Applying biogas infrastructures will cause a change in the current situation of the Dutch energy system. This could be mentioned as a system change and in terms of system engineering even as transition. The biogas infrastructure could contribute to a more sustainable energy supply that meets the needs of the present without compromising the ability of future generations to meet their own needs. Yet the potential production volumes of biogas in the Netherlands will not be able to meet the total required energy demand, so it will only contribute partly. The impact of the system change is therefore unclear. The eventual end-product green gas is a relative clean resource, but it is not fully sustainable, therefore green gas will probably not be the final state of the energy system. Yet since green gas has less emission on the whole supply chain compared to conventional resources, biogas and green gas can be considered a step in the right direction.

TM criteria

To assess whether or not transition management is applicable to the development of biogas infrastructure should be checked upon the transition management criteria. These criteria are:

- Consequence of developments in economy, culture, politics, institutions, technology and environment
- Time span of 25-50 years
- Combination of domains causing complexity of societal dynamics
- Innovation should be at stake at different levels (hard and soft)

Current energy transition has emerged from a combination of developments. The ***environment*** is probably leading here, since effects of climate change (rising temperatures, rising sea levels and a change in average weather conditions (Wikipedia.org, 2011)) are according to some researches expected to threat eco-systems. Causes of the climate change are found in the extensive emission of greenhouse gasses, especially in western countries and emerging countries like China and India. These environmental concerns ended up high on the ***political*** agenda when the Kyoto protocol was initiated, in which countries have committed to national or joint reduction targets. Especially since the United States of America did not sign the protocol lots of negotiation on international level took place and several revisions followed on the original document. Furthermore the ***economic*** value of fossil fuels has increased the last decades. Depletion of conventional resources urges our society to develop substitutes in order to meet energy needs. This is a requirement to consolidate our current industries and society. The ***technological*** development contributes continuously to the awareness of energy waste, for example by improving energy-saving processes or the reduction of industrial emissions.

Considering the variety in developments that underlie the energy transition, with biogas infrastructures the first criteria is met.

Time span

The time span of a transition will reach over generations, as indication the time span of 25-50 years is often mentioned. The energy transition will take probably more time, when aiming on a full sustainable energy supply. However the first phases of this transition (pre-development, take-off and acceleration) seem to be executed within the time span of 25-50 years. The energy transition itself will definitely not be a short-term matter. Considering the acceptance of biogas infrastructures this time span seems more likely. In this case the whole process includes the moment biogas became accepted in The Netherlands, possibilities for upgrades were investigated and gathering hubs would be able to facilitate a significant share of the Dutch (or even European) energy needs. It appears that also the time span criteria for transition management are met.

Dynamic complexity

Different domains that can be distinguished and have common grounds to the biogas infrastructures are economy, innovation sciences, policy analysis and (integral) systems engineering. Let us summarize some examples that indicate the common grounds of these domains: economy for example due to the remuneration of investments, while innovation sciences come in due to the sustainable character of the developing technologies with an emphasis on long-term changes. Furthermore policy analysis involves regulations or subsidy programmes and finally the system engineering which will be helpful to combine the different system components, monitor the interfaces and define the system architecture. These domains are in interrelationship with each other and could cause societal dynamics. Therefore the third criterion for transition management is also met for biogas infrastructures.

Multiple levels

The final criterion concerns the fact that innovation should occur on different levels of the system, like hard technology based and soft organizational based innovations. Since innovation indicates a renew or change of an existing situations, it differs from the concept of invention were changes are made. Realization of a biogas infrastructure would offer an improved energy supply in terms of sustainability, which in fact can be seen as an innovation. Innovation takes place on the technological side, with the design of the network, improvements of upgrading facilities or for example local balancing regimes. On the soft side existing regulations needs to be translated to be applicable on biogas, furthermore responsibilities within the system should be determined. Therefore the multiple levels of innovation do apply to the biogas infrastructures in The Netherlands.

Summarizing it can be concluded that the realization of biogas infrastructures in The Netherlands can be considered to be a sub part of the energy transition but that it also could be considered as an independent transition.

Sustainable Development

Transition management is especially suitable to transitions in the field of sustainable development, therefore the common characteristics that are found in most descriptions of 'sustainable development' should also be assessed on the biogas infrastructure case in order to explore the applicability of the theory. These common characteristics are time span (25-50 years), scale level (regional, national, international) and plurality of domains (people, profit, planet) (Rodriguez-Nikl, 2011; Rotmans, 2004).

Sustainable Criteria

The time span of 25-50 years was already examined, since this was a criteria for transition as well. A variety in scale levels is at stake because currently projects are applied in micro scale, located at farms itself and discussed on scale of municipality or province. Additionally realization on national and international scale could be a future opportunity. The final criteria concern the plurality of domains. Profits will be the driving force to participating private companies, while people feel comfortable to a sustainable energy supply and the developments will contribute to an improved preservation of our planet's environment. Therefore the plurality of domains can be defended. Reflecting on the given criteria the biogas infrastructure can be considered a sustainable development. Since it was already examined that the biogas infrastructure implementation could considered a transition, the concept of transition management seems to be suitable as a steering mechanism in this case from a theoretical perspective. Therefore the next section will project the elements of transition management to the empirically defined system of biogas infrastructures in The Netherlands.

5.4 Transition Management projected on the biogas Infrastructures

Now we have argued that a biogas infrastructure meets the requirements as stated by Rotmans (2004) to apply Transition Management we will discuss difficulties that could arise. This is done by reflecting the theory of Rotmans to the empirically constructed socio-technical system (STS) of section 3. Since the STS is an interpretation of reality this will give an insight in whether or not the theoretical approach will be advantageous to the emergence of biogas infrastructure. The reflection is performed by comparing a theoretical recommendation to the described system. Mind that this combination with the STS results in recommendations on the operational level, section 6 discusses the transition management on a higher aggregation level.

Transition Paradox

Within the STS the government is influencing the system with subsidies and regulations. In other words the terms and conditions to the transition are created. This is exactly the role that needs to be fulfilled according to the theory. However the theory also states that one should be aware to not reform the transition process to a policy process. Empirical research made clear that installing taskforces and advisory groups creates unrest and resentment on the side of participants and even policy makers as well. This is also mentioned as the transition paradox, where the government manages, controls and arranges system innovation and creates thus the biggest barrier to the transition by themselves. It is important to create some space surrounding the transition arenas, so participants could perform their own initiatives. Usually the government tries to accomplish this by creating an institutional context, e.g. regulations. Rotmans argues that this context will harm the process more likely than achieving a positive contribution (Rotmans, 2004).

Meanwhile the theory suggests to start 'policy teams', at the same time it considers taskforces to have a negative influence. Here arises a contradiction within Rotmans theory. Since it is questionable whether or not the effect of a taskforce or advisory group(discouraged by Rotmans) is so different of a policy team (encouraged by Rotmans). One could also argue that the same concept, namely people who discuss opportunities of a certain technology, are just named and framed differently by Rotmans. This will cause different interpretations which is confusing for involved stakeholders. When evaluating the current taskforces (discouraged by Rotmans) related to biogas infrastructures, it appears that current pilots originate from here. From an empirical perspective the effect of the taskforces seems to be positive.

Government distance

According to the Transition Management theory incumbents need to left out of the system, they would block the process. However in the case of the gas market there are only a few stakeholders involved in the field of distribution, transport and shipping. Therefore it seems unlikely that no incumbents are involved with a biogas infrastructure project. Let us consider the influence of the establishment (national government, Ministry of Economic Affairs, energy producing companies, distribution network operators and gas related companies) on the energy market in the STS. The establishment tends to preserve a 'control over the situation', this needs to be avoided. It could be disastrous for the process within a transition arena. Some stakeholder have a suspicious attitude to the government, due to former experiences in which the perception of throughput times of projects are long. Expressions of the establishment needs to be avoided and on the other hand stakeholders are encouraged to setup 'transition agreements' or 'ambition statements', yet these do not need to be binding, they should be challenging enough to stakeholder to participate. This seems to have similarities with the covenants that are often used in the public sector to agree on a policy direction. Trajectories to these covenants are time-consuming and the effectiveness within the energy sector is not yet empirically proven. However researches argue that by using covenants the initial initiative should be left to parties outside the government. This will keep involved stakeholders stimulated (Dijkgraaf et al., 2009).

Public funding

In line with the previous point is the claim that public officials should be kept outside the process as long as possible. This would create trust among the other stakeholders, who have usually a deep-seated mistrust in governmental organizations. At the same time broad support is not necessary from the first start, however political support is a must. This will legitimate the continuation of the transition process (Rotmans, 2004). It is questionable whether or not political support and a proper distance of the national government could be combined in reality. An example is the financial funding that is a prerequisite according to the theory and numbers between the 1 and 10 million euro. This money will in most cases be derived from government funds. But when the public officials need to keep distance from the process and on the other hand invest significant amount of money a mismatch arises. Political stakeholders will not get away with investments without a proper clarification. The risk that the investment will not be recovered is at stake. When it can be recovered it will probably be indirectly, by the generated services by the infrastructure. This indirect recovery of investment will hardly contribute to political appreciation. In the case of biogas infrastructures the government was strongly involved in the beginning. The Platform New Gas was the first initiative in 2006 and was majorly occupied by governmental organizations (Dumont, 2011). The follow-up was intended to be a private collaboration, yet also here the involvement of public stakeholders appeared to be inevitable to achieve progression.

Voluntary stake-holders

The STS shows the involvement of a wide variety of stakeholders operating in different arenas where commitment is required. According to Rotmans this means that involved stakeholders should be willing to participate without any obligations or compensation. When they are not willing to do this, there would be no place for these participants in the transition process. In other words it is claimed that the transition process is actually a disguised form of voluntary activity. This is somewhat strange since the general interest is served by the initiation of biogas infrastructures and it makes a contribution to the society as a whole. Therefore it should be more likely that related activities can be financially allocated. As appears from the STS, most of involved stakeholders are located in the private domain, as a consequence people are focused on profit. This makes them less eager to participate in projects voluntary.

Attract citizens

Citizens need to obtain a stronger position within the transition process. Of course the societal organizations represent them, however this is mainly an indirect representation (usually in the consumer role (see the STS)). The individual citizen is hardly involved in the transition process, although according to Rotmans (2004) this is very important. To attract citizens for a transition with a 25-50 year time span could be hard to achieve. However citizens have a long-term orientation from a personal perspective, the societal orientation is majorly short-term. Furthermore the biogas infrastructures are not specified sufficiently to the citizens, the direct win is not clear to them.

Initiation of process

When Transition Management is applied, there is much to be done. Besides the transition arena's that should be designed, innovation space should be created, a shared problem perceptions needs to be formulated, instruments should be developed and applied, etcetera. All of these activities relate to many elements in the STS. To manage this complex situation in a proper way is not an easy job and could not be achieved by a single stakeholder. An incentive is needed to activate stakeholders in starting the transition process. In case of biogas infrastructures the gain is clearly an environmental one, furthermore slowing down the depletion of fossil fuels and the creation of independence towards oil producing countries are incentives to realize biogas infrastructures. But to whom is this incentive applicable when the government needs to take some distance from the process? One could argue that societal organizations should take initiatives here, since there objectives are served by the emergence of biogas infrastructures. Yet this process cannot be unrolled by one party, the private stakeholders and intermediaries are needed as well, but due to the lack of economic attractiveness it is not likely that they will participate. The profitability will be the most serious reason for market parties to participate. Furthermore considerations like the sustainable image of a company or the future market position within a mature biogas infrastructure market could make them eager to participate. Yet these least considerations do not seem to have a major impact on the involved stakeholders. The financial attractiveness is decisive and a logical key player to improve this attractiveness is in this case the government. Subsidy programs need to be restructured to support the initiation of the biogas infrastructure realization process. Subsidies are aimed on serving the general interest, which makes that the costs are being socialized over society. Apparently it is the government who needs to take the supporting role in the start of the transition process by developing terms and conditions in which the market is triggered to start cooperating in the transition arenas. This is a logical effect, because the current gains of such an infrastructure are contributing to the society in general. Societal values are safeguarded by the government.

Focus on long-term

To come back to the role of societal organizations, these should make a change from 'one-issue' towards 'multiple issue' organizations. In the daily activities 'one-issue' organizations will be effective, however when the interests are on the long-term level the impact of combined societal organizations will be more effective. Directly linked to this is the fact that also the private sector, as energy producers and suppliers, should develop long-term visions in terms of sustainability. According to strategy consultant Arthur D. Little the private sector in the energy transition has defined concrete ambitions already. In technology intensive sectors also emissions are significant, therefore high investments with long depreciation times are at stake (Eikelenboom, 2011). Therefore the presence of long-term sustainability targets is needed here.

Success measure-ment

Unlike is the case at physical design processes, for the design of a transition process it is hard to measure success. Yet to a design process the possibility to measure success is essential. There are no typical milestones of completion available within a transition, process objectives would probably approach this the most. Examples of these could be: had the process of change started, have the right stakeholders been involved, have projects been launched to let the transition materialize? Finally it is also difficult on who will answer these questions; this is another example of the lack of success measurement. In order to properly formulate process objectives and to maximize the chance on success, transition management require a basic understanding of the socio-technical design space, and of the complexities and the uncertainties involved in bringing socio-technical systems or parts of it into being (Chappin, 2011). This directly supports the argument that a thorough understanding of the systems perspective could contribute to a successful realization of infrastructures in a later phase (section 4.8).

The projection of the transition management approach on the socio-technical system (STS) resulted in majorly process-oriented recommendations and challenges. The physical elements of the STS are hardly influenced by the transition management thinking. Yet the roles, responsibilities and exact interpretation of the processes that are underlying those physical elements are subject to discussion. In the next section the fourth research question will be answered.

5.5 Research question 4

At the conclusion of this section, we can reflect on the fourth research question:

- To what extend could theoretical concepts from transition management be translated to the case of biogas in The Netherlands?

According to the defined criteria the transition management theory is applicable on biogas infrastructures in The Netherlands. Yet whether or not an application will work out properly in reality is another question.

The socio-technical system that was constructed in the empirical research step could be combined with the transition management approach, however a clear emphasis was on the process elements instead of the technical sub system.

It appeared that especially the role of the government is rather vaguely described in transition management, there are even several contradictions found. The government should offer essential supported by funding the initial process, while at the same time distance and aloofness is needed. One should be aware on the transition paradox in which the national government tries to create incentives by designing regulations and subsidy arrangements, ends up causing the most important barriers to innovation. Within the STS the role of the government was announced a necessary one.

Furthermore the voluntary basis that is implicitly announced to be the precondition to a successful transition management process will probably cause problems. The private sector is essential in the energy value chain and their objective is majorly profit based. Besides the general interest is served by a more sustainable energy supply, there will be possibilities to make a financial allocation here.

Finally the initiation of a transition process is a point of discussion. The most important gain is the sustainable energy generation that is achieved. A circumstance that especially meets the objectives of societal organizations, however they have not yet the strength to motivated other stakeholders to start a transition. A possibility would be to transform to a multiple issue organization and seek for like-minded stakeholders. Section will treat the applicability of transition management on a reflective manner.

6 Synthesis of empirical, historical and theoretical perspectives on biogas infrastructures

"A kind of synthesis, but with some elements that perhaps you wouldn't have expected in advance.

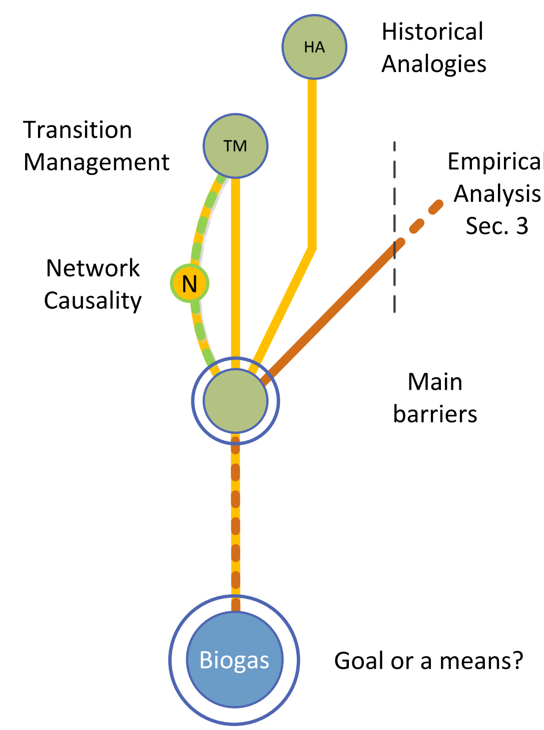
I always like that when that happens, when something comes that is more than the sum of the parts."

Evan Parker, British Musician

➔ The perspectives discussed in section 3, 4 and 5 are combined in this section. Here the relevance and utility of the historical analogies (6.1) and the theoretical transition management approach is presented (6.2). Furthermore the section elaborates on remarkable aspects, respectively the network causality dilemma (6.2.1) and the main barriers on strategic level (6.3). Finally 6.4 will mention the fundamental discussion whether or not biogas infrastructures can be considered a means or a goal as such.

To explain the coherence in this section the accompanied pathway in Figure 21 is developed. Section 6.1 will start on top with a discussion on the relevance and utility of the historical analogies. In parallel the usability of the transition management approach will be discussed in 6.2. In this case the level of analysis will be on a strategic level, can we manage a transition anyway? Besides the transition management a short consideration on the network causality dilemma is provided. This latter can be seen as another theoretical approach to achieve an infrastructural development. This theory is suggested by Prof. Wempe. Thereafter the main barriers will be discussed that arise when also the empirical analysis from section 3 is included in the synthesis. The barriers that will be discussed in section 6.3 are of a higher strategic level compared to the analysis in the individual sections. When the main barriers could be overcome by private and public stakeholders, they will be able to realize biogas infrastructures. However in that case the consideration that will rise in 6.4, whether or not a biogas infrastructure should be seen as a goal or as a means for the energy transition.

Figure 21 – Pathway section 6



6.1 Historical analogies

Relevance and utility

The analogies provided useful insights to infrastructural development, also with respect to the situation on biogas infrastructures. However consciousness is of main importance when applying them, since infrastructure development will always take a different pathway. This also become apparent from applying the Transition

Management theory: there is not one final recipe available. Continuous changes in cultural, technological or economical fields do not allow us to come to such a recipe. The historical analogies are real-life cases that were already confronted with influences from real-world mechanisms. For example, the way users adopt an infrastructure or public and private entities are involved in the emergence of an infrastructure.

The changes over time have a major impact which we cannot change by applying one or three of our conditions. Consider for example the way utility regulation is embedded in infrastructures according to Clifton et al. (2011). It has gone through three 'waves' from 1830 until 2010. Infrastructures evolved from private sectors towards nationalization and 'back' to the market-driven environment in contemporary times. This is only one example of market conditions that changed fundamentally. In addition for current or future transitions a larger number and variety of stakeholders needs to be included in the process compared to e.g. the development of the current natural gas network (Correlje et al., 2004).

In the considered cases the recognized conditions have shown their positive contribution, therefore it is likely that they have a positive influence on future infrastructural development as well. Yet this cannot be guaranteed. Furthermore the dynamic environment in which infrastructures arise does not allow us to distinguish the conditions in 'necessary' and 'pretty'. Every situation is unique in this field, which will also account for the effect of the conditions.

When evaluating the compatibility of the historical analysis with the socio-technical, it can be conclude that these can be easily combined.. The socio-technical system as described in section 3.6 is useful for the assessment of the recognized patterns. However the recognition of the analogies is highly influenced by the researcher's subjectivity since the distillation of situation are made based on a limited amount of information. The historians who stood on the basis of this information already made choices whether or not elements are relevant to include in their analysis. In addition also these sources have their shortcomings, since history especially affected with political processes is difficult to trace back.

6.2 Transition Management

Manage-ability

Transition Management assumes that a transition can be managed. However, this raises a fundamental discussion on the nature of transitions. Perhaps it is the complexity, dynamics and long duration period of the process that make the process relatively uncontrollable. According to Chappin (2011) the question how could 'we', i.e. who is responsible for it, manage an energy transition successfully, appears to be a design problem. Which, in case the government is considered as a problem owner, would be the following question: what assemblage of transition instruments is required to initiate and manage the transition process (Dijkema, 2004)? We should realize that the design of a complex socio-technical system itself is a contradictio in terminis (Herder et al, 2008). These systems evolve as a never-ending series of discrete events and interactions amongst themselves and their surroundings. However, the end situation of the system seems hard to manage and to predict, managing the transition process towards a next situation offers more possibilities according to literature (Rotmans et al., 2000; Chappin, 2011). Of course the trajectory of a transition is subject to lots of uncertainties, which makes manageability only partly possible.

Refreshing perspective

Transition Management offers a refreshing perspective on transitions related to sustainable development, at least compared to the conventional way stakeholders approached transitions. The extensive description of the processes, phases and levels indicate the highly complex environment in which transitions are taking place. One of the lessons that transition management offers is the fact that patience is of importance. Short-term results are not assured. Furthermore, the benevolence of involved stakeholders is essential. The reluctant attitude of a single stakeholder could severely disturb or frustrate the process.

Entrepreneur

Besides the refreshing perspective, another positive of transition management is that it mentions the role of entrepreneurs for transitions. Before the work of Rotmans, the role of entrepreneurs in innovation systems was hardly appointed. Only the protection of niches was discussed, not the importance of these activities (Chappin, 2011). Furthermore, the analogies in section 4 again proved the added value of starting a niche.

Governmental role

By applying the Transition Management theory there are also points of discussion that become apparent. For example, the role of the government is disputable. And together with the government also the public organizations, like the distribution network operators. In section 5 it was argued that public organizations have shortcomings, slowing down and harming the transition process. This seems contradictory as these organizations are striving for the protection and maintenance of public values. It is possible that the expectations of market related parties are focused on fast processes and profit-driven results. Yet the market parties should take into account the importance that such a vital network as the gas network has to society. Networks and infrastructures function as deep structures in society and have surpasses even natural geography and politics as key drivers of societal change. To a large extend they influence where people live, work and play (Hughes, 1983). Therefore awareness in guarding the public values of safety, reliability and affordability needs to be at stake.

Pre-defined objective

Furthermore the statement that the energy transition from a fossil-based to a more sustainable energy supply has a pre-defined objective is remarkable. This is due to the fact that transitions usually arise due to coincidence and serendipity. On the start involved stakeholders normally do not know where the transition is going to end. In this case some would argue the focus is on a fully sustainable energy supply, for example based on renewable energy sources like solar, wind or water. Yet also the installation of large amounts of wind turbines and solar panels will bring complications, like scarcity in other resource. An example would be the availability of rare earth metals (Barras, 2009). This would affect the definition of sustainability presented in section 2.5.3. Here a sustainable energy supply would cover an energy production that "not compromises future generations".

Stagnation and decline

Due to inspiring concepts and process conditions people could be distracted from reality when applying Transition Management. Within the theoretical approach there is minor attention to phases of stagnation and decline. However the adaptive cycle of Gunderson and Holling (2002) is included in the theoretical foundation of transition management, there are no operational explanations on periods of stagnation or decline available. Yet during the current crisis no collapse of investments in sustainable energy has occurred, it is still feasible that sustainable development gets a setback (Agentschap NL, 2010). Companies that invested in sustainable energy like Shell have already announced to stop their investments concerning sustainable energy (NRC, 2009). Therefore it is important that involved stakeholders stay aware of unforeseen troubles during the transition.

Insight providing

Transition Management appeared to be a particularly structured way to approach the development of a transition. However, most concepts are not new and were already used in established approaches (e.g. covenants). Transition Management combined these concepts in an original way by focusing on sustainable development and gives an inspiring insight in how dynamics within decision-making processes could work out in the long term. However to understand the concept of Transition Management knowledge is needed about a wide variety of abstract concepts. In practice it will be questionable whether or not this really contributes to the process. As professor Wempe mentioned, when changing the names of concepts it is not sure the understandability of a situation is increased.

An important notion is that Transition Management inspires a significant amount of people and as a consequence think about the future and dream about sustainability. Whether or not Transition Management is the way to reach that does matter that much, it has certainly a positive influence on the perspective stakeholders have on transitions.

6.2.1 Network causality dilemma

At the start of this research the network causality dilemma was defined: a dilemma which arises the biogas producers do not start to produce biogas because no infrastructure is available to inject the produced biogas. At the same time, infrastructure will not be realized as long as there are no producers available that are operational. For an example, consider a bus-line: People are not going to wait on the side of the road for the bus, while there is not yet an operational bus line. And to busses it does not make sense to start driving when there are no passengers waiting for the bus. The same logic accounts to biogas; insufficient biogas producers are operational, since they cannot distribute the biogas. The biogas infrastructure is not available due to the fact that there are too little biogas producers available. Prof. dr. Wempe came up with the idea to start with the biogas infrastructure before biogas producers are operational (Eenkhoorn, 2011, Van Dam, 2011). But while discussing this statement during an interview he slightly nuanced this. According to prof. Wempe there is “a need for an infrastructure that ensures the sales of produced biogas”. Whether or not such an infrastructure needs to be a biogas-pipeline is not determined. By installing a CHP and create a useful destination to the produced heat , there is also a platform created that ensures these sales. The realization of a biogas infrastructure will take away economic uncertainty to biogas producers and increase their willingness to start a production facility. However when an infrastructure is realized without any producer available one of the conditions of section 4 is harmed, the initial high investment costs are made in an early phase. This could lead to a lock-in effect. Also the lack of an eager investors makes this solution unlikely.

A narrow foundation of support will be needed. In order to reach this, stakeholders should according to prof. Wempe seek for interaction with each other and start to cooperate. Specifically the distribution network operator and local producers of biogas needs to start collaborations, preferable together with potential consumers. In this case the realization of the infrastructure will be based on discussions and consultation (Wempe, 2011). Suggesting concepts as cooperation and consultation match the ideas of transition management. Therefore the questions rise what distinguishes this network causality dilemma solution. Overall it can be qualified best as a concept to trigger stakeholders, involved with sustainable energy projects, in thinking out-of-the-box.

6.3 Main barriers on the strategic level

Reluctant attitude

During the different research steps within this project the reluctant attitude of the government appeared to be a recurring factor. Starting in the strategic analysis, where the drawn sustainability visions were not translated to concrete policies by the government. In the empirical analysis the government argues that the initiative to biogas infrastructures lies with the private parties. At the same time private parties face unfeasible business-cases and argue there is a need for legislative reform. The government is according to them key in the development of biogas infrastructures. In addition the transition management theory posed a two-sided impression of the governmental role. On the one hand there is a need for a reserved attitude, but on the other hand side-conditions need to be arranged and financial aid is essential. Furthermore the historical analysis showed that private investors were decisive in most of the historical infrastructural developments, only the canals were initialized by the government (considering our examples). This accounts especially to the early development of infrastructures. Most of the analyzed infrastructures became state-owned before they were available to the majority of the population. There is a need for a rather short-term advantage to the government when they get involved. This for example was the case with the extension of the national gas grid by Gasunie in 1964 (Stout et al., 2005). These activities offered quick wins, since state facilitated the creation of a cash cow. Overall it appears that the governmental role can be reluctant, but it needs to create stable conditions to facilitate the initializing phase. A legislative framework will create certainty among stakeholders, furthermore reform of the financial incentive structure could lead to solid business cases for private investors. This role is hard to execute since it requires some distance on the one hand, combined with close collaboration in the field of terms and conditions on the other hand. To find a balance between those aspects will be the main challenge for the government for infrastructure development.

Sustainable contribution

Sustainable development currently barely offers opportunities to a solid business case (some exceptions on specific solar- and wind energy projects). Most projects are dependent on the subsidies delivered by the government. For green gas and biogas subsidies are in the current situation inevitable (Dumont, 2011). However the contribution that a sustainable energy supply will have in the future is hardly expressible in money, the current political landscape does not offer opportunities to high investments. According to the majority of politics energy generation needs to be cost-effective, no possibilities are offered to large-scale innovation projects.

Democratic system

It is questionable whether or not infrastructures were realized in an effective way before the current democratic system was initiated. The reason to this reluctant attitude of the government is difficult to define. In 't Veld, announced that political parties have become marketers, seeking for the biggest group of followers (In 't Veld, 2010). The current political landscape created a situation in which the interest of the own political party could rise above the interest of the country itself. Since the elections are organized every 4 years, politicians are willing to pose a positive impression to the voters. Of course short-term policies are easier to defend towards the followers of a political party when it is compared to sustainability climate contributions that prove their effect perhaps in 28 years. Long-term policies will hardly get a chance, something that could be inherent to our democratic system. On the other hand it could be because of this democratic system that sustainability has been put on the political agenda. Ideas of the minority could, after some years of reflection, reach the majority. . Though besides the political parties and their voters, there are also other forces that have their impact on the political playing field. The so-called 'fourth branch of government', includes the press, interest groups and administrative government agencies (Smith et al. 2006). These could offer opportunities towards sustainable policies.

Different regime

The general right to vote for the elections (general suffrage) was initiated in 1917 to male and in 1919 to female voters. After investigating several infrastructures in the historical analysis it seems that the realization of infrastructures before 1919 were rather straight forward. At least this was the case when stakeholders were convinced of the added value the infrastructure had. The railways, mail services and telegraph services are examples of infrastructures that arose rather uncomplicated. After this period some projects developed pretty joggly. The gas network extension seems to be an exception, an important advantage was in this case the short-term economic advantage that was linked to this project for the government. Think about the realization of the fiber network infrastructure that is developing slowly accompanied with several setbacks (Essers, 2011). An emergence of a newly developed physical infrastructures is scarce in the 20th century, it were especially IT-related infrastructures that were implemented. Physical infrastructural developments that can be mentioned are the Betuwelijn, High Speed Connection(HSL) and the underground connection in Amsterdam (Noord-Zuid-lijn). These projects all faced major problems and resistance from stakeholders and although these are just single projects they are part of an overall infrastructural development. Of course it is not assured that a regime change would have led to a better situation, since side-conditions also changed over time.

European role

As was already mentioned in the empirical analysis, Europe could play a major role to the sustainability policy in The Netherlands. The political landscape in Europe has a middle-long term focus. Consensus between all member states is a time-consuming process. In addition also the directives take a long period before they become operational. These conditions enable the European Commission to focus on the longer term, which could also support the policy on biogas infrastructures. Yet a successful implementation is not guaranteed, as also on European level established powerful stakeholders are active to support the interests of the fossil-based industry. This appeared also in the statement above in which the financial support of mines by the European Union was mentioned.

Established regime

A remarkable notion is that the active taskforce, which are seven in total, are dominated by the established regime instead of the niche players who are active in green- / biogas development. According to Rotmans these taskforces started as horizontally structured organizations, yet due to a 'lust of power and control', more layers were created which caused a vertical organized structure. This binds the niche players and disturbs their degrees of freedom. "The original energy transition taskforces are encapsulated by the established fossil based energy regime. The energy transition is institutionalized, structures are created and it is integrated in the bureaucratic regime" (Rotmans p.2, 2011). Of course Rotmans should be aware that 'the energy transition' cannot develop without interaction with the applicable institutions in The Netherlands. Whether these are advantageous to the energy transition is not sure, but it will certainly guarantee other objectives of general interests. Maybe the prioritizing of these objectives should be reconsidered.

Competive ness green

On the long-term sustainable energy should be a competitive form of energy. The costs of fossil energy seem to increase, besides due to innovation and economies of scale the sustainable energy production becomes more cost-effective. However it will take a long period of time before the difference between both energies will be in the advantage of sustainable energy (Dumont, 2011). This period will depend on lots of factors like, technological development, energy prices, geopolitical developments and energy related policies. Besides the subsidy that is used to stimulate sustainable energy, also the grey energy is subsidized by the European Union. Until 2018 at least 3 billion euros is used to support uneconomical coal mines in Spain, Germany and Romania (Ecofys, 2010). Due to this financial support of conventional energy, the competitive position of green gas is vulnerable. Employment seems to outweigh apparently the chances sustainable energy has currently. Indirectly the current employment is therefore seen as more important than the long-term effects sustainable energy generation will have on our society. Yet as appeared in section 3 the renewable energy sector offers significant potential for employment, therefore renewable energy should be seen as a chance instead of a threat.

Incentives to valley of death

The subsidy program SDE+ was discussed in all parallel research elements. There can be concluded that the current structure for application is focused on cost-effectiveness. In other words, achieve the current sustainability targets within the given time by spending the least amount of money. This is in line with the objectives of our current government. Developments that could have effects on the longer-term, and therefore also contribute to long-term sustainability targets, are not yet supported financially. The application structure of the SDE+ is 'sound', according to the governmental objectives. However we should think about the legitimacy of the current subsidy policy. Our analysis also mentioned the economic advantages a sustainable sector would bring in terms of e.g. employment. Probably this is a reason to re-consider current possibilities to create incentives to the sustainable energy sector. Besides the exploitation subsidy there is a need for incentives to overcome the valley of death that economically unfeasible technologies face before they can become a competitive mature energy producing technology.

6.4 Biogas Infrastructure as a means, or a goal in itself?

After the potential of several biogas infrastructures was explored a lobby started to include the concept of biogas infrastructures in the SDE+ subsidy. The perception is raised that a biogas infrastructure is a cheap solution to accommodate biogas producers in the sales of their gas. This could lead to the situation that biogas infrastructure are seen as a goal instead of a means to accommodate producers. It is not by definition an economically attractive solution, since the widely spread pipeline network is an expensive investment. Every single biogas producer's case needs an independent assessment of the specific situation. There a various alternatives available besides a biogas infrastructure. An example rises when the direct biogas consumer is closely located to the production location. This example occurs in Leeuwarderadeel where the public swimming pool is heated and provided with electricity using a CHP directly connected with a nearby biogas producer (Leeuwarderadeel, 2010). Furthermore a farmer could also be able to use the biogas by themself, in case of CHP generation the effective use of heat is always of importance.

To large scale green gas producers the dependency of biomass supply created economic risks, since biomass producers are not eager to agree on multi-years contracts. The produced biomass of farmers can also be transported to large scale producers by means of transport trucks. When more green gas producers will start in The Netherlands the possibility that the transport distance outweighs the transport emission is getting more likely.

There are numerous alternatives that can contribute to a sustainable energy supply, whether or not a biogas infrastructure would be the best alternative depends on the characteristics of the specific situation. Yet it is important for a successful realization of biogas infrastructures that is considered a means, instead of a goal in itself.

7 Roles within the biogas infrastructure playing field

"Do not worry about holding high position; worry rather about playing your proper role."

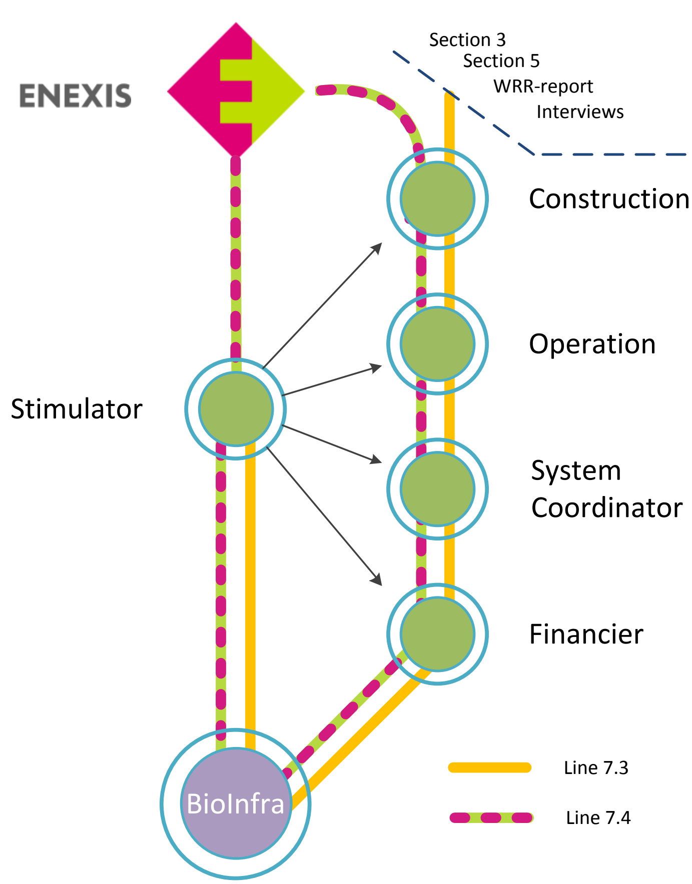
Confucius, Chinese philosopher and political theorist (551-479 BC)

➔ Section 7 will start with a short explanation of the approach used to explore the roles in the biogas infrastructure playing field in 7.1. This is followed by discussing the fundamental choice underlying the eventual roles, whether it will be a private or public oriented organizational model (7.2). Then in 7.3 the roles that should be present are explained. Thereafter a more thorough explanation of the position of DNO, Enexis, will be in section 7.4. Furthermore 7.5 will answer the RQ 5 and 6 on the roles in the playing field.

7.1 Research approach - Roles in the biogas playing field

The approach which is the starting point for this section is visualized in Figure 22. It starts with the input of the analysis. Based on the empirical system description of section 3, combined with additional sources on roles in energy related playing fields (WRR-report (2008), Transition Management (Rotmans, 2004), the Critical System Heuristics (Ulrich, 1983)) and interviews a variety of roles was gathered that could be present in the playing field of biogas infrastructures. By comparing these roles it appeared that a lot of them doubled each other or appeared to have overlap. Therefore a selection of five main groups is identified. The *construction* of the system will accomplish the actual emergence of the biogas infrastructure. When the system is created it will lead to a combination of stakeholders who will take the *operational* roles in the process. Both will need a proper *financier* that enables the stakeholders in building and operating the biogas infrastructure. In addition *coordination* covers developments on a more abstract level of legislation, supervision and vision development. Finally a *stimulator* will activate all roles within the playing field on a successful execution of the eventual biogas

Figure 22 – Approach section 7



infrastructure, for this reason this role is located parallel to the other roles. Now the main roles are identified the roles can be described more in-depth. First a general description will be presented in section 7.3. Thereafter the connection that distribution network operator Enexis has to these roles will be discussed in 7.4. Research questions 5 will be answered in 7.5, while research question 6 is answered in 7.6. But first we will start with an exploration of the fundamental choice underlying the roles, will the organizational model become public or private oriented?

7.2 Organizational concepts within biogas infrastructures

The market mechanism that is embedded within the energy sector is aiming for an increase in consumer choice, quality of services, optimal tariffs and equal access to all (De Vries et al., 2010). The recent unbundling led in most cases to a consumer advantage (WRR, 2008). However these advantages were all short-term effects. The long-term values as sustainability, innovation, maintenance and reliability shifted during the period of unbundling to the background. It is a challenge to create institutional arrangements that can realize both, short-term and long term values (WRR, 2008). The biogas infrastructures are currently lacking such institutional arrangements. This due to the fact the infrastructure is still in development and organizational concepts are not yet defined or crystallized. During the initializing phase some roles are already occupied but there are still uncertainties about who will fulfill which role in the final situation. Of course there are numerous ideas about the possible organizational designs, which were also discussed with prof. Wempe during an interview, the two mainstream solutions are discussed in this section.

Private focus

The first possibility is to concentrate the organization of the biogas infrastructure in the market. Farmers have a judicial interest in a mineral neutral business and a prudential interest in digesting biomass to biogas. These interests can meet the commercial interest of energy retailers, like Essent. Market parties will have the lead, additionally the national government, with the ministry of Economic Affairs in particular, will fulfill a supportive role. This support could for example manifest itself in permitting, licensing or by purchasing the green gas. However this 'market-steered' situation could cause some risks. A long depreciation period could make it unattractive to private stakeholders to unroll the infrastructure on a large scale. Profitability is of more importance than the facilitation of biogas producers throughout the country and the stimulus of renewable energy. Furthermore private ownership of gas transport is undesirable from a safety perspective. The ownership causes a dilemma versus quality and profit. It is questionable whether or not the choice of pipeline material and gas related installations should be driven by profitability or a public value like safety. Long depreciation times and a natural monopoly create an incentive for the infrastructure holder to invest to maintain the profitability of their operations over time. However, that incentive is potentially insufficient to guarantee long term public values (WRR, 2008). Another risk that could arise under private stakeholders relates to local monopolies. When one developer realizes the gas infrastructure, farmers will be urged to use his specific services because there is only one infrastructure available. This could lead to market imperfections.

Public focus

The second possibility for an organizing model of biogas infrastructure will be concentrated within public authorities. These include among others the Ministries of Economic Affairs, provinces, the local municipalities and the distribution network operators. The distribution network operators would get responsibility for the transport and distribution. These operators have expertise on this scale and they will be able to plan, realize and maintain the physical components of a biogas infrastructure. Yet these activities could only be performed by the commercial sister companies that are directly related to the distribution network operator. In this case no pre-set tariffs are applied per connection, which does not guarantee compensation (Wempe, 2011).

Of course also hybrid solutions could be designed, the discussed possibilities are just the two most feasible extremes considering private or public leadership. In the next session it becomes clear that both possibilities, public and private, are currently proposed and partly developed.

7.3 Roles in the biogas playing field

The identified roles are investigated by tracing the following: who is fulfilling this role currently and who should fulfill this role during the transition to a period in which biogas infrastructure realization is able. The current roles are identified by interviews and by observing the pilot projects of Salland and BioNOF, which are the two main pilot projects of biogas infrastructures in The Netherlands. The diagram below will be used as a summarizing tool for each role description.

7.3.1 Construction role

The construction role is directly connected to the physical emergence of the biogas infrastructure. To achieve an implementation, involvement of three types of specializations is essential: knowledge of the technology, implementation skills and leading instructions. In terms of specific roles these specializations can be translated to three specific roles: the professional, the construction facilitator and the project leader.

The professional needs to cover the specific knowledge field of biogas infrastructure technology. This involves understanding of the system components like, the pipelines, the biogas production facility, and institutional know-how on the subject of safety requirements, construction permits, environmental law and contracts (e.g. property rights). This professional needs to communicate this specific knowledge to the more practical oriented executors of the construction project.

The executors of the infrastructure's construction are the construction facilitators. They will take care for the implementation of the technological foundations of the system. Certified personnel and experience on gas related infrastructures will be necessary to the construction facilitator.

Within the construction role there is a need for a leader in the project. An entity who is able to take decisions and has authority in a legislative and monetary environment. The project leader will also give direction to the organizational model as discussed in the previous section. Will it be more public or private orientated?

Construction –Project Leader

The construction roles seems to be more or less fulfilled. Yet differences can be recognized between Dutch biogas infrastructure pilot projects. This is specifically the case for the leader role. At BioNOF it was for example a private oriented entity who took the lead. It was Essent who is one of the initiators of the BioNOF project, supported by distribution network operators Enexis and Stedin. The energy producer believes in a future solid business case and is eager to become the first player on this market in order to be involved in future projects (Dumont, 2011). The initiation of the BioNOF project has been arranged before the unbundling of the energy sector started in 2008. At that moment Essent had public shareholders (Van Dam, 2011). It is of importance to consider this regime change since from that moment the profitability has become the major objective to Essent. Considerations on the sustainability of our energy supply or environment could have got more attention under the public ownership. It is questionable whether or not Essent would invest again under their private shareholders. According to the project leader of the BioNOF project also Eneco would be interested to become project owner (Van Gorkum, 2011). This means that private stakeholders are willing to participate also without public stakeholders, yet Eneco did not start such a project.

Another organizational model arises in Salland where the focus is on public organizations. Here the leading role is fulfilled by Enexis, ROVA (waste processor) and Gasunie. Furthermore municipalities, province and Saxion (knowledge institute) are strongly involved (Wempe, 2011). This pilot project is not as far developed compared to BioNOF, but it is remarkable that no private entity is involved. This can be due to the fact that they are still in an explorative phase.

The project leader in biogas infrastructure can be public or private. Yet no private entity has started a biogas infrastructure, Essent more or less came into the project as a spin-off from their former public shareholders. The main dilemma to the project leader role is therefore still whether or not this role is better fulfilled by a private or public entity.

Construction – Professional

Produced biogas is a mixage of gasses with combustible (mainly caused by CH_4) and toxic characteristics (H_2S), this causes safety risks to personnel and the direct surrounding of a production facility (Heezen et al., 2010). It is clear that a biogas infrastructure construction needs to involve specific know-how in the process. However a biogas infrastructure on the supposed scale is not yet realized in The Netherlands, the size of the project (BioNOF aims on 34 km of pipelines) can be compared to a medium sized city grid. The distribution network operator is responsible for the planning, management and maintenance of these local grids. This expertise will be useful in biogas infrastructural projects. While technological expertise is available, expertise on the economic or regulative aspects is not. Knowledge on permits, arrangements covering property rights, gas related legislation, monetary flows and contractual agreements is also of importance. This role is not successfully fulfilled in the current situation. Since the biogas infrastructure is a new specific structure that not yet exists under the Dutch regulatory regime and market there is no established specialist available. Therefore these can be explored in co-development with public and private stakeholders. Obvious stakeholders that should participate are the legislator (Ministry of Economic Affairs, Agriculture and Innovation, Ministry of Housing, Spatial Planning and the Environment), the producers (farmers, energy producing companies) and the DNO. A solution that could intertwine interests of involved stakeholders is to assign project engineering companies. Examples are E-kwadraat (involved in BioNOF) and Witteveen+Bos (involved in Salland). Their experience on project execution of technological innovative projects could contribute to the biogas infrastructure project.

Professionals on gas related systems are widely available in The Netherlands, yet these mainly focus on the technical aspects, as for example the DNO does. The lack of institutional arrangements can be overcome by a co-development of stakeholders. A project engineering company could function as catalyst and bring the participating stakeholders together.

Construction – Facilitator

For the actual execution of the construction practical-oriented stakeholders will be needed. These should be able to implement the physical system components. Biogas production facilities and biogas upgrading facilities are both specialized technologies that usually are installed by the manufacturers of the facilities (such as BioGast). The construction of the pipeline network can be executed by a private construction company. Due to the fact that biogas is not included in the Gas Act, the public owned DNO itself is not automatically appointed to execute these activities. Yet sister companies of the DNO can be used since they have expertise on the construction of distribution networks. But since these activities are indicated as commercial they can function only when the resources allow this, or when other stakeholders compensate these investments. In the case of Enexis the company tries to "facilitate the energy transition". In that perspective these activities are close to the company values (Enexis, 2008).

The actual execution of the biogas infrastructure construction can be performed by the construction companies or sister companies of the DNO. Also in the case the DNO is executing the project sufficient amount of money needs to be available since the costs will not be socialized as is the case for natural gas infrastructures.

7.3.2 Operational role

After the physical and institutional accomplishment of the biogas infrastructure the operation of the system will start. This will be an ongoing process as appeared in the technological analysis the biogas production is less flexible compared to the current natural gas production out of the Groningen field. To successfully achieve the operation activities on several levels needs to be executed. First of all there is a need for farmers on the basic production level of raw material, furthermore an operator is needed for the infrastructure itself.

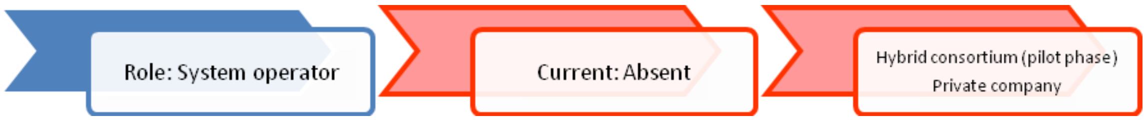
Operation - Farmers

To the biogas infrastructure the performance of the farmers is essential. Without their production volume the economic viability of the infrastructure could be insufficient. As appeared in the strategic analysis the gathering of raw material could be a logistical challenge, however in case of the farmers the raw material is usually produced at their own site therefore this challenge is taken away. To achieve an economic feasible situation the farmer's collaboration is needed. To ensure this a contractual obligation could be arranged to make him produce in favor of the biogas infrastructure. In this way they will not have the possibility to individually generate electricity by means of a CHP, when the electricity price rises above the gas price. This takes away the competitive tension between gas and electricity which could be advantageous to the infrastructural development as appeared in section 4. For the short-term contractual arrangements would improve the economic viability of an biogas infrastructure. Therefore it is logical that this is used during a pilot phase.

The farmers will operate the starting points of the biogas infrastructures. Though to ensure their collaboration for a longer period, contractual arrangements should be agreed on which obliges them to produce in favor of the biogas infrastructure.

Operation – System operator

The system operator will be responsible for the core of the system. This involves the biogas gathering process from surrounding producers and the upgrading process to green gas. It would be a logical choice when this exploitation is executed by one single stakeholder. The exploitation of the biogas gathering process only adds value when it is coupled to the upgrading process. Therefore it is of importance that both are included in the responsibilities of a single stakeholder. This is preferably a market orientated stakeholder, since this entity also will be concerned with the trade of the gas. When the objective is profit-driven, cost reduction could lead to a feasible business case. Especially in the pilot phase, but also in the eventual organizational structure a hybrid consortium could be feasible. In that case the emphasis is more on the safety and future opportunities of the biogas infrastructure. With a hybrid construction the effectiveness of the market mechanism can be combined with the assurance that no monopolized market power will rise. Furthermore the pilot environment of the infrastructure can be used to explore future applications of the technology.



The system operator is not appointed yet. Due to the fact that the system operator will be involved in market processes a private entity is the most suitable choice. Though this role could also be fulfilled by a hybrid consortium during the pilot phase. This will create the opportunity to safeguard public values on safety and also explore future possibilities of this sustainable energy application.

7.3.3 Financier

The previous discussed roles, construction and operation, both will need financial compensation for their activities. For the operations this will be majorly generated by the revenues on green gas. These will be paid by industries that purchase the gas directly from the biogas infrastructure or to shippers who will sell the gas to users connected to the gas network. In this section two kind of financiers will be discussed. First of all the financier that is limited to the pilot phase of the biogas infrastructures. The second kind of financier is more focused on the long-term, this role is more decisive to the project. As appeared from the analysis of section 3, the desired financier, and therefore the eventual decision-maker in future projects are the energy producing companies. In the current situation this role is majorly left to public entities.

Financier – Pilot phase

The biogas infrastructure has an additional objective when it is classified as pilot. Research and development of this new concept could stimulate future development of biogas infrastructure (as also appeared in historical infrastructures). Research and development is often performed by commercial entities, though it is also considered part of the government's responsibility. Policy measures, like subsidies, education and investments in research and development could have major implications to the economy in the long term. This concept is known as the "endogenous growth theory" (Malerba et al., 2007). In addition to this theory Guellec and Ralle (1995) identified two situations that require the government to act:

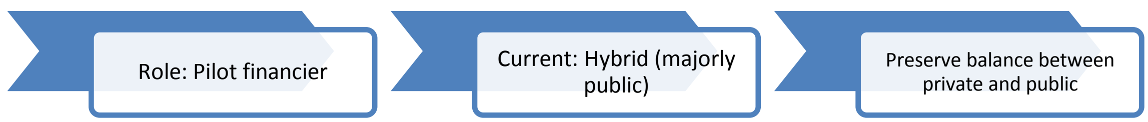
1) " The government should manage externalities that are created by the three factors of accumulation, i.e. physical, technological and human capital; *it must fund basic research* and create conditions in which intellectual property rights will be observed in respect of applied research; *where none exists, it may create markets or other institutions enabling private players to co-ordinate their decisions;* but the way in which governments act will depend on the specific exogenous measures to be managed. So no ready-made formulae for the areas of research are available

2) The state may provide public goods to help improve private productivity; numerous studies point to *the positive effects of infrastructure investments on growth*, but questions of the marginal efficacy of public investment and relationships between rates of taxation and private behavior are not solved." (Malerba et al., 2007, p. 476)

A third perspective (Callon, 1994) suggests that aid to basic research should be justified as an investment that allows technical and economic networks to be renewed. In that case the main objective is the promotion of diversity, by setting out new networks and in the range of the scientific options that are open to companies. This will create jobs and deliver specific expertise. Still there is a need for conscious investments. Hekkert et al. suggests limiting the number of options to allow for enough resources per option (Hekkert, et al., 2007). This also applies to the funding of biogas infrastructures. It should be compared with other sustainable energy projects. Based on the available alternatives the most promising technology will be given the chance to flourish, the potential cost-effectiveness is a key . In the case of biogas this is done by the Ministry of Economic Affairs, Agriculture and Innovation. They composed a top 3 of most promising technologies in renewable energy generation. These are wind-energy on land, biomass and green gas (Dumont, 2011). Since green gas is included in the top 3 projects are for example allowed to apply on SDE+ subsidy. This subsidy program SDE+ compensates the difference of cost price and market price. Although this supports the generation of sustainable energy, it does not stimulate the emergence of innovative technologies that will need some space for further development.

The WNF and Roland Berger criticize the way the Dutch government is investing in renewable energy sources. However the investments in research and development are relatively high compared to other countries, higher sales of a sustainable technology is not accomplished. Individual technologies are not supported consistently over the life cycle of the product. A significant investment is made for example in the R&D while there is a lack of support for demonstration and market development purposes (WNF, et al., 2009).

In the current situation only Essent is involved in a pilot phase as a private investor. Other private involved parties are generating revenues in the pilot project. In this case it are majorly public owned organizations as the DNO, ROVA or Gasunie who contribute by means of financial investments. These cover indirectly the governmental responsibility of supporting development.



Since a pilot can be considered part of research and development related to sustainable energy technologies, besides private entities also governmental support is acceptable. Yet in order to bring the technology to the market eventually, the role of market parties needs to be maintained as well. A balance between private and public needs to be achieved.

Financier - General infrastructure

Infrastructural projects are bound to high initial investment costs. As a consequence the depreciation period of networks is usually longer compared to conventional investments. The depreciation period approaches 40 years, compared to 12 years in case of normal investments in the private sector (Wempe, 2011). This creates problems to the involvement of private investors. In addition the expectation that biogas will be included in the Gas Act increases uncertainty. The inclusion of biogas in the Gas Act will make the involvement of the distribution network operator easier, since they can be compensated by regulated tariffs in exchange for their services. On the other hand this discourages private investors. An example can be found in relation to the Warmtewet (Heat Act), which is currently under discussion in Parliament. This act prescribes a maximum threshold of 7% return on heat network investment, this is the regulated pre-determined threshold. Essent as a commercial entity applies an internal minimal threshold of 11% return on investments (Wempe, 2011). Due to this discrepancy the profit forecast of the project is insufficient to the private entity to participate.

This again leaves space to public organizations that are often considered important in order to gain financial funds to sustainable transition projects. Public action can be justified in case an individual market is unable to accept the risk of intangible investment and to take a collective and long-term view. The right and need of a government in remedying this situation using public funding is, however tacitly, acknowledged. At the same time it is recognized that the risk on 'government failure' is not greater than that of 'market failure' (Malerba et al., 2007). So apparently the damage on the collective is considered less harmful compared to damage on a specific stakeholder in the energy sector. These companies are essential in maintaining reliable infrastructures. E.g. the function of distribution system operators and energy producers are essential in the energy system. On the other hand the question is, what is in the name? When the organization or institute will disappear this can be intercepted by peers who fulfill the same function, in case of the energy supplier this is even arranged by law. The distribution network operators need to arrange an emergency supplier to a customer in case of an energy supplier's bankruptcy (Electricity Act, 1998). It is very unlikely that a distribution network operator will go bankrupt, especially since their shareholders are provinces and municipalities. As Malerba already announced it is preferably to socialize the costs of an unprofitable investment in biogas infrastructures among tax payers, instead of harming a single company. Though a thorough investigation of the gains of such an infrastructure is required, in this case the Energiekamer will make this consideration.

A well-functioning system of biogas infrastructures needs a proper investor. This was already suggested as positive influencing condition of infrastructures in section 4. Furthermore according to the interview with Agentschap NL, the government does not take this role and assigns it to private entities.

For the long-term the presence of private investors is essential, yet these are not present currently. In case the added value to society is clear the costs could also be socialized and compensated by public organizations.

7.3.4 System Coordination

In the previous sections the financial and more practical oriented roles are discussed. These comprise mostly to the micro level of the transition. The coordination role is more focused on the meso (and macro) level, as defined in section 5. It involves the function of legislator, who is able to define rules and regimes, furthermore it involves the compliance of this legislation by means of check & control.

System coordination – Legislator

Green gas is acknowledged in the Gas Act, while this is not the case for biogas. As appeared in the empirical analysis and the historical analogies, there is a need for a legislative framework for biogas. This will have a financial advantage due to the fact that regulated tariffs will be introduced. This creates the opportunity to divide investments over a longer depreciation period, which can make the business case more feasible. Furthermore this contributes to the safety requirements since in the current situation every construction company can realize a biogas pipeline, the Gas Act creates constrains and obliges the construction and maintenance of pipelines to be the responsibility of the DNO. In the current situation the playing field is more or less waiting for the Ministry of Economic Affairs, Agriculture and Innovation to act. They are expected to include biogas in the Gas Act, therefore current investments are relative expensive since the same investment one year later could probably be socialized. The Ministry will be the most obvious stakeholder to fulfill this role. European platforms and initiatives have been setup to produce robust strategies, with the aim of facilitating major system innovations (WRR, 2008). These platforms form the basis of our current sustainability policies, since the directives that are approved in the European Parliament urge the national legislators to translate them in short-term legislation. Examples of European platforms related to green- and biogas are the European Renewable Energy Council (EREC) or the European Biomass Association (AEBIOM) (Euractiv, 2010).

A government that prescribes actions and takes an urging role is an old-fashioned concept. The welfare state is created by a hierarchical top-down management. Economic and social values were ensured by the government, but since the market mechanism became popular the role of the government became modest. The market mechanism appears to need arrangements and preconditions designed by the government. This brought the current believe that a well-functioning government is a precondition for a market mechanism (Geelhoed, 2001). Inherent to the unbundling was the separation of institutional and operational functions in the sector, which made the industry no longer able to dictate the regulatory system aspects, whereas the national policy became unable to dictate the operational system aspects (WRR, 2008). If the main societal players do not accept new policies, it will be extremely difficult to implement them (De Bruijn et al., 2008). The transition management theory, which was discussed in section 5 indicates that especially the private sector should take initiative to develop long-term vision. Effective communication with stakeholders, that are willing to generate progress towards economic prosperity, social justice and environmental quality, is a decisive characteristic of corporate responsibility. Companies will need a proper balance between people, planet and profit (Elkington, 1998). When the legislator role is performed pro-actively by the ministry, also the industry and societal stakeholders could contribute to the policy design process. Yet one should be aware that this involvement should probably slow down the process.

The legislating role is performed on the long-term by European platforms on sustainable energy, while the short-term is performed by the Ministry of Economic Affairs. Unfortunately the achievement of this short-term appears to lacks decisiveness. Together with involved stakeholders the needed regulatory arrangements needs to be discussed. This creates clarity in the playing field of biogas infrastructures.

System coordination – Check & Control

Network monitoring can be fulfilled in several ways. In Australia a national network monitor is introduced. The organization is equipped with technical expertise and resources to identify major maintenance and investment requirements. Since they are independent from politics or industry, they are not driven by political opportunism. Furthermore broader interests are reflected in network planning and monitoring (WRR, 2008). The introduction of an external monitor may be useful in order to ensure that the often hybrid stakeholders are guided by multiple longer-term incentives in the public interest, instead of mainly short-term commercial goals. In the current Dutch gas network the DNO is responsible for the maintenance and investments in their network. By means of a financial benchmark mechanism the performance of a DNO will be compared to other DNO's performance. For biogas the DNO's responsibilities will only be the case when it will be included in the Gas Act.

From a legislative perspective the monitoring role should be fulfilled by the minister of Economic Affairs, Agriculture and Innovation. He should ensure that national policy strategies for major infrastructure development are drawn up and revised at regular intervals (WRR, 2008). However it is questionable whether or not the biogas infrastructure can be appointed as a major infrastructure development. Probably the answer is: not yet. Stakeholders currently mention the dilemma of unregulated biogas activities and the willingness to invest in sustainable energy supply. This attitude of involved stakeholders should be proactive, by appointing points of improvement function as sensors to the legislator. Another reason that shows the importance of sequential monitoring on the regulatory framework is the fact that stakeholders are seeking for legislative loopholes from which they can benefit. Take for example the case of biogas producers that switch their production from gas production to electricity generation, based on the present electricity or gas prices (see also the historical analogies of section 4). The WRR argues furthermore that a structured link between regulator and ministries will help to increase policy stability and coherence. It will lead to a joint vision, not just by state actors, but by all stakeholders that are relevant regarding investments in infrastructures (WRR, 2008). This again touches the recommendation of section's four historical analogies to formulate a clear governmental objective.

As a consequence of the regulatory uncertainty there is no stakeholder appointed for check and control responsibilities. Anticipating on the future situation in which the Gas Act includes biogas, the DNO will be responsible for the operational part while the NMa will take care for the legislation. Especially during the emerging phase it is important to sequentially revise policies to ensure they fit the needs of involved stakeholders.

7.3.5 Stimulating Role

To start the emergence of a biogas infrastructure and to keep this process going, there is a need for stimulating stakeholders. These stakeholders can activate the process and put the playing field in motion.

Innovation Stimulator

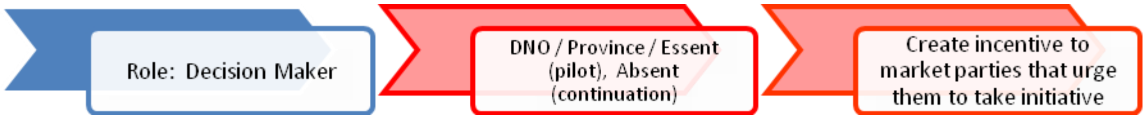
The current biogas projects that started in The Netherlands had a basis of support among several stakeholders. This fact is not attributable to one specific stakeholder. Due to the Platform New Gas, the taskforce Green Gas was initiated in 2006, and offered a structured way of discussion between public and private stakeholders. Actually it was the government (Ministry of Economic Affairs, Agentschap NL) that created an environment where innovation could arise. They stimulated innovative stakeholders to gather and exchange information. Knowledge was shared and minor ideas grew out to concrete plans, like BioNOF and Salland. This concept is closely related to the gathering of available support which appeared to be a condition within the historical analogies of section 4.

When a group of firms is active in developing sector's products and in generating and utilizing sector's technology they will go in interaction and cooperate in the development of their technology. Processes of competition, selection in innovative and market activities will generate a process of sectoral systems innovation (Malerba,2004). So it is actually the interaction between and within a sector that will make innovation possible to a certain extent. This will offer more efficient technology and smart and integrated applications. As was explained in section 5 the intermediary is operating in between these different arenas. Engineering and consultancy firms like Witteveen+Bos can fulfill this coordinating role here. The intermediary could well prove pivotal for the development of a robust sectoral strategy (WRR, 2008). Since financial and human resources are necessary as a basic input to innovation systems (Chappin, 2011), the innovator needs to cooperate with other stakeholders in the playing field. These could be used for additional resources. When he wants to succeed it is for the innovator of main importance to create legitimacy and minimize the resistance to change (Hekkert, et al., 2007). In the current situation there are no clear responsibilities considering knowledge sharing.

The innovator role was initially taken by the Platform Groen Gas, who brought together supporting stakeholders. Now the initial phase is completed the project engineers and DNO can fulfill the role to share knowledge in order to intensify innovation. Currently there are no clear responsibilities about this knowledge sharing.

Stimulating – Decision maker

Who will take the decision whether or not to realize a biogas infrastructure? That would be the decision-makers role. It appeared during the interviews that there exists a discrepancy between the different views here. From the empirical analyses it appeared that the (future) society is the actual 'client' of the system. Their interests are safeguarded by the government. But they do not feel the realization of the biogas infrastructure as their responsibility as the Ministry of Economic Affairs argued, "the government wants to leave the realization of biogas infrastructures to the market parties" (Dumont, 2011). On the other hand it appears that market parties are reluctant, mainly due to economic reasons, this result in slow progression of biogas infrastructures emergence. As discussed in section 3 the proposal to oblige producers to reach a certain share of renewable energy can make energy producers more creative in achieving this. Anyhow there is currently no powerful stakeholder in the biogas playing field available that appoints the responsibility of a successful biogas infrastructure to themselves. However the energy producing companies are probably the most powerful because of their available resources, when they are not urged to handle in a pro-active way they will not take the initiative.



The entity that decides for the project to proceed is defined for the pilots. Both private and public entities have taken this role. Yet for future projects the Ministry of Economic Affairs appointed private parties to claim this role. However these entities seem to face a lack of incentives to invest in biogas infrastructural development.

7.4 Role of distribution network operator – Enexis

The current role of distribution network operators in the field of biogas infrastructures is functionally focused. However their role is still in development as is also the playing field itself. In this section we will explore the possibilities for distribution network operators, like Enexis, in the playing field on biogas infrastructures.

It is desirable when a specific role to a stakeholder is appointed, their objectives, instruments and competences strengthen this role. The company values that are presented in figure 22 form the basis to Enexis' objectives. Additionally Enexis formulated a specific objective to itself: facilitate the energy transition. The transition pathway towards sustainable energy generation is pre-eminently applicable on the biogas infrastructures (as appeared already in section 5). Therefore a pro-active participation of Enexis in projects related to biogas infrastructure is legitimate.

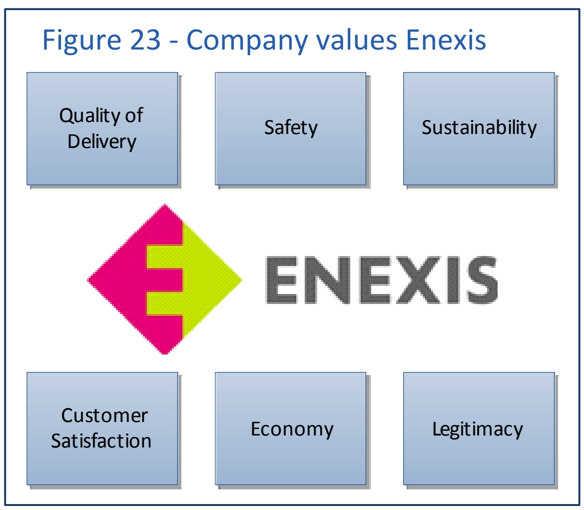


Figure 23 - Company values Enexis

Considering the instruments that Enexis has available (see Appendix 3) it appears that the distribution network operator functions as a hub in the energy sector. Not only in their physical role as distribution operator but also because of their extensive contacts within academia (Universities of Technology in Delft, Eindhoven and Twente, Saxion, etc.), research institutes (KEMA, Kiwa, TNO, etc.) and governmental organizations (Ministry of Economic Affairs, Agentschap NL, etc.). Due to their neutral role also market parties are likely to cooperate with Enexis. Yet there is a chance that newcomers in the energy market are suspicious towards the operator. However Enexis may fulfill a neutral role, they are part of the establishment of the Dutch energy sector and could therefore be experienced as a rather static organization. Furthermore due to different objectives the priorities of market parties and Enexis could differ.

Enexis regarding the Construction role

The current position of Enexis has a rather functional focus. Due to the fact that the DNO has comparable natural gas infrastructures in ownership the technological expertise has added value to especially the construction role of the biogas infrastructure.

The implementation of the biogas infrastructure and necessary connections with the distribution or transmission network are key for a successful gathering hub. Within these sub elements of the system the expertise of the distribution network operator is present. The role of ***technological professional*** is therefore obvious to the DNO. Yet the biogas and green gas production is also accompanied by new technologies and therefore technological risks arise, as was mentioned in section 3. Supported by specialized engineering companies and possible some knowledge institutes a thorough understanding of the system can be achieved. This will contribute to a successful realization of the infrastructure, an advantageous condition in case of emerging infrastructures as appeared in section 4.

Besides the role of technological professional, Enexis is also involved in the implementation of the pipelines and production facilities itself. In this perspective they participate in the physical ***facilitation*** of the infrastructure.

Due to the fact that Enexis technological competences are highly developed they are involved in fairly all subcomponents of the system. As technological professional the distribution network operator is able to understand subsystems, interfaces and the system as a whole. Especially in the emerging phases all kind of activities influences the system in a high tempo, which makes the system understanding highly evident to the process. Since Enexis is able to develop a system understanding of the biogas infrastructure system the company is driven to fulfill a project leading role in the construction. Within pilot projects the fact that public organizations take the lead can be required, as appeared in 6.2 the public funding of basic research is needed to stimulate innovation. The innovation should be initiated from both, a financial and an operational matter, when market conditions do not make the market to do it (Guellac and Ralle, 1995). However considering the further development of biogas infrastructures Enexis needs to reflect on itself whether or not they should take the lead in the construction of biogas infrastructural projects. A distribution network operator should consider the most optimal solution to a specific situation. In case of biogas infrastructure, this is only the case when the volumes are high, the local producers are geographically concentrated and no demand is available in the direct neighborhood. This situation occurs in North-Eastern part of Friesland, since this is a low-density area.

Maybe the company values of Enexis have a mismatch with these future projects that will be focused on profitable energy production. Do the characteristics that distribution network operators have fit on the characteristics that a leading role requires anyway? The DNO is owned by public organizations, majorly provinces. Since the Ministry of Economic Affairs frames the current policy as an incentive to the market to take initiative, it is questionable whether or not other public organizations should act in line with these policies. A proactive attitude of the DNO could facilitate the energy transition, however this could disturb incentives that stimulate market mechanisms and create efficiency. As the Minister of Economic Affairs mentions in a memorandum on commercial activities of distributed network operators, there needs to be a possibility for the DNO to realize synergy advantages with comparable activities. In this case the biogas infrastructure seems to be a comparable infrastructure. The minister argues that it is the responsibility of the DNO to explore and identify the chances and realize them (Minister of Economic Affairs, 2006). Though for a real effective change the private sector is needed since the upgraded gas also needs to be adapted by the market.

Enexis regarding the Operational role

To reduce uncertainties in the organizational model of the gas hubs, the ownership of system elements should be arranged on short-term. The distribution network operator seems to be the logical entity to support the system operator in the maintenance of the biogas grid and the connections to the distribution network. This is especially the case with respect to public values as safety and network reliability. The actual role of a system operator is more suitably to a market oriented company. He will act as a producer on the market, trading its end-product. The unbundling of the energy market has split the production and the transport/distribution of energy. The biogas infrastructure could be seen as a stand-alone energy producing system, therefore the exploitation of the system would not fit the profile of the DNO, since this is not permitted by the Gas Act. Furthermore a market-oriented production will benefit from efficiency in production processes, while by trading upon a commercial market with enough suppliers the affordability will also be influenced positively. Currently Essent is project owner of the BioNOF project and will fulfill the role of system operator.

Enexis regarding the Financier role

New technologies that have potential in generating renewable energy is effected with the, so-called 'valley of death'. In which the step from niche toward a fully commercialized production is progressing slowly, due to a limit market (Martin, 2010). To expand these projects with a longer depreciation time there is a shortage of venture capital (RLI, 2011). Due to the fact the market parties are not yet stimulated to fully invest in biogas infrastructures and since there is a believe that green gas production could contribute to a sustainable energy supply in The Netherlands, an investment incentive is created to the government (Malerba et al., 2007). Enexis with its public shareholders could function as investment possibility in the pilots. They could facilitate the innovational process in order to bring the innovative technology to a solid market condition in the future. There is a need for legitimacy in spending a significant amount of money to the project, so it is important to consider the potential of biogas infrastructures in the future.

Enexis regarding the System Coordination Role

In terms of *check & control*, Enexis is used to continuously monitor and check its network and perform a preventive replacement strategy. This will also be applied when a biogas infrastructure is under their maintenance responsibility. Furthermore the DNO can function as legislative sensor in the playing field. However it is the minister's responsibility to ensure their policy is in line with the current situation. A publicly involved entity as the DNO can easily fulfill a pro-active observing role within the stakeholder playing field.

In the empirical analysis it was already argued that European Directives usually form the basis of our national sustainability policies. Yet the interpretation and translation to national legislation as for example the Gas Act occurs on a national level. Distribution network operators have, unlike the energy producing companies, the right to propose legislative changes to the NMa (Straver, 2011). Using this right the DNO can participate in a *legislative co-development* on a national scale and create a fruitful legislative framework for biogas infrastructures. However it would be positive to the emergence of biogas infrastructures when biogas would be included in the Gas Act, not all distribution network operators desire this legislative reform. Since not all DNO's are experienced with the realization of biogas infrastructures an obligation to implement infrastructures cannot be defined.

Enexis regarding the Stimulator Role

As was mentioned by Ronald Eenkhoorn the most decisive criteria to involve stakeholders in the Salland project is enthusiasm of persons themselves. This would be even more important than the core tasks of the organization to whom they are employed (Eenkhoorn,2011). The fact that Enexis has appointed enthusiast people to the subject of green and biogas is therefore an opportunity to this organization and to biogas and green gas in general. Due to their extensive contacts within the energy sector, Enexis could facilitate the role of ***innovation stimulator***. By creating the sectoral systems innovation, interaction and cooperation between active firms will lead to further development of their technology. Enexis should be part of the interaction within and between involved sectors. This role can be compared to the intermediary function from the transition management theory (section 5.3). Here it is also important that this role is taken by a stakeholder that is involved by both, technological and organizational issues, which is the case for Enexis. Distribution network operators are able to invest human resources in promising innovative projects, which is a basic input to the development of innovation systems (Chappin, 2011). An important precondition to this role is the legitimacy that needs to be created. Other stakeholders need to accept the input of Enexis and respect their role.

A general notion that accounts for the current roles compared to the desired situation is the reactive attitude of most stakeholders. In the desired situation this should shift towards a pro-active attitude. Mainly due to financially and organizational uncertainties the sense of urgency is lacking in the process, which led to postponed decisions and causes delays in the projects (Eenkhoorn, 2011). The biogas projects are to most stakeholders just an additional activity with low priority. A shift to a more pro-active attitude will benefit to the projects and to biogas infrastructures in general.

Reflection on Enexis' role

The current activities of Enexis relating to biogas infrastructures are in the commercial domain. Because biogas is not yet defined as gas in perspective of the Gas Act, no regulated tariffs are set to the distribution network operators. When the budgets are not too extensive these activities can be executed as innovative activities within the own organization. However when the budgets are becoming substantial the activities need to be moved towards a sister company. It is questionable whether or not a public owned company is suitable for commercial activities. Within the organization the processes and the corporate culture are focused on the regulated market, where the public values of a reliable, affordable an safe energy supply are main objectives. An example is their extensive preventive replacement strategy to their assets. Processes which are highly recommended to serve the public values, but will could negative influence short-term efficiency results. Yet the link is present from a content-wise perspective. The pipelines, network pressure, safety requirements and process knowledge are available to the distribution network operators. In this perspective the activities are closely related to their core-business.

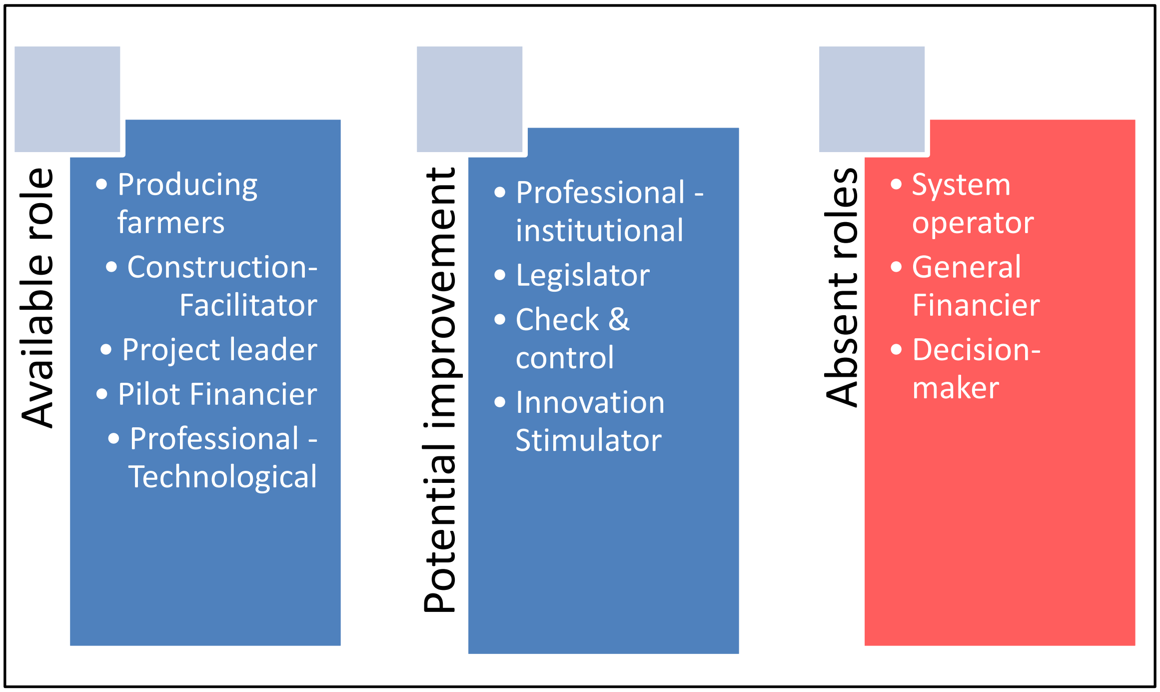
In addition Enexis can be considered an extension of the government. Public funding can be justified to sustainable energy projects like biogas infrastructures, when they are in the research and development phase. In this perspective the investments can be seen as a disguised subsidy. Yet Enexis should limit themselves to these pilots. After several pilots have reached an operational phase the private stakeholders should take the initiative. Depth investment should not come from Enexis anymore. When biogas infrastructures in the coming years cannot transcend the status of pilot technology, it is apparently no cost-effective way of generating energy. And maybe then it will appear that biogas infrastructures were a goal as such, instead of a means to generate sustainable energy in a more effective way.

7.5 Research question 5

This section focused on obtaining an answer to the fifth research question:

- Which roles are (not yet) defined within the Dutch biogas playing field?

Biogas infrastructures are currently in a development phase. As appeared from the socio-technical system a wide variety of stakeholders is involved in this process. In this section the roles possible roles were explained based on among others the WRR report, Transition Management and the Critical System Heuristics. Due to the transition to other phases of the process over time, roles cannot be appointed to a certain stakeholder in particular. Roles can switch between stakeholders. In addition also the possibility that more stakeholders fulfill one specific role is present.



Considering the current situation the shortcomings especially arise at the meso level: actually the design of the specific environment in which biogas infrastructures should emerge. The practical oriented micro level roles are somewhat fulfilled. These comprise the producing farmers and roles related to the construction of the biogas infrastructure; the facilitator of upgrading facilities and biogas production facilities, furthermore the DNO who is able to construct the pipeline network and the project leader that can plan the project and involve contractors. Also the funding to the pilot project, at least in Friesland is accomplished. Now let us consider the meso level. While the knowledge on the technical system is widely available due to the presence of the DNO, the expertise on the institutional characteristics is lacking. This seems to create the largest problems to the biogas infrastructures. Since no pro-active legislator is available no regulated status of biogas is defined. This directly effects the status of the check & control of the biogas infrastructures, as is the case by natural gas the network owner is not incentivized to increase its network performance. The unregulated status of biogas also causes a lack of financiers for future biogas infrastructures (after pilot projects). The absence of an earning structure causes an overall uncertainty among stakeholders. Also no system operator is appointed who can manage the operational infrastructure. The advantages and disadvantages to this role are not yet clarified. As the Ministry of Economic Affairs and private parties do not agree on the initiating role of biogas infrastructures, there is no decision-maker that is sufficiently powerful and can activate the other roles in the playing field. Finally the Platform Green Gas appeared to be successful in the pilot phase as innovation stimulator by bringing the stakeholders together and lobbied for funding. However innovation could be stimulated also in the continuation of the project, which is not achieved sufficiently.

How the roles should be fulfilled in the playing field and especially by whom, also depends on the fundamental choice to a public or private focused organizational model. Also a hybrid organizational model belongs to the opportunities.

A general notion that accounts for the current roles compared to the desired situation is the reactive attitude of most stakeholders. This needs to shift towards a pro-active attitude. Mainly due to financially and organizational uncertainties the sense of urgency is lacking in the process, which led to postponed decisions and causes delays in the projects (Eenkhoorn, 2011). Biogas infrastructural projects are to most stakeholders just an additional activity with low priority. A shift to a more pro-active attitude will benefit to the projects and to biogas infrastructures in general. However this switch needs to be performed by a group of stakeholders in parallel. This could be accomplished for example by using covenants.

7.6 Research question 6

In this section an answer was sought to the sixth research question:

- Which role(s) could distribution network operator Enexis take within this playing field?

Enexis' role in the biogas infrastructure playing field needs a clear differentiation between the role during the pilot phase and the future role when projects are commercially oriented. From a system perspective, the network facilitating role combined with the professional knowledge sharing role that is fulfilled during the pilot phase is a proper choice. Public organizations should stimulate the research and development of promising energy alternatives, like biogas infrastructures. Currently Enexis tends to participate as a leader in the process. The DNO needs to reflect on itself whether or not this is a suitable attitude to them. From the perspective of stimulating research and development it is. Yet when the pilot phase has explored the possibilities of the technology the private parties should take over the initiating and leading role. The process needs to leave the 'valley of death' and become cost-effective in order to play a role of significance in our future energy supply.

In their future role Enexis could fulfill a supporting role to the system operator. The maintenance and management of the small-scale network is especially a task that is suitable to Enexis, since this strengthens the safety and reliability of the system. Yet regulatory reform seems to be needed when the DNO will execute these task as a regulated activity. In this desired situation the role of the DNO is actually comparable with their current position in the natural gas sector.

Most added value can be generated by Enexis when they focus on the gathering and sharing of knowledge between stakeholders. Due to the extensive contacts they have within the energy sector and academia, this innovation stimulating role would be suitable to them. When there is created enough legitimacy within the sector the neutral status of the distribution network operator could create interaction and make active firms cooperate in further development of the biogas infrastructure.

As Enexis innovative activities currently operate in the commercial domain, the company should reflect upon themselves if this is a desired situation. The processes and corporate culture are focused on the regulated market. But since the content-wise link to the project is clear the involvement of the distribution network operator is obvious. Maybe this knowledge could be transferred supporting a commercial constructor in the development of a biogas pipeline. The investments that Enexis makes to facilitate the innovation should be made with care, considering the availability of other sustainable energy sources which might be more cost-effective.

8 Conclusions and Recommendations

"The press, the machine, the railway, the telegraph are premises whose thousand-year conclusion no one has yet dared to draw."

Friedrich Nietzsche, German philosopher, (1844-1900)

➔ *This section presents the conclusions (8.1) and recommendations (8.2) of this thesis, which focused on the emergence of biogas infrastructures in The Netherlands. Within the main text, the sub research questions were answered. For an overview of the specific section per research question, please consult the research framework of section 2.3.*

8.1 Conclusions

*This thesis started with the main research question "*What should stakeholders do to reach a situation in which a structured development is realized that makes biogas infrastructures in The Netherlands available at acceptable costs?" By analyzing the current situation by means of a system study, there appeared to be a fundamental question underlying the main research question: Is the current situation in The Netherlands advantageous to the emergence of sustainable energy? And a more practical interpretation: are stakeholders willing to invest time, effort and money in biogas infrastructures?

The Netherlands has agreed on several sustainable energy targets, most of them originating from European Directives on renewable energy. An example is the fact that 14% of the total energy production should be produced out of renewable energy sources in 2020. In 2010 only a share of 3,8% was achieved in The Netherlands. This indicates that serious action is needed to accelerate the energy transition successful and to keep it going.

Currently most renewable energy is produced using biomass and windmills on land. These technologies are the most cost-effective renewable energy techniques that are available at this moment, given our geological characteristics. Yet, green gas is also a promising energy source- a point of view that is also acknowledged by the Ministry of Economic Affairs, Agriculture and Innovation who selected a top 3 of most promising renewable energy production methods in order to fulfill the sustainable energy targets. With this recognition, green gas projects can apply for SDE+ subsidies. Green gas is upgraded biogas, but as the upgrade facilities are expensive the majority of the biogas producers will not upgrade their biogas to green gas. The concept of biogas infrastructures seems promising to change this situation.

Main reasons

Market parties are reluctant to participate in biogas infrastructure projects. This, while the Ministry of Economic Affairs, Agriculture and Innovation appointed these market parties as the initiators in the development of biogas infrastructures. According to the analysis presented in this research, this is caused by three main reasons.

First of all, the established regime in the energy sector is dominated by a couple of entities with big interests in the extraction, supply and use of fossil-based energy. They mainly experience the costs instead of the benefits of a more sustainable energy supply and with that the energy transition is slowed down. According to van Soest this establishment pushed for gradual improvements instead of radical innovations in the energy sector during the last decade (Van Soest, 2011). This situation is also enhanced by the government, since they disproportionally fund end users of fossil-based energy; form the available 4.6 billion euro to stimulate end users of energy, a total share of 96,5% was assigned to fossil fuels.

Secondly, the current initiators are facing unfeasible business-cases. The structure of the SDE+ subsidy has the consequence that all available funding is divided over sustainable energy projects, other than biogas infrastructures, before biogas infrastructures can apply. This subsidy pushes the most cost-effective production methods to become operational. However the prices of production facilities already decrease, biogas infrastructures are not yet one of these most cost-effective techniques. Therefore the concept does not get the opportunity to leave the valley of death. Currently compensation is available to expand existing concepts, on the other hand there are no funds available for the development of new concepts. At the same time several base load energy plants have been realized, which negatively influences the competitiveness of sustainable energy and therefore the possibilities of a suitable business-case.

The third cause for reluctance of market parties is the institutional uncertainty. Biogas is not included in the Gas Act, therefore related activities are indicated as commercial activities. Some distribution network operators are pushing to an inclusion of biogas in the Gas Act. Currently the realization of a biogas pipeline can be executed by a construction company without any experience with gas pipelines. This could cause serious issues to the safety and reliability of gas networks. Inclusion in the Gas Act would also lead to pre-defined tariffs and therefore for ensured revenues to the distribution network operator. Currently an investment can be spread over 12 years, which is a commercial depreciation period. But when biogas would be recognized as a regulated activity a depreciation period of 40 years can be applied. A longer depreciation period would create a more feasible business case to private investors. In addition not every distribution network operator is able to perform these kind of activities on short notice. An obligation would urge them to execute these activities, which is difficult when not all DNOs are experienced on this field. In addition expected regulations on cattle manure and stables create uncertainty among farmers. They are the most important producers regarding biogas infrastructures. Furthermore the ambitions that governmental taskforces have determined are not operationalized. A clearly defined governmental objective could create some regulatory certainty among stakeholders.

Solutions

When searching for solutions to break this impasse, of a situation in which biogas infrastructure do not develop, four main categories can be distinguished.

The first solution regards the policy-designing circumstances. Within the current political landscape, decisions that have negative short-term effects (costs) and positive long-term effects (environmental gain) are unpopular. Elections that are held on several policy levels (think about municipality, European, Province and Government) spread over a period of 4 years, urge political parties to make a positive impression on their voters (In ‘t Veld, 2010). In this case the interests of individual political parties could become more important compared to the national interest. A short term focus in politics is mostly not in favor of sustainability, since sustainability investments could take more than 20 years to become profitable. This does not fit in the strategy of politicians seeking for quick wins. A phenomenon that seems to be inherent to our current democratic system. The incentive to focus on long-term policy is lacking in this system. Though besides the political parties and their voters, there are also other forces that have their impact on the political playing field. The so-called ‘fourth branch of government’, includes the press, interest groups and administrative government agencies (Smith et al. 2006). These entities have the power to get long-term policies on the political agenda. Compared to the national playing field the decision-making process in Europe, will take usually more time and is subject to a broad consensus (27 member states). In this political arena long-term visions and ambitions could be operationalized in legislation. European directives appears to be the main driver to most national legislation related to sustainable energy in recent history. When aiming on a positive influence of sustainable development and biogas infrastructures in particular, the European Commission and the ‘fourth branch of government’ seems to be the most feasible starting point. They are able in starting policy designs using their different energy related platforms. According to the socio-technological system that was created in section 3 Europe could contribute significantly by designing incentives for the development of biogas infrastructures. It is a remarkable fact that involved stakeholders do not attribute an important role to Europe. Apparently they consider other system boundaries.

The second solution opportunity is the framing of the renewable energy and the biogas infrastructure in particular. When this is framed as a chance instead of a problem it is easier to create support beyond stakeholders. In comparable countries like Germany, Finland and Denmark, the employment in the renewable energy sector is significant. Sustainability requirements will become business as usual in service and product-oriented markets (RLI, 2011). Besides the ambitions that are set by governmental organizations, also the private sector will ask for sustainability requirements more often. When surrounding countries and export partners are focusing more and more on sustainability, these products and services will become increasingly important to maintain the Dutch competitiveness. Sustainability is a chance to strengthen the Dutch economy. A clear example of framing this as a chance instead of a problem is incorporating entities who face negative side effects of the energy transition. This would be a comparable situation with the involvement of DSM by the Dutch government in the transition process from coal gas to natural gas (Van Soest, 2011). The future role of the current established entities within the energy sector should be reconsidered. Their function in a renewed playing field and future prospects needs to be taken into consideration.

The third solution could be initiated by the government when they send out a production obligation concerning sustainable energy. In that case energy producers will be obliged to produce a certain share using renewable energy sources. This would create an incentive to the energy producers to become more innovative with respect to sustainable energy methods. At the same time the producer will integrate the costs in their energy prices. In this way it will be the energy user that compensates the required investment instead of the tax payers.

The final solution strategy focuses on the integration and synergy that should be included in biogas infrastructure projects. By (re)using industrial flows and connecting demand and supply an optimal integrative system can be created. All products from the production process like green gas, CO_2, heat and water should be used effectively. When this is achieved that will lead to cost reductions and therefore to a more feasible business-case. Therefore it is important to gather all the available support and where possible integrate them into one project.

Nuance

The suggested problems and solutions seem to –for the most part- focus on the slow process and how this can potentially be accelerated. It is important to mention that a slower process is not necessarily a worse process. To be able to make well-considered decisions and negotiations, a considerable amount of time, effort and most probably are needed. This research created an insight in the situation on biogas infrastructures in The Netherlands, it included the opportunities and threats. And even though guidelines are offered to make the emergence of biogas infrastructures in The Netherlands more successful, it is always important to consider the goal of this realization. Networks and infrastructures function as deep structures in society and surpass even natural geography and politics as key drivers of societal change. To a large extent, networks and infrastructures influence where people live, work and play (Hughes, 1983). This will not be the case for biogas infrastructures since alternatives to renewable energy production are widely available. The growth of the sustainable energy share in The Netherlands needs to be increased and the biogas infrastructure could function as a means to do so, but never as a goal in itself.

8.2 Recommendations to Enexis

The research project proved the complex situation in which the biogas infrastructures are developing in The Netherlands. The road to success appeared to be difficult due to present uncertainties and side-condition. Nevertheless, in this section the recommendations to Enexis are presented that could have a positive influence on biogas infrastructure development.

1) Maintain pro-active role in pilot phases

Currently Enexis is one of the pro-active stakeholders involved in biogas infrastructure development due to their knowledge of the physical system. This enables the biogas infrastructure to develop under protected niche conditions, which will be advantageous to the future emergence of biogas infrastructures. Since Enexis, as a public organization, has an interest in energy-related innovation and especially in the facilitation of the energy transition this also meets their objectives.

2) Explore the potential role for Enexis after the pilot phase

In their future role Enexis could fulfill a supporting role to the system operator. The maintenance and management of the small-scale network especially is a task that is suitable for Enexis. It will strengthen the safety and reliability of the system. Yet regulatory reform seems to be needed when the DNO should execute these tasks as a regulated activity. In this desired situation the role of the DNO is actually comparable to their current position in the natural gas sector. This will offer a compatible situation, where institutions and arrangements do not need to be changed significantly. Furthermore, the network reliability will most probably not be affected. In addition, Enexis could function as an intermediate by sharing knowledge and interacting within and between stakeholders. This could result in an incentive to innovate. The 'neutral' status of Enexis within the energy sector will give it the opportunity to function as an intermediary. This requires a pro-active attitude and the creation of legitimacy within the sector. The current image of Enexis in combination with green- and biogas is a suitable starting position.

3) Search for integration of projects

Cost-effectiveness of the biogas infrastructure will be decisive in the potential success. The most suitable approach to decrease production costs will be an integration of the biogas infrastructure: re-using the industrial flows of other industries as an input, by re-using digestate or integrating the water treatment processes. Especially in the development pilot phase, Enexis should take a stimulating role and should be able to indicate integration possibilities within their service area.

4) Consider the potential of biogas infrastructures in the near future

After the pilot phase, Enexis needs to consider the potential for biogas infrastructures. During the research it became apparent that efforts put in biogas infrastructures are hard to recover. This is something that is not likely to change on the short term, following from our main conclusion. The competitive strength of sustainable energy but specifically biogas is precarious. Therefore investments should probably be made in other more, cost-effective methods of sustainable energy production.

5) Reconsider the role of commercial activities within Enexis

The commercial role that is appointed to Enexis in the current biogas infrastructures is more or less a temporary role. Due to the unattractive business case and unregulated state of the biogas there are hardly any private parties who are willing to invest their resources in the biogas infrastructure. Also Enexis should themselves reflect on whether or not this role should be maintained after the pilot phase. Contribution on technology development is probably only legitimate for Enexis to a certain extent and therefore to a certain amount of time and financial effort.

6) Start lobbying for additional conditions on permitting biogas pipelines

Due to the fact that biogas is not included in the Gas Act, it is simple to get a permit for installing biogas pipelines. Construction companies without any experience on the installation of these networks are allowed to perform these kinds of constructions. As a result of this 'inexperience' serious safety issues could arise. Therefore it is important for Enexis to start the co-development of legislation in order to create additional conditions. This will decrease the risk of gas-related incidents, which could harm the entire gas sector in the Netherlands.

Besides these recommendations, also the conditions based on the historical analysis should be taken into account (these are summarized in the 4.1). In addition the transition management recommendations (5.4) will deliver a refreshing and inspiring perspective, however to Enexis it is important to keep a rational decision process and do not get lost in abstract concepts.

Recommendations for further research

During the thesis project several subjects arose as relevant for further research. The three most important in the view of the researcher are presented in this section.

First of all, the 'effective' potential of biogas needs to be clear, especially since the required biomass is also available to other energy production processes. Then further research is encouraged on the integration of biogas infrastructures with other industrial streams. And finally the capacity issue is brought forward since this is mentioned as an urgent bottleneck to a significant increase of green gas production.

1) Biogas potential in the (near) future

The Platform New Gas appointed green gas to be a promising energy source (Welink,2006). The Dutch government has listed the energy source number 3 of most useful to fulfill the sustainability targets of 2020. However since biomass is mentioned to be the number 1 it is questionable what the potential of biogas in the near future will be, taking into account the parallel development of co-firing biomass. This alternative is currently more cost-effective and uses the same raw material as biogas. With that, the competitive position of biogas and green gas is undermined. Current explorations of potential are based on the amount of biomass available in The Netherlands, yet it will be unlikely that all biomass would be used for biogas production. Further research is needed to explore the potential of biogas within a broad spectrum, including competitive sustainable alternatives, that will develop in parallel with biogas.

2) Integration of biogas infrastructures to other sources (potential, costs and gains)

Current biogas initiatives, especially the ones that include a biogas infrastructure, do not come to a solid business case. Therefore there is a need for cost reductions and economies of scale to achieve an improved business case. Integration and synergy could offer opportunities for this. An example arises in Rilland (Zeeland), where a biomass digester is converting waste of vegetables (potatoes and onions) and creates biogas, water, CO_2 and fertilizers. These can be used in the greenhouses, in the environment and to heat half of the housing in Middelburg (Kutterink, 2011). In addition the rise of district heating could also be an opportunity to biogas production, this would also be the case when biogas is combusted in CHP facilities. Further research could explore the possibilities of integration of biogas infrastructures to other industrial processes.

3) Capacity issue green gas

The increasing production of green gas is facing a dynamic gas demand. The produced gas needs to have a customer and when injecting green gas in a small distribution network a customer is not always present. Solutions need to be explored to tackle this situation. Especially the possibility to transport gas from the distribution network towards the transmission network seems promising. Yet whether or not this is technological and institutional possible needs to be investigated.

In addition the strategic analysis in Appendix 1 can be consulted for the main issues in the current green gas field. These will not all have a connection with biogas infrastructures.

8.3 Reflection

In this section the researcher reflects on the research performed. Firstly with an emphasis on the scientific perspective, here the research approach and process will be discussed. Secondly the research results will be reflected on the practical and scientific aim. Finally a personal reflection will be presented.

Reflection on research approach

It appeared from the very start of the research project that the choice of the *scope & complexity* of the research subject had a significant impact on the execution of the research, but also on the strategic level of the study. Since the concept of biogas infrastructure is relatively new in the energy sector a knowledge base was lacking. 'Standing on the shoulders of giants', was therefore difficult in this case. Furthermore, the interviewees were new to this situation with incomplete information. The chosen research framework, including the strategic analysis, created added value in this process since it enabled the research to identify relevant research subjects. Because of this analysis the relevance of the research to the 'field' was ensured. The use of assumptions and expert validation has probably led to a useful insight in the biogas infrastructural situation in The Netherlands.

It is not likely that, by narrowing down the scope, the same insight could have been generated. One could have chosen to leave the historical analysis or transition management outside the scope of this research. In that case, an overview of the current situation was sketched, but no attempt would have been made to sketch the desired situation. This addition is enabled by using the historical analogies and transition management theory. However this combination offers an inspiring set of results, the validity is doubtful (this will be discussed later). Furthermore the combination of an imaginary system, historical analogies and theoretical concepts create a certain level of abstraction. Yet this is hard to eliminate, which results in less straight forward recommendations.

The main research method that was used during the empirical phase is the Multiple Perspective Approach of Mittrof and Linstone (1993). In this section we will reflect upon this approach by discussing the drawbacks and thereafter the advantages. The MPA takes relatively more ***time & effort*** than compared to other system approaches (e.g. operational research or social systems design, for more background information on system approaches please check the article in Appendix 6). This is caused by the extensive use of multiple paradigms in parallel. This causes a continuous iterative process. Furthermore the preparation period for the execution of MPA can be applied. Since there is a wide variety of techniques available that can be applied within the MPA framework, a modeler needs to be aware of the pros and cons of the available techniques and also the philosophy underlying the originating methodologies. This requires a significant time investment since every system analysis method will have its specific requirements. Another barrier is the ***integration*** step that was required. Without integration of the perspectives the added value of an MPA is negligible, since that would simply be a collection of separate analyses. To be able to make this required integration step, a basic knowledge of all system components is required at least. Mittrof and Linstone found the multiplicity of perspectives to be vital but realized that this would create discomfort to a great many as well. How does one integrate different perspectives? How does a decision-maker finally combine all the inputs he or she obtained, to make a final decision (Mittrof et al., 1993)? Everyone will answer these questions differently; within the chosen approach iteration was key. New developments urged the researcher consider the consequences on other system aspects. As a result, the choices that were made are hard to trace, which is from a scientific point of view a weak characteristic of the integration within the MPA.

When reflecting on the advantages of the approach, the added value of ***combining different perspectives*** compared to single system analysis is worth mentioning. A stakeholder analysis for example, which was in our case part of the Organizational perspective, is usually performed as a stand-alone analysis. The MPA also includes-besides the individual objectives and responsibilities-the overarching themes. By combining the stakeholder analysis with the Critical System Heuristics (Ethical) the analyses shifted from showing the current state of the stakeholder towards the 'transition' that stakeholders needed to make. This leads to a prescriptive description on the direction the stakeholders should take. Such findings would not be able to be made from a single stakeholder analysis. Furthermore, the MPA decreases the chance that essential elements are excluded by the use of the incommensurable sociological paradigms. This resulted in a specifically complete socio-technological system description. A final advantage of using the MPA is the ***degrees of freedom*** that the researcher has when using this approach. The researcher is responsible for the selection of the sub techniques and methodologies. Furthermore the researcher's influence on the interpretation of especially the integration steps is significant. In the perspective of the researcher this is considered as convenient, however it will also have drawbacks on the research results. These will be influenced significantly by the researcher's views. Furthermore not every researcher will appreciate an approach in which he needs to take decisions.

Furthermore, a notion needs to be made on the additions that were made to the MPA approach within this research. Since in the end, a truly multiple perspectives approach is an ideal that one can only work towards. Our practical guidance will contribute to that since it gives an insight on how to select suitable system approaches in a pragmatic way. Applying the MPA could enrich one's assessment of a situation and create a situation in which decisions are based on a more inclusive set of factors.

In the case of biogas infrastructures the practical guidance leads to a well-balanced socio-technical system. Yet whether or not the added value of this specific practical guidance is applicable to more situations is unclear at this time. The defined steps should be performed by other researchers on different subjects. That would enable us to claim with more significance if this is the case; it would give more rigor to the findings of this research.

Reflection on the research results

In this section first the validity of the results will be discussed regarding the practical aim followed by a discussion on the scientifical aim.

The practical aim of this research was to investigate the inability among stakeholders to realize a biogas infrastructure. In the beginning of the research, the assumption was posed that one could create a suitable starting point for realizing infrastructures related to the energy transition by applying historical and theoretical lessons on an empirical constructed system. This assumption can be criticized, and during the research several elements needed to be accompanied by disclaimers. It is for example the historical analogies that could have a limited relevance when it is translated to our current society. At the same time, theoretical lessons on transition management are not generally applicable due to the unique circumstances of each situation. The research results can therefore only be used as an inspiring guideline to new biogas infrastructural projects; they can never be seen as the ultimate truth. This never has been the ambition of the research in advance. For this, too many uncertainties are present in the system.

The more general research results on the position of sustainable energy and the role of the national government should be interpreted in a different way. During the research period, these results were supported by other research reports that were published; examples are the 'Remmen los'-report of the RLI(2011) and articles of Van Soest(2011), Rotmans(2011) or Wiltink(2011). Therefore these findings are not isolated, which makes a more serious reflection from the involved stakeholders necessary. The practical aim of the research has therefore been fulfilled.

The scientific aim was to come up with scientific evidence that prove the added value of the transition management approach. During the research an attempt was made to gather scientific evidence of the applicability of the theory to real-life cases of infrastructural development. When applying the transition management theory shortcomings were identified. These clarified that the transition management approach will not exactly fit a specific project. Yet the concepts that are used to support the transition management approach have an inspiring character. Therefore it is recommended to stakeholders involved in projects related to the energy transition to be aware of the transition management ideas. It should be noted that some of the interviewees were already familiar with these concepts. The scientific aim did not bring evidence on the applicability of the transition management theory, but the study did show that applicability of the approach will never fit a project exactly. One always needs to adapt it to the situation at hand. This is not really unexpected, since motives underlying choices and activities in a transition are hard to trace back. It is therefore difficult, if not impossible, to prove scientifically the contribution of transition management regarding infrastructural development.

Personal reflection

As a final conclusion this section will contain a personal reflection of the researcher. While the research project started with a pretty straightforward quantitative subject, two months later the subject was transformed to a qualitative explorative study on a strategic level. With that the researcher was confronted with the essence of the SEPAM study program: what is the real underlying problem? The step backwards gave the researcher the opportunity to approach the situation carefully, performing an iterative investigation and with that discovered a wide variety of relationships that were not yet clear during the first strategic analysis. However a rigorous change of the research direction could be very disappointing, since the work that has been done seems useless, in the end it appeared that it can be very beneficially to change course. Studying related issues to green gas, created a well-founded context for the further research.

Reflecting on the thesis research as the final product of the Systems Engineering, Policy Analysis and Management master program, the researcher is convinced that the gathered knowledge within the MSc program is applied within this research. Yet it is definitely different when a project is executed in an external organization, compared to the protected environment of the university. Sometimes this can be frustrating, as practice and academia can be two worlds far apart from each other. Yet to finally manage to complete a project in such a dynamic complex environment was a rewarding experience to the researcher.

Bibliography

A

AARTEN, T., 2011, Energiemarkt in beweging, interview van KEMA Topman bij BNR Nieuwsradio d.d. 11/05/2011

AGENTSCHAP NL, 2010, Groen beleggen jaarbericht 2010 met jaarcijfers 2009, Utrecht

AGENTSCHAP NL, 2009, Van biogas naar groen gas, opwaardeertechnieken en leveranciers, Utrecht

AMIN, A., THRIFT, N., 1994, Living in the global. Globalization, Institutions, and Regional Development in Europe. Oxford University Press

B

BARRAS, C., 2009 Why sustainable power is unsustainable, New Scientists, http://www.newscientist.com/article/dn16550-why-sustainable-power-is-unsustainable.html

BEKKERING, J, BROEKHUIS, A.A., GEMERT, VAN, W.J.T., 2009, Optimisation of a green gas supply chain – A review. Bioresource Technology volume 101, issue 2, 450-456

BEKKERING, J., BROEKHUIS, A.A., GEMERT, VAN, W.J.T., 2010, Operational modeling of a sustainable gas supply chain, Engineering Life Science, Volume 10 No. 6 585-594

BOERRIGTER, H, 2006, Green Gas (SNG) in the Dutch energy infrastructure. Wetsus Meeting, Workshop Energy, Leeuwarden 30 March 2006

BOUTKAN, E., 2011, Overcapacity of electricity supply in the Netherlands: an expensive 'pork cycle' in the making, September 2011

BRAAKSMA, A. (2010). G-gas: From Groningen gas to Green gas? An assessment of the Dutch green gas potential and its delivery to the natural gas system, based on Groningen gas quality. University of Groningen, EES 2010-96 T, IVEM training thesis

BRESCHI, S., MALERBA, F., 1997. Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. In: Edquist, C. (Ed.), Systems of Innovation: Technologies, Institutions and Organizations. Pinter, London/Washington, pp. 130–156.

BRINKER, G., DEN, 2011, Fossiele energie krijgt € 5.8 mrd rijkssteun. Financieel Dagblad 23-6-2011

BRUIJN, DE, J.A., HEUVELHOF, TEN, E.F., 2008 Management in networks: on Multi-actor decision making, Lemma

BRUNDTLAND, G.H., 1987. *Brundtland Our Common Future* (1987), Oxford: Oxford University Press.

BURELL, G., MORGAN, G. Sociological Paradigms and Organizational Analysis, Heinemann, 1979

C

CALLON, M, 1994, Is Science a Public good? Fifth Mullins Lecture, Virginia, Polytechnic Institute', Science Technology and Human Values, 19:395-424

CAMBRIDGE DICTIONAIRY, 2011, Definition of the word 'transition' http://dictionary.cambridge.org

CBS 2011. Energiemeter. Den Haag.

CBS, 2011. Land- en Tuinbouwcijfers in collaboration with LEI in Wageningen. Den Haag

CORRELJE, A.F., 2006, Radio uitzending http://www.geschiedenis24.nl/ovt/afleveringen/2006/Ovt-11-06-2006/Afhankelijkheid-van-Nederland-van-het-aardgas.html

CALAND, P. 1860-1861 29-55

CHAPPIN, E.J.L., 2011, Simulations of Energy Transitions, Thesis. Next Generation Infrastructures Foundation, Faculty of Technology, Policy and Management. Delft University of Technology, The Netherlands.

CHECKLAND, P, 2000, Soft-systems methodology: a thirty year retrospective, systems research and behavioral science. Syst. Res. 17, S11-S58

CHECKLAND, P., SCHOLES, J., 1990, Soft Systems Methodology in Action. Chichester, John Wiley and Sons.

CLIFTON, J., DIAZ-FUENTES, D., 2011, La nueva politica exonomica de la OCDE ante el cambio en la economica mundial. Revista de Economia Mundial, 28, 113-142

CLIFTON, J., LANTHIER, P., SCHROTER, H., 2011, Regulating and deregulating the public utilities 1830-2010

CUIPER, N, 2009, We moeten niet wachten met gasopslag, Energiebeurs bulletin, 2009 editie 1, pg.3

D

DAM, VAN, M., 2011, Personal notification 29th September 2011

DAVIS, K., 1945, Annals of the American Academy of Political and Social Sciences, 237:1-11.

DE LISO, N.,FILATRELLA, G., 2008, On Technology Competition: A Formal Analysis of the 'Sailing-Ship effect', Economics of Innovation and new technology 17:6, 593-610, Routledge

DHV, 2010, Groen Gas nog weinig toepasbaar, in Provincies, Volume 9, November 2010, pg. 28-29

DIJKEMA, G.P.J., 2004, Process System Innovation by Design. Towards a sustainable petrochemical industry. Dissertation, Delft University of Technology, Delft

DIJKGRAAF, E., JONG DE, J.M., SPIJKERMAN, M., Tanis, O.,2009, Effectiviteit convenanten energiebeleid, Erasmus Universiteit Rotterdam, SEOR

DIRVEN, J., Snellen, Th., Rademaker, O., Schild, J., 2000, Stuur of Overstuur, Elsevier, Den Haag

DUMONT, M. 2008. Vision of Green Gas and the role of certification in The Netherlands. Groningen: Senter Novem.

DUMONT, M, 2011, Interview on the 28th of September 2011, Ministry of Economic Affairs, Agentschap NL, Projectmanager in bioenergy

E

EBN, 2011, Visie en Ambitie van EBN, http://www.ebn.nl/over-ebn_visie-en-ambitie.php

ECN, 2011, Kosten-batenanalyse van alternatieve stimuleringsystemen voor hernieuwbare elektriciteit, 15th March 2011

ECOFYS, CE DELFT, 2011, Overheidsingrepen in de energiemarkt, onderzoek naar het Nederlandse speelveld voor fossiele brandstoffen, hernieuwbare bronnen, kernenergie en energiebesparing.

EENKHOORN, R. 2011, Interview Province of Overijssel, Energy Advisor on the 29th of June 2011.

EIKELENBOOM, M., 2011, Interview Release of the Remmen Los Report, Managing Director Arthur D. Little Nederland.

ELEKTRICITEITSWET 1998. Elektriciteitswet. Den Haag: Ministry of Economic Affairs.

ELKINGTON, 1998, Cannibals with forks: The triple bottom line of 21st century business, New society publishers

ENERGEIA, 2010: Dutch green gas certificate not successful Accessed on the 1th May 2011http://www.e-energymarket.com/news/single-news/article/dutch-green-gas-certificates-not-successful.html

ENERGEIA, 2011. NMa verwacht dat 2011 eindelijk veel goed brengt voor groothandelsmarkt. http://www.energiekeuze.nl/nieuws.aspx?id=518 . Accessed on 26th April 2011.

ENERGIEGIDS, 2011. Netbeheerders in Nederland, Aantal aansluitingen per netbeheerder. http://www.deenergiegids.nl/marktpartijen/Netbeheerders.aspx Accessed on 27th April 2011.

ENERGIEGIDS, 2011. Marktpartijen, http://www.deenergiegids.nl/marktpartijen/Marktpartijen-in-de-Energiemarkt.aspx Accessed on the30th of September 2011

ENERGIEKAMER 2005. Wettelijke taken LNB van algemeen belang. *In: Energiekamer* (ed.) *0.2.2.* Den Haag.

ENERGIEWERELD.NL, 2011. Waarop baseert de consument nu eigenlijk zijn keuze? Accessed on the 22nd of September 2011 http://www.energiewereld.nl/nieuws/waarop-baseert-de-consument-nu-eigenlijk-zijn-keuze.aspx

ENERGY VALLEY, 2011, Fors belastingvoordeel voor investeerders in groen gas infrastructuur, http://www.energyvalley.nl/archief/22359-fors-belastingvoordeel-voor-investeerders-in-groen-gas-infrastructuur

ENERGY VALLEY, 2011, Hoeveel groen gas wordt er op dit moment geproduceerd? http://www.energyvalley.nl/nl/projecten/werkthemas/21944-groen-gas-in-11-vragen Accessed on the 25th of September 2011.

ENEXIS 2010. Position Paper: Duurzaam gas faciliteren. 's-Hertogenbosch: Enexis.

ENVIRONMENTAL PROTECTION AGENCY, 2010. Methods for calculating efficiency of combined heat and power partnership. http://www.epa.gov/chp/basic/methods.html Accessed on the 8th of September 2011

ELKINGTON, 1998, Cannibals with forks: The triple bottom line of 21st century business, New society publishers

ERP, W. VAN, 2010, Presentatie BIOgas-net NO-Friesland, 26 januari 2010, Stedin/Enexis

ESSERS, L., 2011, De glasvezelstand van Nederland, 2nd of February 2011, http://webwereld.nl/nieuws/105542/de-glasvezelstand-van-nederland.html

EURACTIV, 2010, Biogas: The green gas?, Accessed on the 25th of October 2011, http://www.euractiv.com/energy/biogas-green-gas-linksdossier-369788

EUROPEAN COMMISSION 2006. A European Strategy for Sustainable, Competitive and Secure Energy. Brussels.

EUROPEAN COMMISSION, 1994, Directive 94/9/EC on equipment and protective systems intended for use in potentially explosive atmospheres (ATEX), Accessed on 2th May 2011 http://ec.europa.eu/enterprise/sectors/mechanical/documents/legislation/atex/

EUROSTAT, 2011, http://epp.eurostat.ec.europa.eu/ Indicators used until 26th September 2011

F

FAO, 2011. World Food Situation, 7th April 2011 http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/

FERRAND, J.H., VAN DER KUN, L.J.A., 1850, 136-137, Rapport Rijkswaterstaat

FNR (2009). Handreichung Biogasgewinnung und –nutzung. Institut fur Energietechnik und UmweltgGmbH. Fachagentur Nachwachsende Rohstoffe e.V. ISBN: 3-00-014333-5

G

GASLICHT, 2011. Gaswijzer: voor objectieve en actuele vergelijkingen. Accessed on the 19th of April 2011, http://www.gaslicht.com/energie-vergelijken/gaswijzer.aspx

GASWET 2010. Gas Act. Staatsblad 810 ed. Den Haag: Ministry of Economic Affairs.

GASWET 2011. Gas Act. Staatsblad 2011 131 ed. Den Haag: Ministry of Economic Affairs.

GEELHOED,L.A., 2001, De kritische dimensie van politiek en overheid, Interview in Publiek management 5, 40-45

GEELS, F.W., 2002, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy 31 1257-1274

GEELS, F.W., KEMP, R., 2000, Transities vanuit een socio-technisch perspectief, Rapport voor het ministerie van VROM, University Twente and MERIT, University Maastricht

GIGLER, J., BOERRIGTER, H., BURGEL, M. VAN, CNUBBEN, P., HOOGMA, R. 2008. Vol gas vooruit! De rol van groen gas in de Nederlandse energiehuishouding. Platform Nieuw Gas.

GORKUM, VAN, K., 2011, Notitie beheer en onderhoud biogasleidingen, Enexis, 18 september 2011, Rosmalen

GREEVE, J., 2009, Haalbaarheid van kleinschalige vergassing van biomassa tot groen gas in het kader van Transitiepas Groen Gas. E Kwadraat.

GROENGASMOBIEL, 2011, De prijs van groen gas. Geraadpleegd op 19 april 2011, http://www.groengasmobiel.nl/tanken/prijs-van-groengas/

GUELLEC, D., RALLE, P, 1995, Les nouvelles theories de la croissance, Paris: Reperes, La Decouverte

GUNDERSON, L.H., HOLLING, C.S. (eds.) (2002), 'Panarchy: understanding transformations in human and natural systems', Island Press, Washington, D.C., USA.

H

HAFFNER, R., HEUVEL, J.VAN DEN, POSTEMA, R., POSTEMA, B., 2006 Het minimale aantal monopolisten. Economisch Statistische Berichten, 14 juli 2006 pg 344

HANAFIZADEH, P., ALIEHYAEI, R., 2011, The application of fuzzy cognitive map in soft systems methodology, Systemic Practice and Action Research, Volume 24, p.325-354, Springer

HAUSMAN, W., HERTNER, P., WILKINS, M., 2008, Global electrification: Multinational enterprise and international finance in the history of light an power, 1878-2007. New York: Cambridge University Press.

HEEZEN, P.A.M., MAHESH, S., 2010, Veiligheid grootschalige productie van biogas, verkennend onderzoek risico's externe veiligheid. Centrum externe veiligheid, RIVM, Bilthoven

HEKKERT, M. P., SUURS, R. A. A., NEGRO, S. O., KUHLMANN, S. and SMITS, R. E. H. M., 2007. Functions of innovation systems: A new approach for analysing technological change, Technological Forecasting & Social Change 74(4)

HERDER, P.M., BOUWMANS, I., DIJKEMA, G.P.J., STIKKELMAN, R.M., and WEIJNEN, M.P.C., 2008, Designing infrastructures using a complex systems perspective, Journal of Design Research 7(1)

HET FINANCIEEL DAGBLAD, 2010, De knelpunten op de Nederlandse gasrotonde, 19 december 2010

HUGHES, T.P. (1987), The Evolution of Large Technological Systems, in *The social construction of technological systems: new directions in the sociology and history of technology* (Eds, Bijker, W. E., Hughes, T. P. and Pinch, T. J.), MITPress, Cambridge, Mass., pp. 51-82.

HUGHES, T.P., 1983, Networks of power. Electrification in Western Society 1880-1930, Baltimore, The Johns Hopkins University Press

K

KAIJSER, A., JONSSON, D., 2004, The dynamics of infrastructures. Lessons from history. International summer academy on Technology Studies, Urban Infrastructure in Transition

KAMPMAN, B.E., CROEZEN, H.J., VERBRAAK, G.M., and, BROUWER, F.P.E., Rijden en varen op gas, kosten en milieueffecten van aardgas en groen gas in transport. CE Delft.

KARRE, P.M., 2006, Caleidoscooporganisatie. Culturele aspecten van hybriditeit in organisaties. In T. Brandsen, W. van de Donk and P. Kenis(eds.), Meervoudig bestuur, The Hague: lemma pp. 55-72.

KEMA, Endinet, 2010, Groen gas Invoeding in het Gasnet, Scenario ontwikkeling. 8 november 2010

KEMP, R.,SCHOT, J., HOOGMA, R., 1998, Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management, Technology Analysis and Strategic Management Vol.10 No, 2 http://tandfprod.literatumonline.com/doi/pdf/10.1080/09537329808524310

KINGSLEY, D., 1945. "The World Demographic Transition." *Annals of the American Academy of Political and Social Science,* 1945 237: 1-11. classic article that introduced concept of transition in JSTOR

KIWA TECH, 2009, Rapport betreffende odorisatie biogas, 6 februari 2009

KRUIMER, H.T., 2009, Non-discriminatory third party access to the gas transmission network: what does it mean and where does objective justification of different treatment for creditworthiness reasons come from? University of Groningen, Faculty of Law

KUTTERINK, J., 2011, Subsidie voor Zeeuwse 'groene' gascentrale, PZC (provincial newspaper of Zeeland) 6th of September 2011

L

LEEUWARDERADEEL, 2010, Levering Biogas aan zwembad It Gryn komt steeds dichterbij, 3th of November 2011, www.leeuwarderadeel.nl

LENSINK, S., 2009,Biogas in de SDE, 26-10-2009 Energy research Centre of the Netherlands.

LNV, 2006, Tabellenbrochure nieuw mestbeleid Ministerie van Landbouw Natuur en Voedselkwaliteit

M

MADSEN, E., STEWART, D., 2007, Gaswinst: over de Nederlandse gasbel en het begin van de Europese energierevolutie, Nieuw Amsterdam

MALERBA, F, 2004, Sectoral systems of innovation: concepts, issues and analyses of six major sectors in Europe, Cambridge university press

MALERBA, F., BRUSONI, S., 2007. Perspectives on Innovation, Cambridge University Press

MALIZIA, R. 2010, Groen gas als transportbrandstof, een schone lucht komt niet uit de hemel vallen. Conferentie Groen gas in zicht.

MARAMBA, F.D., 1978, Biogas and waste recycling, the Philippine experience, Maya Farms Division, Liberty Flour Mills.

MARKETRESPONS, 2010, Energieconsument: duurzaamheid belangrijker dan prijs

MARTIN, C., 2010, Green Startups: Trapped in the 'Valley of Death'. 7th of October 2010, Bloomberg Businessweek

MATTELART, A., 1996, Networking the world 1784-2000, Minneapolis, University of Minnesota Press

MEEBERG, R. VAN DE, 2011. Interview Business Development Enexis BV

MILLWARD, R., 2005, Public and private enterprise in Europe: Energy, telecommunications and transport 1830-1990. Cambridge: Cambridge University Press

MINISTER OF ECONOMIC AFFAIRS, 2006, Netbeheerder en netwerkbedrijf na splitsing, Notitie n.a.v. wetgevingsoverleg 13th February 2006.

MINISTRY OF ECONOMIC AFFAIRS, 2011, Bestaande bio- energieinstallaties, AgentschapNL www.b-i-o.nl, accessed on the 23th of October.

MITROFF, I.I., LINSTONE, H.A., 1993, The unbounded mind: breaking the chains of traditional business thinking, Oxford University Press

MULDER, M., SHESTALOVA, V., 2006. "Costs and Benefits of Vertical Separation of the Energy Distribution Industry: The Dutch Case," Competition and Regulation in Network Industries, Intersentia, vol. 7(2), pages 197-231, June.

MT BIOMETHAN, 2011, Physical methods, pressurized water scrubbing, http://www.mt-biomethan.com/gb/gas-treatment/physical-methods.html, Accessed on the 24th October 2011

N

NELSON, R.R., & SAMPAT, B.N. (2001), Making sense of institutions as a factor shaping economic performance, *Journal of Economic Behaviour and Organization* 44(1), pp. 31-54.

NIKOLIC, I. 2010, Lecture SPM9550 Agent Based Modelling on Network Theory. Delft University of Technology, Faculty of Technology, Policy and Management

NIKOLIC, I, 2010, Lecture SPM 9550 Agent Based Modelling on System Nestedness. Delft University of Technology, Faculty of Technology, Policy and Management

NMA, 2007. Methode bepaling x-factor regionale netbeheerders, Den Haag, 7 augustus 2007

NMA. 2011. Wie is wie op de energiemarkt: netbeheerders [Online]. Den Haag: Energiekamer. Available: http://www.energiekamer.nl/nederlands/energiebedrijven/wie_is_wie_op_de_energiemarkt/Netbeheerders.asp [Accessed 28-03-2011 2011].

NOS, 2011, Journaal 9h00 2nd of September 2011, Radio 1.

O

OECD, 2008, Economic Assessment of Biofuel Support Policies, OECD Report

OTTENS, M., FRANSSEN, M., KROES, P. and VAN DE POEL, I. (2006). Modelling infrastructures as socio-technical systems, International Journal of Critical Infrastructures 2(2–3):

OVERBEEKE VAN, P., 2001, Kachels, geisers en fornuizen, Keuzeprocessen en energieverbruik in Nederlandse huishoudens 1920-1975, Uitgeverij Verloren

P

PAS, T. VAN DE, 2011, Interview Regulation Enexis BV

PETERSSON, A. & WELLINGER, A. (2009). IEA Bioenergy, task 37. Energy from biogas and landfill gas, Biogas upgrading technologies – developments and innovations.

PLATFORN NIEUW GAS, 2008, Vergezichten in gas, visie en strategie van het platform nieuw gas op de ontwikkeling van een duurzame gasvoorziening naar 2050. Utrecht

PEOSCHL, M., WARD, S., OWENDE, P. (2010). Prospects for expanded utilization of biogas in Germany. Renewable & Sustainable Energy Reviews, 14, 1782-1797.

POLLITT, M., 2005, The Role of efficiency estimates in regulatory price reviews: Ofgem's approach to benchmarking electricity networks. Utilities Policy, Volume 13, Issue 4, 279-288

POLMAN, E.A., 2007. Kwaliteitsaspecten Groen Gas, Report GT-070127

PRICE WATERHOUSE COOPERS, 2009, Crisis or not, renewable energy is hot. To reap the rewards, governments and companies should act now.

PRUYT, E., DAALEN, C.E. VAN, THISSEN, W.A.H., 2008, Lecture notes: Continuous Systems Modelling – System Dynamics, Delft University of Technology

R

RATHENAU INSTITUUT, 1995, Toeval of noodzaak? Geschiedenis van de overheidsbemoeienis met de informatievoorziening, Fatima reeks, studie 28, november 1995

RAKHORST, A., 2010, Nieuwe Energie, Nederland na het fossiele tijdperk, Search Knowledge BV, Heeswijk

RAND, 2000, Research Brief 5044 – Global shifts in population, http://www.rand.org/pubs/research_briefs/RB5044/index1.html

REPPICH, M., DATZMANN, S., LI, X., ROSENBAUER, S., SCHLECHT, C. &TSCHEPUR, S. (2009). Vergleich verschiedener Aufbereitungsverfahren von Biogas zur Einspeisung in das Erdgasnetz. Chemie Ingenieur Technik, 81, No 3, 211-223.

RHODES, C., 2010, Indium shortages creates problems for solar cell manufacturers. Oilprice.com 8th of October 2010

RIEBEN, B., POORT, J., 2008, Van Maatstaf naar Maatwerk: Toekomstvisie reguleringskader netwerkbedrijven elektriciteit en gas. Amsterdam

RIJKSOVERHEID, 2011, Rol van Rijk bij Green Deals, http://www.rijksoverheid.nl/onderwerpen/energie/green-deal/rol-van-rijk-bij-green-deals, Accessed the 14th of November 2011

RLI (Raden voor leefomgeving en infrastructuur), 2011, Remmen los, Advies over de versnelling van de transitie naar een duurzame energiehuishouding in Nederland. 19th of October 2011, Den Haag

RODRIGUEZ-NIKL, T., 2011, What does it mean to be sustainable? Structures Congress 2011 – Proceeding Las Vegas 14th April 2011

ROOIJERS, F., 2010, 'Stop met subsidies groene stroom' as manager of CE Delft, in De Volkskrant, 16th of January 2010

ROSTOW, W.W., 1960, *The Stages of Economic Growth: A Non-Communist Manifesto*, Cambridge: Cambridge University Press, Chapter 2, "The Five Stages of Growth--A Summary," pp. 4-16

ROTMANS, J. 1994, Transitions on the move, Global Dynamics and Sustainable Development, RIVM, Bilthoven

ROTMANS, J., KEMP, R., VAN ASSELT, M.B.A., GEELS, F., VERBONG, G., MOLENDIJK, K., 2000, Transities & Transitiemanagement: de casus van een emissiearme energievoorziening. International Centre for Integrative Studies (ICIS), Maastricht

ROTMANS, J., 2003, Transitiemanagement: sleutel voor een duurzame samenleving. Uitgeverij van Gorcum, Assen

ROTMANS, J., 2011, Staat van de energietransitie in Nederland, Erasmus Universiteit Rotterdam, 5 April 2011

S

SAXION, 2010, Groen gasinvoeding in Olst-Wijhe, een onderzoek naar de mogelijkheden van de benutting van biomassa voor de productie van groen gas. Gemeente Olst-Wijhe, Saxion Hogeschool, Provincie Overijssel

SCHIPPERS, H.W., VERBONG, G.P.J., 2000, De revolutie van Slochteren, Techniek in Nederland in de twintigste eeuw, Volume 2, Delfstoffen, Energie, Chemie, Walburg Pers Zutphen.

SCHOEMAKER, I. 2009, Aanvullende Voorwaarden RNB Groen Gas Invoeder, Enexis BV

SCHOTANUS, B. 2005 Spoorweggeschiedenisperiode 1860-1880 http://www.spoorweggeschiedenis.nl/nl1860.htm

SMITH, K.B., LICARI, M.J., 2006, Public administrations: Power and politics in the fourth branch of government, Roxbury, February 2006.

SMYTH, B.M., GALLACHOIR, B.P., KORRES, N.E., MURPHY, J.D., 2010, Can we meet targets for biofuels and renewable energy in transport given the constraints imposed by policy agriculture and energy?, Journal of Cleaner Production, Volume 18, Issue 16-17 November 2010, Pages 1671-1685

SOEST, J.P., VAN, 2011, Klompen in de machinerie: bewuste en onbewuste sabotage van de transitie naar een duurzame energiehuishouding. De Gemeynt, Klarenbeek.

STABER, U., MORRISION, C. 1999. The Empirical Foundations of Industrial District Theory.

STERN, J. P. 2002. Security of European natural gas supplies: The impact of import dependence and liberalisation. London: The Royal Institute of Internation Affairs.

STOUT, H., De JONG, M., 2005, Over spreektelegraaf en beeldtelefoon, de rol van de overhead bij technologische transities in infrastructuur gebonden sectoren. Lemma, Utrecht

STRAVER, F., 2011, Energiebedrijven willen hun eigen regulerende codes gaan aanleveren. 27th of September 2011, Energeia, http://www.energeia.nl/preview/1450-Energiebedrijven-willen-hun-eigen-regulerende-codes-gaan-aanleveren.html

T

TILBURG, VAN, X., LENSINK, S.M., LONDO, H.M., CLEIJNE, J.W., PFEIFFER, E.A., MOZARAFFIA, M., WAKKER, A, 2008. Technische-economische parameters van duurzame energieopties in 2009-2010. Report ECN-E-08-066

TROUW, 2011, Kritiek op Green Deal komt vooral uit de 'groene' hoek, 3th of October 2011.

TURPIN, M. PHAHLAMOHLAKA, J., MARAIS, M., 2009, The multiple perspective approach as a framework to analyze social systems in a developing country context, University of Pretoria, South Africa

TURPIN, M., 2011, Mailing conversation with researcher

U

ULRICH, W., 1983. Critical Heuristics of Social Planning: A New Approach to Practical Philosophy. Bern: Haupt.

ULRICH, W., 2005, A brief introduction to Critical Systems Heuristics (CSH),, University of Fribourg, Switzerland and The Open University, United Kingdom.

UNITED NATIONS, 1987, Report of the World Commission on Environment and Development, General Assembly Resolution 42/187, 11th December 1987.

URBAN, W., H. LOHMANN, et al. (2008). Technologien und Kosten der Biogasaufbereitung und Einspeisung in das Erdgasnetz. Ergebnisse der Markthebung 2007/2008. BMBF Verbundprojekt "Biogaseindspeisung". Leipzig, Fraunhofer Institut UMSICHT (FhU), Gaswärme-Institut e. V. Essen (GWI).

V

VELD, IN 'T, R.J., 2010, Kennisdemocratie, opkomend stormtij, Academic Services

VERHAGEN, M.J.M., 2010 Stimulering duurzame energieproductie, https://zoek.officielebekendmakingen.nl/kst-31239-103.html

VERKERK, G.C.J., 1883 , De Rijkstelegraaf en de tegenwoordige exploitatie der telephonie, Nijmegen

VIAG, 2011, Veiligheidsinstructie Aardgas voor energiebedrijven, Arnhem 25th May 2011, Netbeheer Nederland

VISSER, H. Personal announcement, Manager Strategy Enexis BV, 29th april 2011

VISSER, M., 2010, Windmolenclub boos op Mark Rutte: Subsidie is terecht! Elsevier 3 juni 2010

VERSLUIS, K., 2011, Weg met de democratie, citation of Leo Tindemans, Intermediair week 38, p23-27

VLEUTEN, E. VAN DER, KAIJSER, A., Networking Europe, Transnational Infrastructures and the Shaping of Europe 1850-2000, Watson Publishing International, Sagamore Beach

VRIES, DE, L. J., CORRELJE, A.F., KNOPS, H.P.A. 2010. *Electricity: Market design and policy principles SPM9541,* Delft, Faculty of Technology, Policy and Management.

W

WELINK, J.H., DUMONT, M., KWANT, K., 2006, Groen gas, gas van aardgaskwaliteit uit biomassa; update van de studie uit 2004, SenterNovem

WEMPE, J., 2011, Interview on the 5th of October 2011, Zwolle

WEMPE, J., 2011, Ruimte voor Groen Gas, article in progress

WFF, 2011, Enabling the transition- Climate innovation systems for a low-carbon future, Sweden

WIGAL, C.M., 2009, Special Session – Using Rich Pictures to Improve System Thinking, 39th ASEE/IEEE Frontiers in Education Conference. University of Tennessee

Wikipedia.org, 2011, Brundtland Commission, Accessed on the 27th of August 2011, http://en.wikipedia.org/wiki/Brundtland_Commission

Wikipedia.org, 2011, Climate Change, Accessed on the 26th of July 2011, http://en.wikipedia.org/wiki/Climate_change

Wikipedia.org Laantje van Van der Gaag, illustration, Accessed on the 4th of May 2011, http://nl.wikipedia.org/wiki/Bestand:Laantje_van_Van_der_Gaag.jpg

WILTINK, H., VAN SOEST, J.P., 2011, Hamlet in duurzame energie, een analyse van het nederlandse beleid voor (duurzame) innovaties, en aanwijzingen voor een uitweg. De Gemeynt, 6th November 2011

WNF, ROLAND BERGER, 2009, Clean Economy, Living Planet, Building the Dutch clean energy technology industry, November 2009.

WOUD, A. VAN DER, 2006, Een nieuwe wereld, het ontstaan van het moderne Nederland, Bert Bakker

WRR, 2008, Infrastructures, Time to invest, Amsterdam University Press, Amsterdam

Z

ZINOVIEV, S. 2010, Next generation biofuels: Survey of emerging technologies and sustainability issues. ChemSusChem 2010, Volume 3, page 1106-1133, Wiley Weinheum

ZOETHOUT, T. 2010, Gassamenstelling onderwerp van discussie. Utilities Volume 10

ZONDERVAN, K. 2009. *National Interest and European Gas Market Liberalisation.* Master of Science, Universityof Amsterdam.

Appendices

Appendix 1 – Strategic Analysis on Green Gas

Appendix 2 – Historically analogies

Appendix 3 – Transition Management

Appendix 4 – Roles of the distribution system operator

Appendix 5 – List of interviewees

Appendix 1 - Strategic Analysis on Green Gas

In this strategic analysis developments related to green gas are discussed. Using literature and interview discussions an overview arose with a focus on issues that have an influence to the distribution system operator. The main issues are divided over four themes that are specified by the researcher on the basis of consistency. The themes that were distinguished cover a broad spectrum: technological, regulatory, organizational and economical. Yet, when an issue is assigned to a theme this will not automatically mean the issue does not relate to other themes. In Table 1 the issues are listed and the related themes are indicated. A capital X announces which theme is dominant to an issue.

Table 1, Issues categorized by themes

	Technology	Regulatory	Organizational	Economical
Supply Chain	X			
Composition Effects	X			x
Composition Changes	X			x
Lack of Demand Capacity	X			
Network Usage	X		x	
European Legislation		X	x	
National Legislation		X	x	
Connectivity Obligation		X		x
Raw Biogas		X		
Certification		X	x	x
Capacity Balancing	x	x	X	x
Gas Hub	x	x	X	x
Demand Developments	x		X	
Responsibilities		x	X	
Monetary flow			x	X
Subsidy		x		X
Food Prices				X
Allocation dis-/advantages			x	X
Subordinated areas				X

For now we will start giving an explanation of the distribution system operator's role within the Dutch gas sector and give a general introduction on green gas.

A. Technology

Technology is the basis of the gas distribution and is also a precondition for a successful implementation of green gas. In this section the technological supply chain will be discussed compared to the upstream and downstream part of the natural gas supply chain. Furthermore the indirect effects of the changed network use are analyzed. Every section will end with a brief summary complemented with notions for further research.

A.1 Supply Chain – Upstream

Within the gas supply chain we could distinguish several elements starting with the upstream side, which includes exploration and extraction of natural gas. The 'upstream' side of green gas starts with the gathering of resources that will be used during the actual production process. For green gas this covers the gathering of resources, the conversion step to biogas and the additional upgrading process. There are lots of different resources that could be used for the production of green gas. Landfill, manure and sludge are commonly used, but actually all organic material could be used as resource. A significant volume of biomass is needed to produce a constant amount of green gas. This would be a major bottleneck for a successful implementation of green gas since import of biomass is a precondition. Transportation is therefore also reported as a critical factor in a bio-energy chain (Boerrigter, 2006).

Compared to the supply chain of natural gas the processes differ in the upstream level. There is no actual production process for natural gas meanwhile we find exploration and extraction on the upstream side. The variety of production processes of green gas were discussed in section 1.2. Developments in these production processes could influence the supply chain as well. A visualization of the above is given in Figure 3.

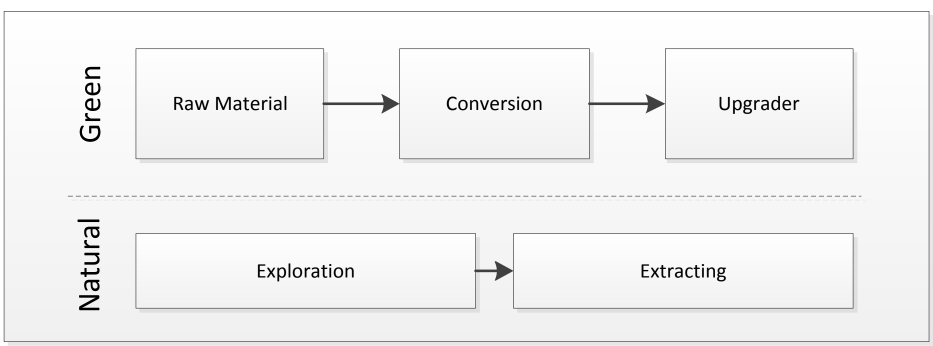


Figure 1 Upstream structure

At the moment the composition of the natural gas that is supplied by GTS has a very small bandwidth, in the sense that the calorific value, methane number and amount of hydrocarbons are relatively constant. In the near future this composition will change significant since more and more gas supply comes from abroad. Supplies from Russia, Qatar and several LNG producers will transport their gas towards the Dutch gas network. This is in line with the possible realisation of a North-Western Europe gas hub in The Netherlands, which will be discussed in section 4.2. However this will lead to more suppliers and could cause more competition in the gas market, the costs and risks of the usage of different kinds of gas has to be compensated by the consumers (Zoethout, 2010).

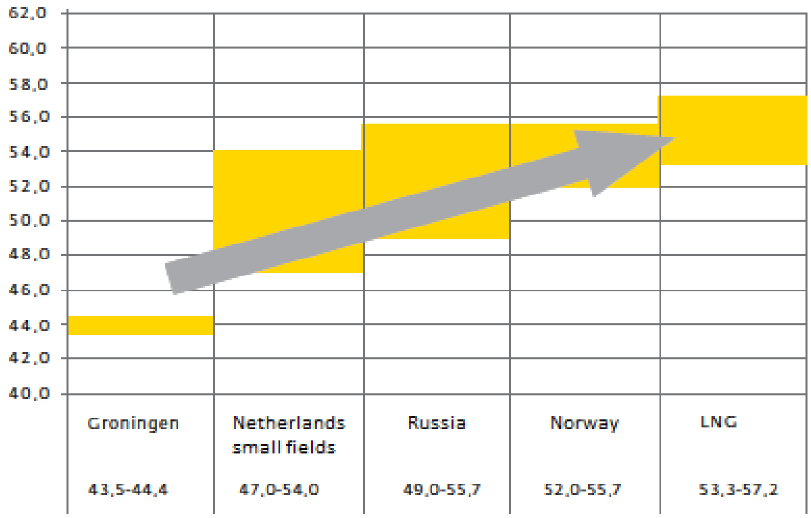


Figure 4 Wobbe index bandwidth different gas qualities (GTS, 2009)

Gas from small fields in The Netherlands is currently upgraded to meet the quality the Groningen field is offering. Yet upgrading of the future sources will bring complications since at the one moment Russia is feeding in, while 15 minutes later an LNG shipper offers his product with different standards to the network. As can be seen in figure 4, the Wobbe index bandwidth is different for each specific gas product. These continuous changing gas specifications will have major consequences for Dutch industries. Some machinery which is directly linked to the high pressure network should probably be substituted since they cannot operate with a broad bandwidth. Industries argue that the costs involved with this transition of their machinery should not end up at the industry alone. The TSO argues that Dutch industries experienced a luxurious position over the past decades and that they depend on the input of their network. A future growing production of green gas will also effect this development regarding the gas composition (Zoethout, 2010).

The supply of green gas production resources is a major bottleneck for large-scale implementation. The necessary volumes make import inevitable and on the long-term, in case more countries start producing on a large-scale, scarcity could arise. There is a need for knowledge on the potential of biomass that a country can meet. Since the sustainability of the supply chain starts with the origin of the resource production, long distance import will increase the carbon footprint and decrease the overall benefit of green gas. It should be monitored whether or not the production really contributes to the environment. Furthermore the impact and complications of changing gas compositions, due to increased import and a differentiation of import countries, needs to be clarified.

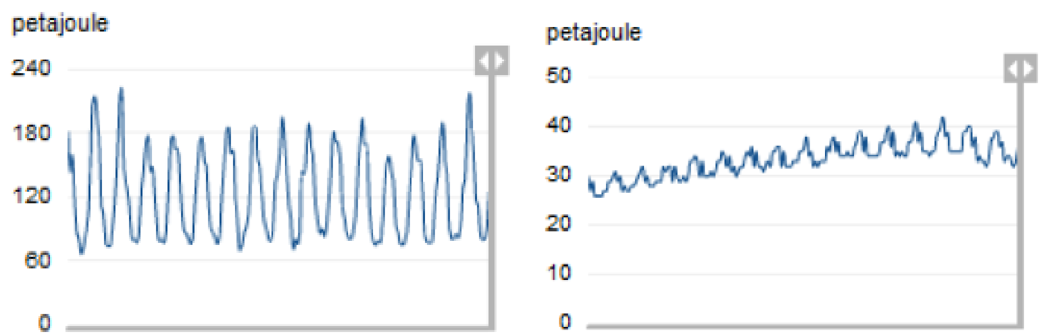
A.2 Supply Chain – Downstream

On the downstream side the supply chain includes transport and distribution to the actual consumer of the gas, like the industry or households.

However the transport system operator (TSO) offers total facilitation of green gas injection when it meets the specifications of natural gas, the TSO is reluctant. The probability of small amounts of contaminants in the green gas raises specific questions. Insufficient knowledge on the effects of contaminants on the transport pipelines of TSO creates uncertainty. Research is needed on the influence of bacterias, fosfines, burning behavior of halogenated hydrocarbons and the possibility of microbiological corrosion of piping (Polman, 2007)

Until more research is performed on these effects in the transport network is not always facilitated by the transport system operator. GTS refuses the injection of green gas that according to their standards could not meet the specifications for transportation (KEMA, 2010).

The distribution system operators (DSO) face difficulties when injecting the green gas directly in their network, mainly related to capacity. The use of natural gas in The Netherlands is variable compared to the energy usage. In Graph 1 both are plotted, especially the significant difference in amplitude is clear (CBS, 2011). Seasonal fluctuations in temperature are the main cause for this. During the winter period, operation of gas operated heating is the major energy consuming activity. Additional also daily fluctuations occur. When focusing on the production of green gas it is important to mention that this is not as volatile as the consumption, but quite constant.



Graph 2: Usage Natural Gas(left), Usage Electricity(right) in The Netherlands 1995-2010

The seasonal difference in production and consumption of green gas creates an imbalance. When the green gas is directly injected to the distribution network the regular production of natural gas will compensate scarcity of green gas. Network operators will supply additional gas to the distribution network. An imbalance could also arise the other way around. For example during the summer period when the demand is at the lowest point and the green gas production transcend the demand. The supply within the direct distribution area of a green gas producer appears to become higher than the actual demand in that specific area. A distribution network does usually not have enough capacity to compensate this difference. Gas could only be injected when there is simultaneously enough demand in the distribution network. But since producers of green gas are usually located in low density areas this demand is lacking periodically (Enexis, 2010). There are three technological possibilities to overcome difficulties of under capacity.

1. Use longer connection pipelines to areas with a high demand
2. Inject the surplus of the distribution network in the high pressure transmission network
3. Use collecting pipes for collective production

The first option is currently executed in Zwolle. The producer needs to compensate the costs of the connection pipeline and compressor. Therefore this option is relative unattractive for small producers, since these costs are relative high.

The feasibility of the second option is currently under research. Advantage will be that the connection costs could be avoided and the producer can use their own consumer connection. At the moment the system components that connect the distribution network with the transport network, Gas Ontvangs Station (GOS), are currently not able to inject the gas in this opposite direction.

The final option will higher the capacity of the central production unit, and is already operational in several pilots. The upgraded gas will be used as direct gas resource or as fuel for a CHP. Rest warmth could be used as well.

The upgrading of biogas is an expensive process. Therefore a significant cost reduction could be made using option 3. Economies of scale will arise when a collective pipeline is used to transport the biogas to a central upgrade. Costs of the pipeline itself are relative low compared to the total project costs (Enexis, 2010).

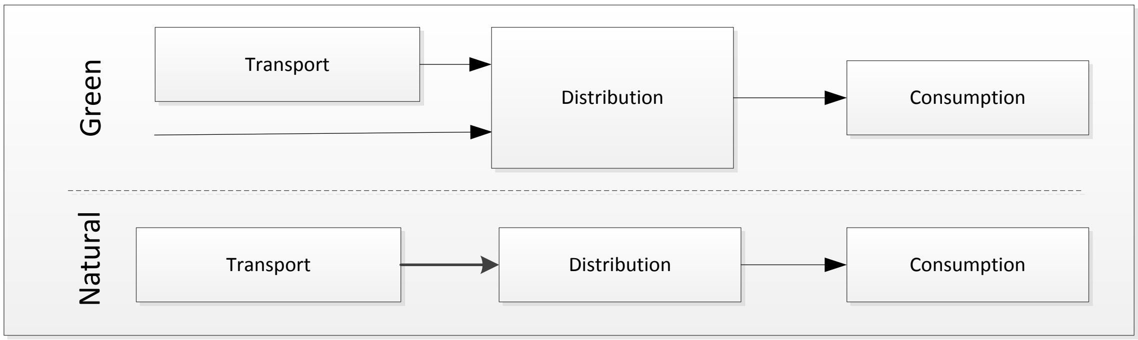


Figure 5 Overview Downstream

The structure of the technological supply chain will change because of green gas. Green gas could be injected in the distribution grid directly without being transported by GTS. Yet this could rise problematic situations when the supply overruns the demand in the distribution network. The gas volume that could be 'stored' in the pipelines is limited. All proposed solutions are still in its infancy. Also the unknown effects of green gas contaminants will be points of attention. Those are all direct effects that influence the technological system the next section will emphasize more on the indirect effects of green gas usage.

A.3 Network Usage

Indirectly an important notion is that there is a need to use the system as a whole differently. The distribution and transmission network were originally designed for central infeed purposes, it is questionable if decentralized gas injection of green gas producers could cause problems from a technological perspective(Gigler, 2008). It is plausible that the assets Enexis owns will be used with a different load compared to the current situation. As the center of gravity is now concentrated in the central infeed and transmission network, considering a major role for green gas this center of gravity will be spread over transmission and distribution networks. More gas will flow in the distribution networks and less is needed from the central infeed towards the end consumers. The operational assets are based on design requirements from a central infeed perspective. A combined infeed with green gas producers, natural gas production from Groningen and several small fields will change the requirements of the network design. Figure 6 shows a schematic representation of both situations. This could probably have short-term effects on the asset replacement strategy of Enexis.

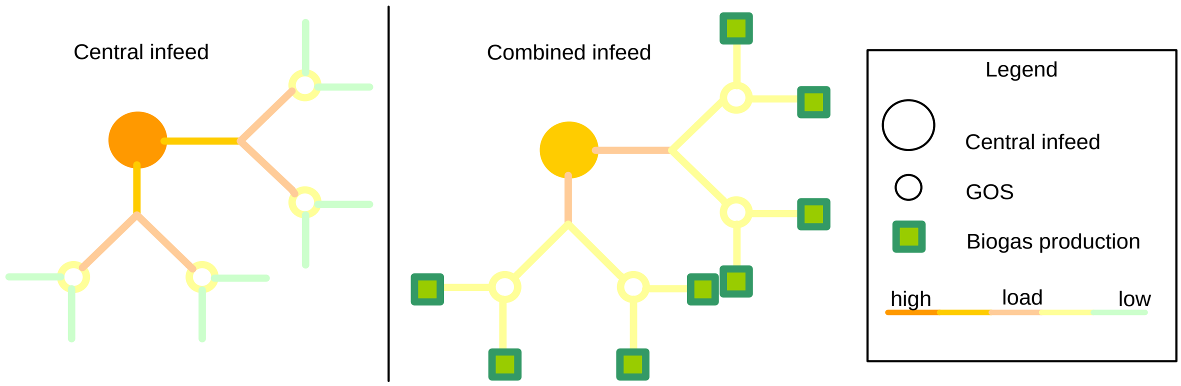


Figure 6 Schematic representation network load

Currently Enexis is monitoring their assets using a Risk Based Asset Management (RBAM). Within this analysis methodology several indicators are included to monitor the condition of assets. For example the specific materials, the connection mechanisms and the risk on gas leakages will have influence. The RBAM is combined with the Failure Mode, Effects and Criticality Analysis (FMECA), that monitors all relevant problems and recovery possibilities for specific assets and results in a conservation strategy. These strategies could be doing nothing, perform periodical inspections, periodical maintenance, overhaul or a combination of them. Since the majority of the current gas infrastructure is installed in a short period of time asset lifetime related failures are expected to concentrate in a certain period of time. According to future predictions the frequency of lifetime related failures will increase. This causes a vicious circle since more operational engineers will be needed to repair or replace these failures adequately. Less engineers will be available to perform preventive maintenance, which eventually result in even more failures. Enexis has developed a preventive replacement strategy to decrease these amounts of failures. In Figure 7 the expected unsafe situations are shown including the preventive replacement strategy.

Figure 7 Expected amount of unsafe situations, current policy and preventive replacement

Enexis has hundreds of different specific assets with specific characteristics, for the gas infrastructure this concerns the connection and main pipelines. The monitoring strategies Enexis applies result in the replacement in assets that are in the worst condition instead of the oldest. Large-scale transport and distribution of green gas will probably influence these monitoring tools. One could imagine that parameters in the calculation of the vulnerability of assets will depend on the average use of the assets. The changing network usage could result in a higher capacity load for the assets in the distribution network, a consequence could be that their reliability decreases.

The assets in the network will be used different, since the center of gravity switches from a central infeed towards the injection of de-central production units. For the DSO this could have direct effects on their replacement strategy which is part of the Risk Based Asset Management. Firstly more information is required to investigate the impact of a different network usage. These results could influence parameters in the preventive replacement strategy model.

Concluding we can distinguish the macro level, potential domestic biomass, and the micro level, techniques for production and upgrading. Additional on the meso-level, operations level of a green gas supply, very little research has been done. Within this meso-level the knowledge gap arises according to Bekkering; more detailed research would be necessary when insight in a local biomass supply to a digester is needed(Bekkering, 2009).

B. Regulatory

The potential success of large-scale green gas usage will considerably depend on the political targets that countries pose (Zinoviev, 2010). Therefore the inclusion of regulation within this strategic analysis is inevitable. An important notion that has to be made on forehand is that there exists a complexity within the legislation of green gas. Smyth et al., clarified the complexity of biofuel legislation in Europe, a major application of green gas (Smyth, et al. 2010). It appears that different regulations share interconnections towards each other and could even have opposite requirements.

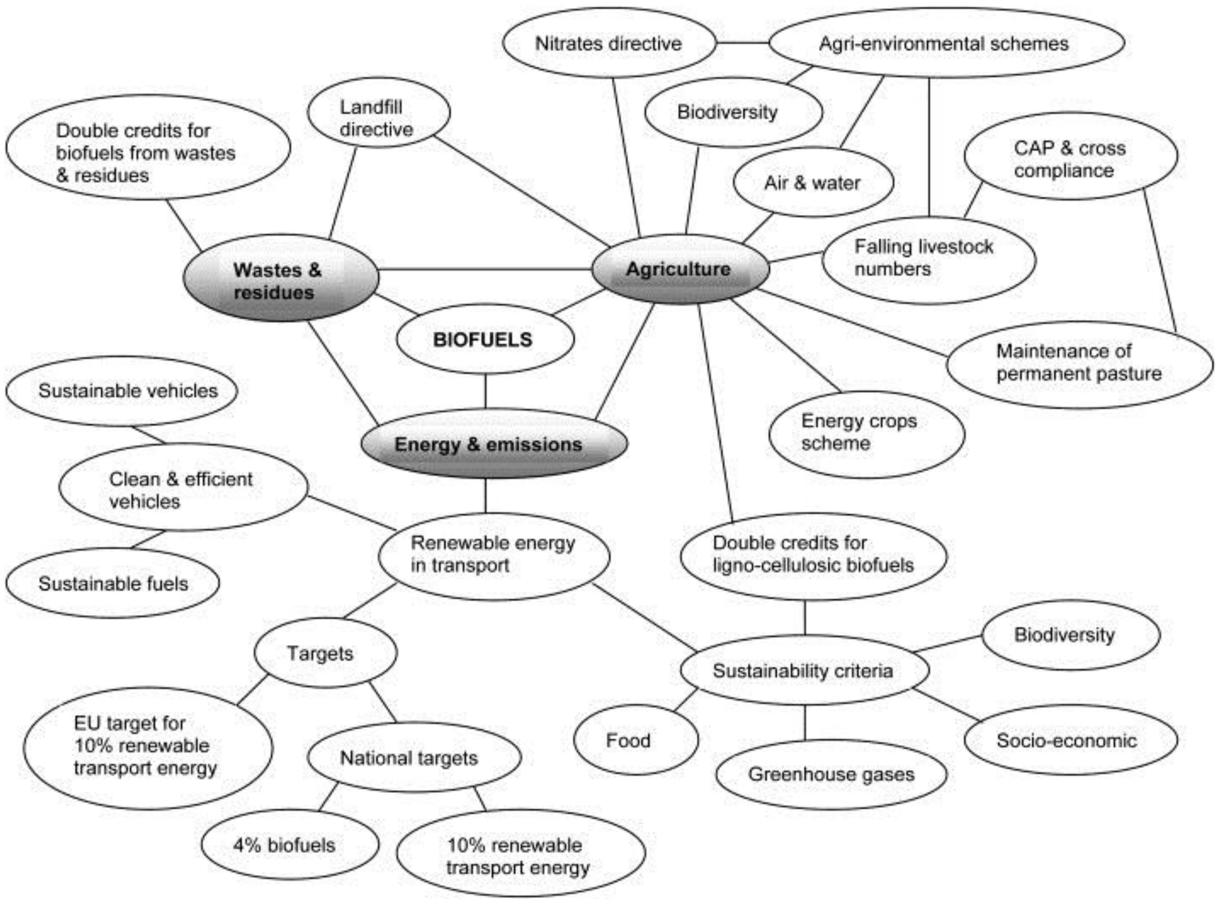


Figure 8 Regulations influencing biofuels in Europe

Figure 8 shows Smyth's analysis. In this regulatory section of the strategic analysis two layers in green gas legislation will be discussed, the European and the national. Especially the connectivity obligation and legislation considering raw biogas are discussed in further detail since these could have a significant influence on green gas development.

B.1 European regulatory framework

Today's energy regulation is motivated by environmental and economic concerns. First of all there are the environmental developments which include emission of greenhouse gasses and global warming. When in 1997 the Kyoto protocol was signed the European Union agreed themselves on a reduction of greenhouse gasses of 5,2% on average in the 2008-2012 period. After allocation this resulted for the Dutch energy consumption in a 6% reduction target. Secondly the awareness of resource depletion could de-stabilize the energy security of the European economy.

The European Commission adopted several directives in order to fulfill those targets.

1. 2009/28/EC on the promotion of the use of energy from renewable sources
2. 2009/33/EC on clean and efficient vehicles
3. 2006/32/EC on energy end-use efficiency and energy services
4. 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport
5. 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market

Above directives sets several targets like a 20% reduction of greenhouse gasses in the period 1990 till 2020, a 20% share of EU energy consumption to come from renewable resources and a 20% energy efficiency in primary energy use compared with projected levels. Furthermore some specific targets were adopted to make the transport sector more sustainable. An example is the aim to substitute 10% of the fuel in transport by biofuels in 2020. This offers a window of opportunity for green gas. Natural gas is already a relative clean energy source but a large-scale usage of green gas would contribute even more to these sustainability targets (Zinoviev, 2010).

Besides the environmental considerations that shape green gas related legislation, the EU also adopted legislation for economic purposes in order to change the market structure of the European gas market. The European Commission assumed that competition would increase the security of supply by sending the right investments signals to participants in the gas industry (European Commission, 2006). But according to Stern the statement that liberalisation improves the security of supply should be made with great care (Stern, 2002 p.4).The fact that liberalized markets are more secure than other markets only holds in specific circumstances. An important precondition is the guarantee that dominant players could not exercise monopoly power over certain commodities or services as transportation. The network ownership that involves a natural monopoly should be regulated to offer suppliers the possibility to compete on a fair and non-discriminatory basis. Something a liberalised market could claim is that it "*offers acceptable and efficient levels of supply security at much lower costs than traditional markets"*(Stern, 2002 p.26). In the original situation the security of supply was safeguarded by the monopolist at probably relative high costs. Market deregulation and liberalisation should bring the user lower energy costs and a better quality of services. Since the exploration, production, transport and supply of gas was often included in one company, the incentive to facilitate the entrance of the market for green gas was lacking.

Another specific element that influences the European legislation is concerning possible crisis situations. Former solidarity obligations have the consequence that member states will be asked to share available supplies in emergency situations. Because of the liberalisation exchange trading will be created and financial instruments will allow for a more efficient allocation of available supplies and provision of the transport capacity in case of emergencies (Stern, 2002 p.24). However this sounds plausible, important notions should be made here as well. Of course the willingness to share gas supplies in case of emergencies is needed, but the infrastructure should facilitate this sufficiently as well. Furthermore the risk exists that gas importing member states tend to rely on their suppliers and their degree of responsibility will be reduced, this could negatively influence security of supply arrangements on a national level (Zondervan, 2009). Green gas could partly prevent this situation since all European countries could produce a certain amount of green gas by themselves and strengthen their own security of supply position.

In line with the European will to remove restrictions in the movement of goods, services and capital the first gas directive in 1998 introduced the third party access (TPA). This gave natural gas suppliers and its customers the right to transport their gas through the existing pipeline network. From that moment on the TSO of natural gas should refrain from discriminating system users (article 13(1b) of 2009/73/EC and article 14 (1a) Regulation 715/2009).

Exceptions could be made whenever the TSO is facing a lack of capacity, an access would refrain the TSO from fulfilling their public service obligations and finally serious economic and financial difficulties with take-or-pay contracts (Kruimer,2009). An unrestricted access to the network is of major importance for producers of green gas, since this would guarantee their revenues, but this is not legally determined.

European regulations and directly linked targets offer a possibility for a large-scale implementation of green gas in the future. However to ensure the desired public value of affordability, the market structure should be organized carefully, liberalization appears not to be a successful recipe by itself. In perspective of the solidarity agreements in Europe, green gas could contribute to the security of supply of specific countries, due to its de-central production possibilities. Unrestricted third party access of green gas appears to be a major precondition.

B.2Dutch regulatory framework

On a national level the European directives formed the basis of the Gas Act of 2000. The former utility companies became private organizations, while the transmission system were separated and owned by governmental organizations. Some industries were immediately allowed to choose the supplier of their own choice, this became also possible for regular consumers from 1st July 2004 when the energy market became totally liberalized. Meanwhile several changes have been made mainly related to sharpen the regulation on network operators and the determination of tariffs. On the 1st of April 2011 a new balancing regime is launched, this will make all market parties responsible for the network balance. The competition authority expects that this will contribute to the safety and efficiency of the network (Energeia, 2011).

The distribution system operators are involved with the policy making process. The outcomes of these processes are usually as expected and do not create any problems for the DSO. This since the DSO's are owned by governmental organizations and the legislator has corresponding goals in line with the DSO: affordability, reliability and sustainability of the energy infrastructure. However Enexis has set itself a goal to actively participate in facilitating the energy transition, they do not lobby actively regarding regulations of green gas. Their current position offers the opportunity to discover possibilities with green gas projects. Lobbying could lead to changing legislation that creates abrupt obligations for the DSO, which could cause a lack of resources (Meeberg, 2011).

Licensing of anaerobic digestions is defined, yet in practice economic feasible installation of digesters up to 36.000 tonnes a year are difficult to realize. Governmental zoning are not accommodating these activities. And additionally there is discussion whether or not anaerobic digestion could be defined as an agricultural activity. The council of state decided in 2007 that a manure digester cannot be seen as an agricultural activity(Dumont, 2008). So it appears that clear definitions are needed in practice.

The new balancing regime will give the need for information on supply and demand a higher priority. Green gas will cause a more supply driven market, compared to the current demand driven market. Information on the supply was subordinate since production could be adjusted easily. The constant production volumes of digesters will cause a constant supply and add a constraint to the balancing activities. Furthermore the legal position of green gas production units should be defined to facilitate starting producers in their process.

B.3Connectivity obligation

Concerning the DSO an interesting addition is made in the recent Gas Act. Even as is the case in the Electricity Act there is introduced a connection obligation. DSO's may not refuse the request for a connection anymore. This does not change much in most situations since DSO's already carried out most of the requests. There is still a discussion about organizations or persons in the so called 'white areas', these are areas located far from populated areas. Currently there is no definition available for those areas, even after the DSO's have offered a definition proposal towards the competition authority. A definition should be uncomplicated and generally applicable. The connectivity obligation only accounts for buyers of gas, so there is not yet an obligation to connect producers of green gas.

The organization or person that makes a request should pay for this connection by themselves when the pipeline is not part of the actual network of the DSO. Farmers are often located on a significant distance of the distribution network and since every meter will approximately cost € 100,- distances of e.g. 3 kilometres will already cost € 300.000,-. However this is a large investment for farmers the costs of an upgrading facility are relatively much higher. Yet the funding of this investment faces difficulties in practice, the connection pipeline is namely in ownership of the DSO. So the end user is paying assets that he could not refund which makes loaning money difficult. There is another issue concerning the connection obligation explained in Figure 9. The connection between Farmer X and the pipeline of the distribution network will be funded by the Farmer. But when nearby Farmer Y also wants a connection to this pipeline (so a pipeline has more than one user) the judicial state of the pipeline between the distribution network and the splitting point of Farmer X and Y will change from 'connection' towards 'network'. The DSO is responsible for the construction and funding of the network part and the restitution arrangement comes in. According to article 2.4.5 of the Gas Act the DSO has to compensate the investment made by Farmer X for the shared pipeline. This means that the whole community contributes to one single gas connection that costs thousands of euro, while the gain is relatively low since the farmers could choose for de-central storage near their farm. Probably the legislator will propose additional rules in the near future that will overcome this situation (Van de Pas, 2011; Gas Act 2011).

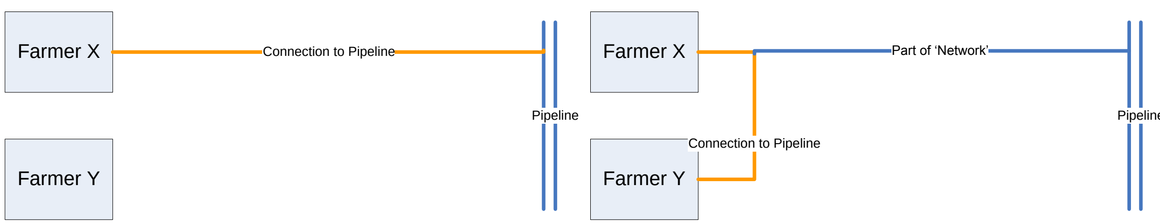


Figure 9 Complication shared connection by connection obligation DSO

With the new Gas Act the ministry seems to force DSO's in supporting the energy transition by creating the connectivity obligation. This resulted in above complication. Probably this would not have happened when the DSO's took the lead in the process towards new regulation.

Difficulties that are faced due to the connection obligation concern the delineation of the 'white areas'. Under which conditions should the society compensate gas connections. The explained farmer dilemma is a clear example here. This raises questions on how to select solutions that meet the lowest societal costs of green gas projects. Further research on how public values relate to the costs made by the society could provide a guideline including requirements for future projects.

B.4Raw Biogas

Since the Dutch target would require a total of 1500 million m3 green gas, ca. 2500 m3million biogas needs to be produced annually. One farmer will probably reach an output of ca. 300 m3 biogas per hour (Van Tilburg, 2008). Assuming a total of 8500 operating hours a year, in total 980 digesters would be needed in The Netherlands (Bekkering, 2009). It is questionable whether or not so many digesters are desirable in the country, additionally questions rises how to connect these digesters to the grid. A commonly suggested option is the creation of hubs, what also could lead to economies of scale.

Because the costs of an upgrading facility are high, some producers initiated the idea to gather their raw biogas and transport this to one central upgrading facility. This could make the overall system commercially more attractive. From 2010 the first Green Gas Hub initiatives in The Netherlands started their initializing phase, pipelines should connect 12 Frisian farmers and gather a significant amount of biogas. The biogas is upgraded to natural gas quality and the network of GTS is used for transport purposes. Four other green gas hubs are planned in the near future, producing enough to supply a total of 150.000 households (Rakhorst, 2010). An interesting notion is that the necessity of biogas upgrading is unknown. Very little is known about the possibility of mixing off-spec gas with natural gas (Bekkering, 2009). So probably the production of biogas without upgrading with digesters will economically be more advantageous.

There rises a chicken or the egg causality dilemma since governmental organisations suggest the DSO's in starting the installation of biogas pipelines to create an incentive to start biogas production. The DSO's argue that there is no reason to realize pipelines when there are no potential producers available. Legal and economic circumstances are main causes here. According to the Gas Act, raw biogas is not defined as gas. A DSO has therefore no rights or obligations. Yet Enexis is still pro-active in supporting these producers of raw biogas because the company positioned itself as a key player in the facilitation of the energy transition. Concerning the installation of biogas pipelines a DSO acts as a commercial player. Besides Enexis also other DSO's or construction companies could be requested to install a pipeline network. However when people suspect a gas leak they will automatically warn the local distribution system operator, who is in this case not the owner of the pipeline. So clear defined rules have to be made that covers the responsibilities and remuneration in construction and maintenance activities. When additionally the national legislator includes biogas in the Gas Act, responsibilities could be formally arranged. This would offer the system operators better opportunities to collaborate in these projects, especially concerning the economic perspective (Van de Pas, 2011).

On the other hand the possibility of suspecting a gas leak is also an issue here. Several kinds of raw biogas are not suitable for odorisation there they consists to much dominant fragrances like sulphur. The odorisation process is therefore also an important step in the upgrading process towards green gas.

Furthermore the costs of the biogas pipelines are relatively high, compared to the feasible pipelines. Due to uncertainties of biogas effects additional safety measures are applied, e.g. biogas cannot be odorized which makes it necessary to add secondary safety measures(KIWA TECH,2009). These measures increase the costs of the pipelines significantly and cause that they are not economically attractive. Biogas project are therefore unattractive to investors. Here the government should also reconsider current structures. The combination of safety, which is of course an inevitable public value, and the innovative technology to facilitate biogas, which is a prerequisite towards a viable energy transition, makes the realization of biogas projects financially and technological impossible(Visser,2011).

Stimulation of biogas production, the final product phase before it gets upgraded to green gas, will also contribute to green gas possibilities. Therefore it will contribute to the energy transition when the DSO could also offer a helping hand to biogas producers. Currently the chicken or egg causality dilemma is at stake, governmental organisations wants the DSO to realize biogas pipelines to create an incentive for potential producers, while the DSO does not want to realize pipelines without the availability of potential producers. The legal position of biogas is such that the DSO will not be compensated for distribution or maintenance services. Economies of scale will make the upgrading process more attractive, so small-scale hubs between biogas producers could create a more economical attractive industry. Something that would contribute to the potential of biogas since the current safety constraints boosts the cost of the projects to unacceptable levels. On the other hand also the quality is under scrutiny. The possibilities of mixing off-spec gas with natural gas should be investigated, since this would offer a significant cost reduction.

C. Organisational

As was mentioned in section 1.1 the current gas sector has a variety of actors. These actors have network characteristics as variety, interdependencies and closeness. The variety becomes clear when taking a look at the goals, objectives and interests. Where consumers probably will focus on affordability, organizations with processes highly-depend on reliability of the energy supply such as hospitals will be willing to contribute relatively more money to ensure this reliability. Furthermore an important notion concerning this network is that actors share certain interdependency among each other. This could include funds, authority, information, political friends, etc. Where the one actor needs the other in financial perspective, the other could have more influence within the legal world. These mutual dependencies could exhibit moderate behaviour of the actors towards each other which in the end could lead to a cooperative attitude. When actors are not by definition sensitive for external interventions the closeness of organisations comes in. Intervening actors who are willing to realize specific goals need the support of others. But when certain interventions do not fit in actor's core values there is little chance of success (De Bruijn, 2008). The organizational network of actors is complex and dynamic, in the sense that all network characteristics will change over time.

Organisational needs concerning green gas create additional implications for involved actors, like certification, capacity balancing, responsibilities and inter sectoral cooperation.

C.1 Certification

In 1.2 the production process of green gas is described. There producers use a wide variety of resources, in a variety of production volumes and using different methods of production, quality measurement is a main issue. Especially since the impact of the presence of contaminants in the green gas is unclear. The probability of assets' corrosion caused by 'polluted' green gas is unknown but not unlikely. Safeguarding the public value of a safe gas infrastructure urges the sector to arrange a solid certification trajectory. In The Netherlands Vertogas is responsible for the certification. The certificate would guarantee the origin of green gas, comparable to the already existing green energy certificates. The intention was to make green gas more visible and make the product negotiable. Certification is not obligatory and currently consumers are not demanding the certificate from the supplier. According to suppliers there are other ways to guarantee the origin of your product, e.g. using a qualified statement. Though Gasunie claims that certification is one of the preconditions to come to a successful implementation of green gas (Energeia, 2010). In the situation without certification the producer was obliged to arrange a virtual buyer and a physical consumer connected with the distribution network where the green gas is injected. Injection of a certain amount of green gas will become available. A consumer will buy a certain amount of gas from the network and the certificate. This decouples the demand and supply, which takes away a huge barrier for the producers. Additional an advantage that is mentioned by the Energy Transition Platform is the possibility to make a direct coupling with the national monitor for sustainable energy (Dumont, 2008).

The certification organisation Vertogas is in 100% ownership of Gasunie, this could raise questions. This means indirectly that the TSO decides whether or not green gas meets the requirements to enter their network. Gasunie itself has low priority to making green gas successful. The company is facilitating gas transport and produces natural gas, which is actual a competing product of green gas. But most important issue, Gasunie is not willing to take much risks on their expensive assets. Besides it seems that most green gas producers are willing to inject their green gas directly in the distribution network, which makes the DSO a more important actor in the certification process. An independent authority would probably bring more transparency and offers opportunities to green gas producers by creating a wider specification bandwidth. Although it is important to mention that effects on the assets are still unclear and that this is a major issue for further research.

The risks and uncertainties that are related to green gas created opportunities for certification in the sector. But the current total ownership of Gasunie over certification organization Vertogas raises questions on the transparency of this organization. To come to successful certification that the acceptance of the green gas producers to join the process is of main importance. A certification obligation could help here, since currently the number of certified companies is very low. The decoupling of supply and demand will take away a barrier for the producers.

C.2 Capacity Balancing

As is the case for electricity also gas is bounded to a precise balancing regime. This process is compared to electricity relatively easy for gas. When the pressure in the network meets a certain level the production of the Groningen field can be reduced partly or totally. This offers a flexibility that meets the volatile consumer behaviour, which is discussed in section 2.1.2.

One organization needs to be responsible for the balancing regime, which is in The Netherlands, GTS. Consuming information of large industries are known on forehand, which offers GTS the possibility to plan domestic production capacity, import gas from abroad or fill/use storage facilities. Production of green gas is constant, which gives a balancing organisation the obligation to create sufficient demand space. Most green gas producers are located in low-density areas because the production of resources is often an agricultural activity. Consequence will be that the balancing task becomes even more complex.

Figure 10, production locations green gas The Netherlands (Vertogas, 2011)

The produced green gas is located in areas where a lack of demand is at stake during a significant period of the year. Information of producers and a reliable indication of small consumers will be key in realizing a successful balancing regime when green gas takes a significant market share. This will give the balancing organisation the opportunity to allocate the produced gas in the most effective way. The renewed Gas Act of 2011 makes a step in the right direction with the changes in the wholesale market organisation. Large consumers become responsible for their own balancing position (Gaswet, 2011).

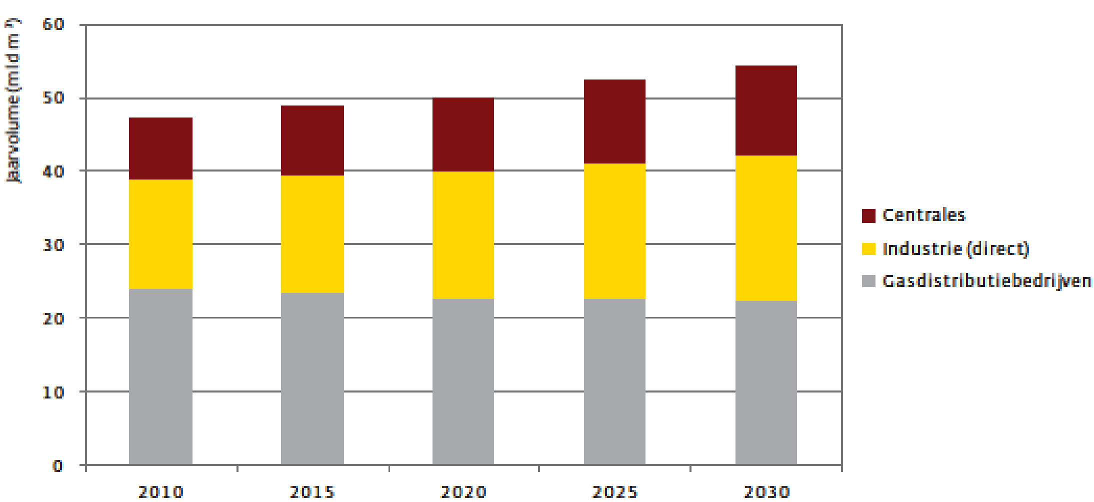
The ministry of Economic Affairs has set the goal to realize the Gas Hub of North-Western Europe within The Netherlands. The Dutch characteristics look promising, since the existing infrastructure is of high-quality, offers reliable transport services and has potential storage locations available in former gas fields, which could offer some additional flexibility. As was discussed in section 3.1 European directives urge member states to deliver supplies to other member states in case of emergencies, a service that needs certainly to be facilitated by a possible gas hub. Realizing a gas hub would also offer several economic advantages. The role of the country will shift from production oriented towards a more facilitating and service role especially in the future role of The Netherlands when there gas reserves are depleted. An important risk is the opposition of citizens within the country on realization of storage facilitates. Examples in Bergen and Pieterburen have proven that these storage projects face difficulties. Critics argue that neighbouring countries, like Belgium and Germany, would not support The Netherlands in the realization of their Gas Hub. These countries are currently investing in LNG terminals and storage capacity themselves. Without collaboration from surrounding countries the Gas Hub is likely to fail (Financieel Dagblad, 2010).

When becoming an important hub in the network the balancing regime is becoming even more complex due to the extension with more users and a larger capacity. The potential implementation of green gas will contribute to a diversification of the gas mix and would therefore make the country less depending on one supplier.

The capacity balancing regime will face challenges due to the presence of green gas producers in low-density areas. Production and demand information will be key in meeting the public value of reliability. Cooperation between various stakeholders is necessary and should be facilitated within an organizational structure. Here responsibilities, rights and obligations should be defined, also the allocation of costs related to capacity issues needs to be covered. Furthermore the Netherlands should be able to cope with even more fluctuations when it wants to fulfil their ambition to become the Nort-Western European Gas Hub. Green gas will contribute to the objective the gas hub is aiming for, creating independency due to a diversification of the resources.

C.3 Demand development

The Dutch energy market seems to switch from supply driven towards partly demand driven. Customers are aware of the origin of their energy and an increasing amount is willing to pay for green energy (Geels, 2002). This is an advantageous development for green gas, but what it the future potential? To estimate this green gas potential in the future, developments in the demand on natural and green gas should be investigated. The overall demand in North-Western Europe tends to increase the coming years. However the domestic use by households is expected to decrease slightly, this because of energy efficiency of households and an improved isolation. Compared to 1978 the gas consumption of households was decreased by 50% until 2007. Parallel to this the industrial demand will increase which will result in an overall increase of 15% in 2030.



Graph 2. Demand The Netherlands specified by end-user (GTS, CPB, ECN, 2009)

An interesting notion on the demand side is that gas and electricity both are getting involved into each other's market and also their infrastructures seems to get more integrated. Electrical heat pumps are developing as a serious alternative over the current heating methods by gas, while the gas driven CHP develops an equal position for electricity generation. Since also the heat demand of households is decreasing, e.g. improved isolation, the question is raised whether or not the installation of gas infrastructures is economical feasible in newly developed areas. Electricity supply could cover the overall energy need. Future developments will depend on price differences. Developments in storage technologies for electricity, heat and cold will influence the dis- or advantages of both energy sources.

Because of the CHP and other de-central generation both infrastructures will become more integrated. Using the CHP the electricity market could better respond on limited steerable sustainable energy sources. Furthermore the flexibility could be improved using gas turbines (Platform Nieuw Gas, 2008).

Energy demand will increase in the near future. Yet the role of gas in the future is uncertain, due to the integration of electricity and gas in usage and parallel their networks. The role of gas could mostly being substituted by electricity, but this mechanism could also work the other way around. Overall the expected potential demand strengthens the potential in green gas.

C.4 Responsibilities

However European, national legislation and core values of several companies create the expectation that everyone is willing to contribute to a more sustainable society, no project leader is appointed. In 3.2 we already announced that Enexis claims to facilitate the energy transition and this is the main reason for their involvement in sustainable potential projects like electrical cars, smart grids or bio- and green gas.

Also responsibilities regarding risks are not identified. Which actor in the supply chain is responsible for gas that does not meet the required specifications? According to the terms and conditions the producer is responsible for the gas quality. The producer will also be held responsible for damage related to the injected gas caused to any legal entities including the DSO's assets (Schoemaker, 2009). When gas is injected in the distribution grid it will mix with the gas that is already within the network. It will be hard to prove that any irregularities are caused by a certain green gas producer. So in practice Enexis seems to be responsible for a product that has unknown effects on their assets and the machinery of its consumers. Therefore there is a need of uniform quality standards which also relates to the certification issue.

Ownership of assets could also be reconsidered when, as suggested in section 2.2, the network will be used also in the opposite direction. GTS owns the GOS, while the DSO owns the casing house. The DSO is making agreements with green gas producers currently and faced capacity issues, a GOS that could distribute gas in two directions would be advantageous for them. When the GOS facilitates the gas transport from the high pressure pipelines towards the high pressure pipelines a larger take-off area arises. This shifts the problem owner from Enexis to GTS that needs to allocate the produced gas. When green gas production meets the expected potential of 50% of the total usage in 2050 also the domestic demand could be insufficient and the TSO should search for storage facilities or export the green gas.

Responsibilities is case of failures causing damage are unclear. However they are defined more or less in terms and conditions, the gas product will be mixed soon with gasses from other origins which makes it difficult to trace the cause. This makes a need for a uniform quality standard necessary and it clarifies the profit a functioning system of certification could bring. The other point of attention includes the asset ownership. Since additional function to the GOS will shift the problem-owner from DSO to Gasunie, it would be logical when the DSO has influence and/or ownership over this kind of assets.

C.5 Innovation

Within The Netherlands the abundance of natural gas created a unique situation. The presence of small and specialized firms, located in close proximity and embedded in local social structures that supports a mix of cooperation and competition, could lead to an 'industrial district'(Staber, 1999). According to literature these industrial districts are credited with several sorts of benefits. This includes stimulation of innovation and the support of business adaptability(Amin, 1994). Although the presence of specialized firms is at stake it is questionable whether or not the local social structures between the involved stakeholders accommodate a successful environment in enabling high-level innovation for green gas.

To come to a successful implementation of green gas in society cooperation within and in between different sectors is inevitable. Production could only flourish when consumption can be guaranteed, as is also the case for distribution and transport of the gas. Transition needs to be supported throughout the whole supply chain. Especially the agricultural sector could play a decisive role, however they will need technological knowledge and probably support of energy companies. Furthermore green gas offers the possibility to invest in subordinated areas in the country. This has also economic advantages. The green gas industry will create job opportunities and could on the long-term substitute jobs that will disappear due to the depletion of the natural gas production in The Netherlands.

An important driver of green gas innovation will be the economic funding of the projects. Part of the Dutch competition authority focused on energy, DTe, applies two main strategies to ensure innovation in the regulated part of the gas sector. The first is a direct cause of the price cap, which will be discussed in section 5.1, that will make the DSO eager to realize their services in a more efficient way. These innovations will be focused on productivity efficiency. Secondly the investments made directly for innovation purposes will be taken into account in the price cap calculation, innovation caused by this regulation could support the facilitation of the energy transition.

The circumstances within the Netherlands concerning the gas sector could lead to an industrial district. Innovation could flourish here when the presence of specialized firms is embedded in a local social structure that supports a mix of cooperation and competition. This local social structure is a point of attention. Stakeholders need to support others in their business, which could lead to a more vulnerable position for their own. Besides the sectoral cooperation, the inter-sectoral cooperation is of main importance for green gas. Especially the agricultural sector should be fully integrated within the supply chain, because this is a new core business to them.

Considering the investments for green gas projects by the DSO's. Currently the investment will be decided for each specific case independently. In case of Enexis the contribution to the energy transition will always be taken into account. A prescribed procedure could be useful.

D. Economic

Whether or not green gas could be a successful and economic viable energy source depends on lots of factors. Economies of scale, availability and costs of resources, waste costs digestate, transport costs, energy prices and the availability of subsidy measures. This section will discover the economic main issues for green gas.

D.1 Monetary flow

As mentioned before the network operator has a natural monopoly. Consumers will not have the choice to select their own network operator. Therefore the tariffs that have to be paid to compensate the transport and distribution services are regulated by the NMa (Dutch competition authority). This is not calculated by volumes but by the amount of connections with end-consumers. The compensation is included in the energy supplier's invoice. Because the network operators should not earn more money than necessary, a price cap (x-factor) is introduced that creates an incentive for a more efficient network operation. This yardstick competition, using a correcting x-factor, changes the tariffs in a way the DSO revenues are equalized by an equal performance. Currently 11 distribution system operators are active in the Dutch market, with 3 players covering 85% of the total market as depicted in Table 1.

Distribution System Operators	# connections	%
Liander	2.162.000	30,41%
Stedin	1.977.000	27,80%
Enexis	1.971.000	27,72%
NRE Netwerk	446.000	6,27%
Delta Netwerkbedrijf	185.000	2,60%
Conet	137.000	1,93%
Westland EnergieInfrastructuur	51.000	0,72%
RendoNetbeheer	98.000	1,38%
Inframosane	48.000	0,68%
ONS Netbeheer	35.000	0,49%
Totaal	**7.110.000**	**100,00%**

Table 1 DSO in The Netherlands, total gas connections and market share (Energiegids, 2011)

According to Pollitt a proper functioning of the incentive in this yardstick competition could be undermined by changes in the market structure. Firstly the possibility exists that consolidation of DSO's undermines the base of the competition incentive (Pollitt, 2005). Mergers and acquisition of the DSO's will decrease the number of companies, this could lead to a loss of comparator situation (Tieben, 2008). Since the market is already concentrated on 3 large DSO's it is questionable whether or not this loss of comparator situation already takes place. Three effects are distinguished by the NMa caused by this loss of comparator principle: the static effect, the dynamic effect and the scale effect. The static effect, makes the merged company bigger which gives them more influence on the mean performance. Furthermore there is the possibility of strategic behaviour, it will be easier to differ from the desired costs on a coordinated basis. The dynamic effect is caused by a decreasing amount of management styles that makes the possibility to have an excellent performing company low. The third effect includes the economies of scale, which in the end should lead to lower consumer tariffs. However it appears that in case of DSO's economies of scale hardly exist (Mulder, 2006; Haffner, 2006).

There is currently a lack of instruments available to ensure the public values of consumers when DSO's are willing to merge. Public shareholders should guarantee these and should not agree with merges that will harm the public value.

Additionally to the yardstick competition the ORV (objectiveerbaar regional verschil) is introduced. One could imagine that there are regional differences which make it more cost attractive to make connections in a highly-density area compared to a low-density area (NMa, 2007). The set tariffs will raise parallel to domestic inflation and decrease with the x-factor. When a DSO succeeds to realize a higher efficiency compared to the price cap they will earn additional profits. The price regulation and tariff structure the DTe applies have significant impact on the company results.

The current compensation for DSO's, actually the main revenue for these companies, is based on the connections between the distribution grid and properties, like households or industries. This also includes farmers who produce green gas. The possible depth investments that have to be made by the DSO because of the green gas production within their network, e.g. the lack of capacity prevention, are not included in the compensation.

The yardstick competition creates the incentive to handle innovative and efficient as a DSO. However the loss of comparator that could play a role in the near future and will affect the way tariffs are calculated. Additionally the discussed effects which are caused by a merger situation will also influence the tariffs, positively and/or negatively. The revenues made by the DSO will affect the possibilities to invest in green gas projects. With more financials the DSO is able to make depth investments in supporting green gas. Compensation to these investments is not defined, the DSO is only compensated for a connection of households or industries to the network. Therefore it has no direct advantage of the investment. So it is questionable who needs to take the responsibility to decide whether or not investing is necessary and as a consequence of that who will compensate the costs.

D.2 Subsidies

There are green gas technologies available that already could compete with natural gas. However most of the technologies will need governmental subsidies. The Dutch energy subsidies are divided into three parts, the first category covers innovation on energy technology, the second category to purchase machinery and develop efficient machinery compared to the currently used machinery and finally the third category that covers sustainable energy. This category is also called the SDE (stimuleringsregeling duurzame energie productie) regulation(Rakhorst, 2010). Since 2008 also green gas activities are included in the defined as sustainable energy sources.

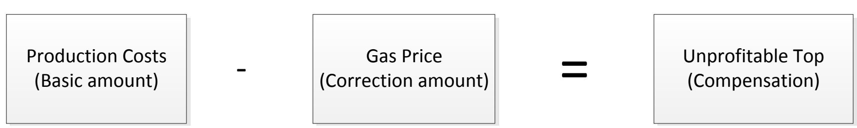


Figure 10, structure of SDE

While the natural gas price is on average lower (ca. 55 ct/Nm^3 (Gaslicht, 2011)) compared to the price of green gas(ca. 85 ct/Nm^3 (Groengasmobiel, 2011)), compensation is needed to cover the difference and create an economic attractive alternative. The SDE regulation is depicted in Figure 10. It offers a compensation between 28,7 ct/Nm^3 and 79 ct/Nm^3. Depending on the used technology a *basic amount* is defined that indicates what the acceptable *production costs* are. The gas prices will be subtracted as a *correction amount* to reveal the *unprofitable top* of the value chain (Lensink, 2009). The subsidy comes from a raise on the energy invoice and possibly from additional tax on coal and gas prices. This will create a direct link between the use of energy and the investments in the energy transition (Verhagen, 2010). Developments in the production and upgrading technologies will decrease the costs on the middle-long term. Additionally we could consider the increasing prices of oil and gas in the future, all together this will lead to decreasing gap between subsidized green gas and natural gas. To create a kind of economic guarantee for investors a subsidy allocation will obtain for at least 12 years.

In practice it seems to be hard to obtain a subsidy. Regulations are changed regularly or even cancelled. In other cases the amount of subscriptions is too much and the subsidy is depleted within one single day, as was the case for solar panels. Another hurdle is that there is a maximum of three months period between the subsidy submission and the investment decision. On the other hand the initiator is expected to have not made any investment or contractual obligation until that moment (Rakhorst, 2010).Subsidies in similar countries e.g. Germany are more effective in stimulating sustainable energy compared to the Dutch situation. A reconsideration of the current subsidy procedures could improve the effect of the procedures.

Investors in green gas projects could also make use of tax benefits up to 10% of their total investments. This due to the inclusion of green gas production in the EIA and MIA lists of the Ministry of Finance. Since January 2011 green gas is defined as an activity of environmental benefits and could therefore take part in advantageous regulations (EnergyValley, 2011).

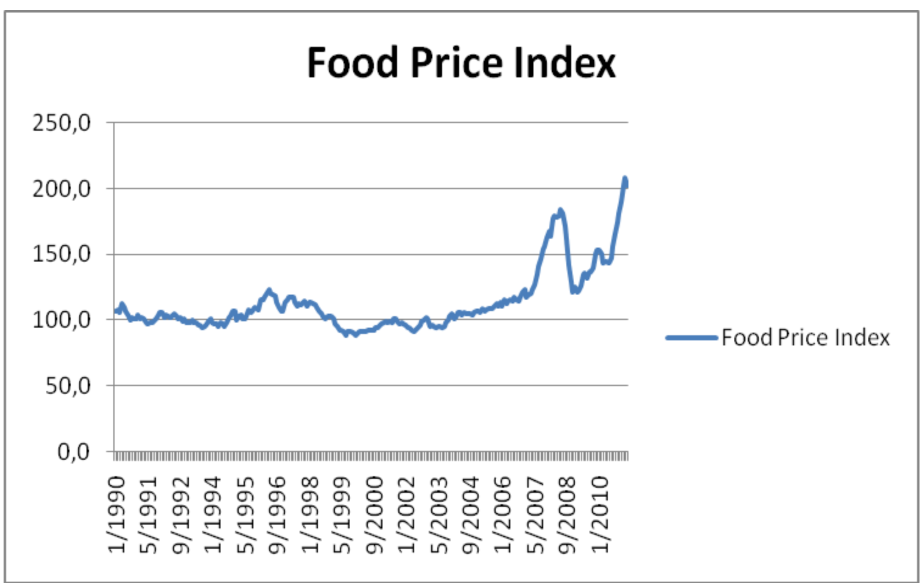
A variety of subsidies could be used by private parties starting green gas projects. Yet investors have negative experiences with the subsidies and their requirements. The Dutch subsidy procedures concerning sustainable energy could be reconsidered to make sustainable energy projects more attractive. Besides, also more certainty in the future of subsidy programs is necessary to enable people in the realisation of green gas projects.

D.3 Economic considerations

Two minor economical issues are the influence of green gas production on the food price and the allocation of advantages and costs among the stakeholders. Yet both are mentioned in the media on a regular basis.

D.3.1 Food Prices

An economic risk that is mentioned in several articles (Dumont, 2008; Zinoviev, 2010), is the opportunity that the resource for energy will compete with food prices. This consequence would especially harm less developed countries. Some estimates expect a 70-75% increase of food commodity prices when they get attributed to biofuels.



Graph 3. Food Price Index

The current level of the Food Price Index (FAO, 2011) is depicted in Graph 3. It appears that the food prices increased during the last 8 years, mainly driven by the increase of sugar, oils and cereals. Especially vegetable oil is a common used product in Europe to use in green gas production processes. According to the OECD Europe is using a share of 47,2% of the world total on vegetable oil and has projected initiatives to use a share of 129,3% of the crops for production. The policy support of the US and EU have already contributed significantly to the raise of several food commodities, +6% for wheat, +12% for coarse grains +6% for oil seeds and +35% for vegetable oils (OECD, 2008). The food prices could significantly effect the green gas price.

D.3.2 Allocation of advantage and costs

Another element that has influence on the economic feasibility is the difficulty to allocate the costs in line with the gains related to the green gas. Green gas producers, energy suppliers, shippers, DSO's, environmentalists, governmental organisations and producers of green gas technology do all have benefits. But it is questionable who has to compensate the additional costs that stakeholders have to make in order to facilitate the green gas infrastructure. When an allocation could be defined which allocates the advantages equally all stakeholders will have an interest in the production, transport and distribution of the green gas (Dumont, 2008). In the desired situation the energy transition will develop with the lowest social costs. Here the market will contribute substantially and (semi-)governmental organisations (e.g. DSO) will make the investments as effective as possible. This means relative the lowest investments in exchange for the most substantial development of green gas. Which investments and supporting measures would lead to this substantial development is hard to predict. The related public values need to be monetized before the societal gain could be monitored.

However it is stated often as an important condition in making green gas successful, food prices seem to suffer from the 'energy crops'. This could be a minor problem for Dutch society. However taken a broader view this could have influence in an international perspective. The Netherlands will depend on import of biomass, probably also by developing countries. Local citizens should not face the negative effects of the Dutch energy provision. Another economic element that will contribute to a broader support of green gas is an allocation of costs and gains. Also the attempt to develop green gas in exchange for the lowest societal costs will be a part of this allocation. A successful implementation would offer an incentive for all involved stakeholders to participate on an equal basis.

E. Conclusion

There is green gas potential in The Netherlands. Natural gas is of major importance for the Dutch economy, due to the money involved with the export of the domestic resources but also due to industries that rely on gas as energy resource. Furthermore the domestic and international potential to generate biomass for green gas production is available, however it is not concentrated and therefore the process to gather these resources is a point of attention. As also accounts for the risk that energy crop biomass could increase food prices.

The targets that are defined by EU and the national parliament suggest that sustainable energy can flourish almost at their maximum. Unfortunately this does not account for green gas in The Netherlands. However semi-governmental taskforces suggest long-term strategies, major changes within regulation and economic structures are still not defined. There is a lack of green gas related long-term policy in the field of subsidies, responsibilities, tariff structures and ownership. This situation combined with technological uncertainties in composition and network usage give also private investors a wait-and-see attitude. It is questionable whether or not the government is the stakeholder to take the lead, but with the targets on sustainable energy it would be a likely choice.

Currently the distribution system operator is facilitating projects in a field that is not regulated. Since the facilitation of the energy transition is one of their objectives. However they are not compensated for these activities on a regular basis, as accounts for regulated activities as the distribution of natural gas. This makes these activities kind of risky for the DSO. Besides also the collaboration within the sector could be improved. Exchange of (network) information and expertise on specific issues as e.g. green gas will contribute to a successful implementation.

Appendix 2 – Analysis on historical analogies of emerging infrastructure

The infrastructures were all assessed on five areas of interests, which are composed by the researcher: objectives, pre-conditions, drivers, barriers and advantageous policy measures. These areas of interest will describe the initial state while the infrastructure emerges in combination with the reasons of change and additional policy designs that the national government found necessary. By assessing the emergence of each infrastructure using these five areas of interest we have the possibility to compare those different case-studies. This leads us to the recognition of conditions that could serve as lessons learned to biogas infrastructures in 4.6. Simultaneously this could be used to answer research question 2 on the pre-conditions that could make infrastructure realization (un)successful. First a general notion will be presented about change and innovation in The Netherlands throughout history, this contains information that was founded relevant during the research and cannot be assigned to a specific infrastructure (section 4.1).

1 Change and innovation in The Netherlands

System thinking

From the nineteenth century changes came in a high tempo and in a more effective way. According to literature from that moment innovations were described as systems, this was the case for scientific, technological, economical and also constitutional innovations. Newly developed procedures and actions were called systematic. A good example is the human body with its organs, the limbs, muscles; they all appeared to be a system that consists of other systems. The discovery that nature could be ordered in a systematic structure resulted in the definition of physical laws (Van der Woud, 2006, p.12). This made it easier to improve certain situations since interactions became more transparent. The understanding of fundamental characteristics of nature prelude a period of progress. Progress was more or less the increased conscious of people on that they appeared to be able in improving living standards. Future was nothing to just sit back and wait for, from now on the future could be influenced by people themselves.

The citation below illustrates a spin-off that was created by this newly found perspective:

> "Only that what is well-adapted to its environment and functions well, will survive. The chaotic, un-adapted will disappear: it is abnormal." (Van der Woud, 2006, P.13)

Influence of infra-structures

Numerous historians have investigated the rise of infrastructures. Thomas P. Hughes criticizes on most of them since they focus on the invention of certain artifacts, like the light bulb and telephone, instead of studying the entireties or 'systems' wherein these artifacts are just integrative parts. Furthermore he criticizes the lack of contemporary history and sociology for overlooking the enormous societal influence of such systems. Networks and infrastructures function as deep structures in society and have surpasses even natural geography and politics as key drivers of societal change. To a large extend they influence where people live, work and play (Hughes, 1983). Hughes presents a 'loosely defined pattern' of system building. This Hughesian system building, which is based on path-dependency and economic lock-in situations, argues that large technical systems needs strong economic and political actors and a strong market demand as key drivers to expansion(Van Vleuten, 2006, p.301).

Disturbing factors

Considering infrastructures as integrative systems was widely supported in Europe and in The Netherlands. Yet on two other characteristics the Dutch situation was and is maybe still distinctive. Ideas and innovations that would contribute to the public values have often failed to succeed in The Netherlands. According to Van der Woud jealousy of the public opinion was a main issue during the nineteenth century. People who came with good ideas faced opposition since people did not allow people the appreciation they earn. Ideas were framed as utopias (Van der Woud, 2006, p.107). Discoveries and innovations after 1850 all originated from foreign countries. Also the implementation went slowly and on a relatively small-scale. The Dutch railway can be seen as the clearest example of the low priority the Dutch gave in high developed technology, this example will be further elaborated in section 4.4.

Lack of metro-politan area

Secondly there was a lack of a potential metropolis in The Netherlands compared to other countries. The metropolitan area appeared to be the ideal soil for infrastructures to be implemented. Requirements for such a metropolitan area can be summarized in the presence of the economic, cultural and governmental center of the country. Cities as London or Paris included all of these elements, these cities flourished indeed. But in The Netherlands these were divided over 3 medium sized cities (Rotterdam, Amsterdam and The Hague)(Van der Woud, 2006, p.233).

Society-shaping role

Developments of infrastructures have been important for the nineteenth century awareness that all individuals together form one single nation and later on one single continent. During those times European countries were pretty divided. The formal and judicial structure of the nation and continent could profit from the rise of infrastructures. These indirect effects could occur since the nineteenth century society had idealistic characteristics, with motives and ideas as starting points. This situation was created in the civilization through education, public government, religion and the press (Van der Woud, 2006, p.20). The religious motives and ideas did not totally disappear in our current society, but the role of these specific ideals is minimized. Other values have become more important to our modern society. Younger generations focus with more intelligence and energy on the power of modern tools, like IT. There is more focus on knowledge and skills with a specific purpose. Powerful infrastructures were build leading to a world that is in a continuous movement: highways, television channels, lunar modules, microchips, jumbo jets, internet, etc. (Van der Woud, 2006, p.24). The society-shaping role that transnational networks had in Europe appeared also in the twentieth century. For example the completion of the channel tunnel between England and France which was a political and economic priority to those countries for centuries. The connection integrated the countries to one coherent, prosperous and peaceful unity (Van Vleuten, 2006, p.3). However, the transnational network building was not aimed on the creation of an integrated Europe, but on securing national and economic interests. Yet the first world war triggered the political visions of an united Europe (Van Vleuten, 2006, p.10, p.12).

More than technology

It becomes clear that the development of infrastructures has indirect effects, other than the pure technological consequences. The non-technical elements may constitute historical events in their own right. Hughes illustrates this using the example of Edison's construction of early electricity supply systems. Besides novel technologies he also included a concept of electricity sales to external consumers, a business structure, and franchise defining relations between companies, local politics and an advertising campaign. This combination brought him a rather successful and stable socio-technological system. When Edison's companies merged into General Electric, it shuffled the US business landscape, becoming a first rank economic, political and employment factor in the US (Hughes, 1983). The fact that large technical systems could have such political impacts made designers come up with systems that specifically achieve such a political or societal change. An example can be found in the policies of Sweden to set up their first large state-owned hydro power plant. There underlying objectives were focused on decreasing the energy dependency of Norway (Van Vleuten, 2006, p.291-292).

Utility regulation

The role of the national government and especially considering utility regulation is heavily changed throughout history. According to the articles of Hausman et al (2008) and Millward (2005) three successive waves can be recognized. The first wave that is identified covers the phase the infrastructure is initially constructed. Within this period the high amounts of investment required in sectors such as electricity, telecommunications and railways, as well as perceptions of great risks, made private alliances of entrepreneurs and families with banks and holdings essential as financiers. The state is involved in its capacity of adjudicating and granting rights of way, as well as regulating prices and service quality (Millward, 2005). Yet also the state acted as financier, especially when there were shortages (Millward, 2005, p.59). From the end of the nineteenth century the second wave started. Here the state's role gradually increased in the management and ownership of utilities. States thus became managers and, often, owners of large technical systems. Currently the third wave is ongoing, in which an increased role of the domestic and foreign private sector and of market forces is at stake. Compared to the first wave it differs in the sense that in this case the public utility companies were appointed a market role (Clifton, 2011).

20th century systems

Of course times and cultural differences changed our society. Changes to infrastructural development can be attributed to two domains. Firstly to the task that the government believes it needs to perform. And secondly the judicial context where development is taking place (Stout and De Jong, 2005).When thinking about twentieth century large technical systems, Joachim Radkau suggests three specific characteristics. First there is the increased importance of ICT in these systems. Secondly there is the consumer's choice that has a more significant role in these systems. An example is the diffusion of telephony and motorized road transport, which ousted rail transport and navigation. Now the system users shape the network flows. The third characteristic is the 'second-order' feature of the large technical systems. Here familiar, first order, systems are combined to create a new function (Van Vleuten, 2006, p.287).

Sub-conclusion reflected on Biogas Infrastructures

Innovation appeared to become faster when people are able to translate the situation into a system perspective. Interdependencies and interfaces are identified which will lead to a situation in which bugs are often eliminated. This would therefore also be a good starting position for biogas infrastructures.

Another notion that could be desirable for a successful implementation of new infrastructures will be that it should serve the interest of the majority and should be supported from one united perspective. This was the case during the times that the European countries were relatively divided, it brought unity to European society. An example is the completion of the channel tunnel between England and France. Of course it is questionable whether or not the size of a country, in this case that of Europe, will approach an optimal size from an infrastructure perspective. In other words, by taking a larger subset of individuals the resistance could possibly grow in an absolute number. It will then be possible that the majority still is in favor of a certain infrastructure, however the resistance is concentrated on geographical basis. For example when European countries decide to process the waste of the whole continent in The Netherlands. This may get a majority in the European Commission, but resistance will be geographically concentrated within The Netherlands. This is not a desired situation.

Currently a market-driven environment is created within modern infrastructures. Here the domestic and foreign private sector and market forces have a major role. But also the public utility companies are key players within the market-driven environment.

The society-shaping role of infrastructures causing indirect political and economic effects have proven the inevitable role of infrastructures, also in a world that is dominated by ICT, the consumers choice and complex intertwined systems. These 20th century system characteristics are also applicable on biogas infrastructures. Due to the growing consumer interest in sustainable energy, the information technology based balancing regimes and the interaction with the existing gas networks creates a complex intertwined system.

2 Canals in the Netherlands

Water has always played an important role in The Netherlands, in this section the canal infrastructure will be analyzed. Italian novelist Edmondo de Amicis described the Dutch canals as 'the veins of the country, the water is their blood' (De Amicis, 1874). The Dutch canal structure is a combination of natural and artificial waterways that are more or less connected. The objective of the infrastructure was the facilitation of more efficient transport routes throughout the country.

Drivers of the infrastructure

Prospe-rous river control

The first part of the nineteenth century could be characterized by the Dutch control over the major rivers. Hendrik Blink described this in 1892 as a creation of friendship between the Dutch and their major rivers. The waterworks were successfully completed because of three important factors: the government, the engineers and the Dutch citizens, which were responsible for the huge amount of tax money that was gathered to cover the costs. Recent historical studies describe these same factors as administrative stability, technological development and economic growth. Yet this is an explanation afterwards and cannot be seen as cause that started the huge water related projects (Van der Woud, 2006, p.324). Reasons that could have led to the start of the widening of the major rivers that are mentioned in literature:

- The endless sequence of disasters related to above average water levels (1855 Gelderse Vallei, 1861 Bommelerwaard)

- German pressure on the Dutch government to improve the water and trade routes between the North Sea and the Ruhr area.

- The new spirit that went through the country (an often used notion in historical sources, which is quite abstract but it indicates the overall willingness to generate wealth and try new things)(Van der Woud, 2006, p.198)

Railways vs canals

Within The Netherlands the domestic characteristics created the high potential of an extensive waterway network. The availability of natural waterways, the in general flat character of the landscape and the soil which is suitable for digging activities. In the middle of the nineteenth century it was uncertain whether or not railway infrastructure should be the transport modality of the future. This discussion became one of state interest since it directly related to the national economy and the international trade. This link with trade made it also major impact on the future development on canals in The Netherlands (Van der Woud, 2006, p.234). The government argued that the railway would probably be too expensive for some goods and chose the reconstruction of the waterways above the roll-out of an extensive railway network. Here The Netherlands differed strongly from his neighboring countries. The other way around, the realization of waterways like the Noordzeekanaal was defended with the argument that this would provide additional trade for the railways. Thorbecke argued that the railways were considered to be the infrastructure of the future (Van der Woud, 2006, p.243). It appeared that politics used argumentation two sided and at the moment and time that was most suitable.

Barriers

Coordina-tion problems

The biggest and most long-lasting political and constitutional problems did not occur at infrastructures on national scale like, the major rivers, the highways, railways or telegraph lines. The most problems occurred at hundreds of small waterways and motorways that connected the national network. Here arise coordination problems between the stakeholders that served the public interest from a different point of view, the national government and the province. Within this tension between the central and de-central government the systematic regulation of the water household arise in order to improve the infrastructure. Instead of autonomous operating districts the supervision became a national matter, which posed the possibility to come up with a more system based policy

(Van der Woud, 2006, p.175). Water, transport and communication infrastructures got an increasing amount of interrelations with each other, projects were likely to fail when this interaction was not present between organization, government and technology. Yet some historians argue that large technical systems, also these in history, did not have central planning or coordination as a prerequisite for system development (Van Vleuten, 2006, p.268). Apparently the realization was also achieved without a coordinated organization. But when this coordination was at stake in large technical systems it became a driving force towards organizational hierarchisation and centralization in state institutions and industry (Van Vleuten, 2006, p. 293). This relates to the society-shaping role that was discussed earlier.

Risks discovered

The major rivers are unpredictable and they can cause damage when high water levels are reached. "It is a well-known matter" was the disappointing conclusion of experts after they revealed their research and recommendations about the risks that was related with the rivers (Ferrand, Van der Kun, 1850). A few years before other scientists came with identical conclusions after 40 years period of investigating the water system. The recommendations in the researches were outnumbered, which faded the necessity, as a result nothing substantially happened so nothing really changed. The reason that the first research took 40 years and the second research only a few was the systematic structure of the rivers and canals that was encountered around 1850. This led to a more specific notion on how to improve the water system as a whole. It was e.g. Caland who encountered that the Merwede river should be taken in the context of the whole delta of Zeeland and Zuid-Holland, the system of sea inlets. This systematic perspective had also organizational consequences, decisions in one district will affect others (Caland, 1860). The independent water boards had to give up parts of their responsibilities in order to reach a shared responsibility together with the national ministry. However this development of changing responsibilities started slowly, when time passed by and science and technology became more intervened, the role of Rijkswaterstaat as the institute that had the best overview over the field of exact science.

Lack of information

One of reasons that made it difficult to define a detailed plan around 1850 was the lack of complete information related to the cartography of the rivers. In a significant part of Zeeland most water levels and heights were not related to the national standard Amsterdams Peil (later this changed to the Normaal Amsterdams Peil)(Van der Woud, 2006, p.209).

Act on expropriation

The act on expropriation that was adopted in 1851 was of historical significance (expropriation: politically motivated confiscation of private property). To make decisions related to the expropriation a trade-off needed to be made on the general interest of infrastructures. It is questionable whether or not the general interest, which is the interest of the majority overruns the interest of the individual. As a result of this the support of some regions was more favored then others. This resulted for example in the policy to support some regions more than others. The national economic interest as a whole was stimulated more by investments in the western part of the country (Van der Woud, 2006, p.168).

Alluvial sand

From a legal perspective there appeared to be also uncertainties around the ownership of the alluvial sand. Sand that was added to the river side due to natural or artificial circumstances. It was questionable whether or not the additional sand caused by the water works should come in direct ownership of the landowner of the river shore. There was no definition of shore available in the civil code, this made those discussions more complex (Van der Woud, 2006, p.206).

Remuneration

Another legal difficulty concerned the remuneration of the costs of riverbed maintenance. It was for example the province of Friesland who declared the costs directly to the adjacent landowners. But in 1865 a farmer argued that the canals served a public interest and that the remuneration of costs should be covered by the whole population. This started a long process of discussion between all kind of stakeholders, which were attracted to the process. There was no almighty civil servant who decided what to do, using discussion to come to a consensus. The government's role shifted from a monitoring role towards a full responsible one. And when the governmental role was growing in preserving the public value, water related activities got more signals of state influence. An example is the clothes that clerks of the ministry worked (Van der Woud, 2006, p.236).

Continuous change

Improvement of the waterways appeared to be an ongoing process. Ships became larger, wider, deeper and faster, what required correspondingly larger, wider and deeper rivers. Besides the maintenance of riverbeds is a continuous process anyway since these are naturally changing over time.

Concluding notions

The waterways infrastructure in The Netherlands had some specific advantages like the domestic characteristics of the country itself. Rivers, lakes and streams were already available in abundance. Besides there were also strong drivers available that made the government eager to improve the waterway infrastructure: disasters related to floods, pressure of Germany on the North Sea – Ruhr connection. Furthermore there was the situation that the substitutes to water transport, the railways and highways, were considered to be too expensive to transport specific goods.

Most problems occurred due to ineffective management of the canals. Both guards of the public interests, the national government and the regional, appeared to have different objectives. The national government wanted to realize a generic waterway network between the major trading points in the country, however the regional authorities were more focused on the most important trading points in regional perspective. Furthermore there was a growing amount of interrelations with other infrastructures, which also varied for each region. This eventually led to the centralization of the coordination towards one single entity within the national government. Think about maintaining water levels and decide upon certain connections. The role of the state shifted from a monitoring to a more executive operating. Especially in the beginning this can be considered as a sort of top-down management.

Furthermore we distilled three general problems that counteract the implementation of the infrastructure. First of all the lack of general information on location, height etc. was missing. The quality of information on the area where the infrastructure will be constructed needs to meet a certain level, at least on the basic key figures. Design information as the decay and width of the canals will depend on differences in height and the flow of water passing by. The second issue considers the legal clarity that was missing in this case. New infrastructures will face society with new situations, situations that will not be described in civil codes or other legal documents. To prevent disagreements there is a need of a clear judicial framework. The third issue is related to the cost remuneration. Where in the early days the directly linked landowners were charged for water constructions, the construction became of public interest which led to a spread of the costs over all tax payers. This seems logical, but the definition of an infrastructure that serves public interest is quite subjective. Table 10 gives an overview of the findings in this section.

Table 10 - Situation for canal infrastructures

	Canals
Objective	Facilitation of more efficient transport routes throughout the country

Pre-conditions	• Reliable and stable government • Good engineers that make use of technological development • Dutch citizens to fund expenses with tax money
Drivers	+ Substitutes were poor and expensive + Sequence of water related disasters + German pressure on Dutch government + Canals would provide additional trade to railway + New spirit that went through the country
Difficulties	- Lack of information related to cartography of the rivers - Coordination between stakeholders - Legal definitions missed
Advantageous policies	Central supervision and a clear judicial framework Expropriation regulation

3 Telegraph and communication lines

This section will treat the telegraph and communication lines. Communication networks widened the borders of time and space (Van der Woud, 2006, p.354). It created the opportunity to gather and share information from all over the world. Furthermore it gave us the possibility to connect with public, private and personal entities. Business as well as personal life changed radically due to the extensive availability of communication using different modalities. The objectives that needed to be fulfilled by the communication network was to make communication comfortable and fast instead of dangerous and time-consuming. When time passed by reliability and safety became increasingly important (Van der Woud, 2006, p.337). Today's economy is highly depending on a reliable communication network including, telecom and internet. Most of the businesses will not function properly when their communication network fails. Furthermore the impact of confidential information leakage could be high which explains the need for safe and secure characteristics to this infrastructure.

Drivers of the infrastructure

Influence of railways

The implementation of the telegraph infrastructure was strengthened by the railway network. Both infrastructures were built parallel. This was advantageously since both infrastructures required preferably straight routes that linked places using the shortest path and connecting the highest density areas. The stations could also fulfill a double function as railway and telegraph station (Van der Woud, 2006, p27). Kaijser argues that interaction with other systems can cause system dynamics, on the one hand this could improve the position of both, but they could also compete on market share and decrease their joint success (Kaijser et al., 2000)

Integrative approach

Growth of the telegraph services was going much faster in the United States compared to Europe. In European countries municipalities took their time spending money and effort to integrate the new communication technology in the existing environment. Behavior that became more generic due to the system based perspective. The incorporation was done by developing requirements for the telegraph poles and by defining judicial preconditions (Van der Woud, 2006, p.40). An example here is the rights of landowners where the poles were installed. Should these people being compensated?

Protectio-nism

The telegraph lines started as a service open to the public that was exploited by the railway company Holland Spoor. This ownership is of course another prove that the relationship on both infrastructures was close, since this did not only have a physical but also an organizational basis. In 1847 the Holland Spoor company was willing to exploit the telegraph line commercially, however the government was not convinced of the advantage of this development since they were anxious that a successful telegraph line would harm the national post services. The national government had spent lots of money to bring the post services on a high quality level. This, while the objective of communication is the same for a telegraph infrastructure as well as for the national post services. To protect these public investments the government gave permission for the exploitation on the condition that, when the post services should start performing worse, the telegraph company would financially compensate the financial loss (Van der Woud, 2006, p.343). Since communication was still in its infancy it appeared that there was enough demand to make both infrastructures flourish. Later on the government would gain significant shares in the telegraph infrastructure, which will be discussed in the next paragraph.

Public values

To ensure the safety and reliability of the mail infrastructure the government organized the mail service as a monopoly. The government argued that when they should leave the mail service to the market, private parties would only facilitate the profitable areas which would leave the more deserted areas without any mail services. This would probably urge the government to cover these areas by themselves. The monopoly brought normalized tariffs and ensured a nationwide coverage of the services (Van der Woud, 2006, p.337). A similar discussion was raised by the railway network, but here the government handled differently and left the development of the railways to the market. Apparently those trade-offs were not only based on economical or constitutional grounds

(Van der Woud, 2006, p.338). Letters have a personal character, intuitively it seems better when an independent organization takes care of them. Of course also the government themselves used the post services on a regular basis, including confidential documents. This could be one of the reasons the government decided to put more emphasis on this.

Added value

When technology developed over time the telegraph was substituted by the telephone. Yet when the telephone came up, the belief in this new technology was poor. Why should people want to hear each other, when a telegraph already sends the information that is needed in a compact way? Later people became aware that information could be incomplete, e.g. when the context is not present. Overall we can conclude that the telegraph became a success because of its speed, the telephone because of its directness (Van der Woud, 2006, p.365).

Network behavior

While the telephone lines widened the borders in space and time the evolving structure of the network became organic. It is a main example of network behavior. The users and the structure of the infrastructure might change over time. As a consequence the network created its own nodes, centers and periphery, in this way the network created its own efficiency (Van der Woud, 2006. p.354). Actually this organic behavior has never stopped and is still an ongoing process. Part of this network behavior is the so-called path dependency, which is also visualized in Figure 2.

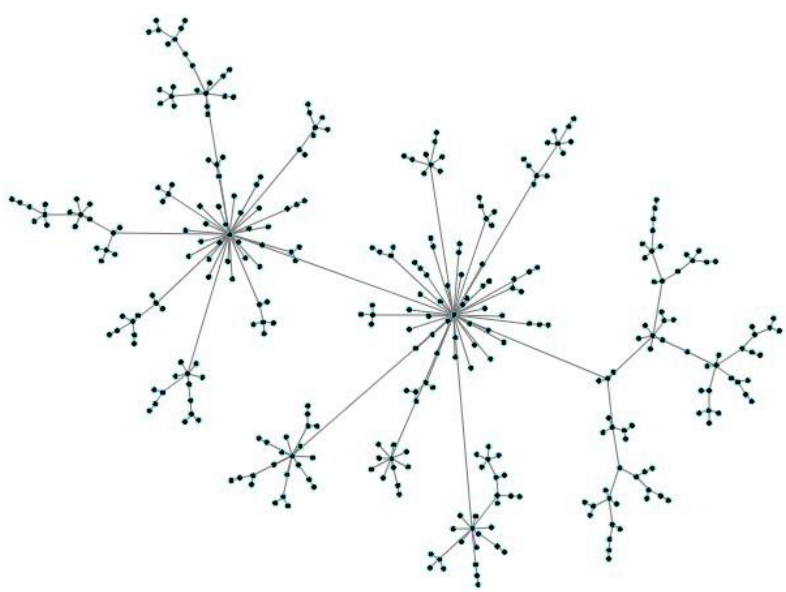


Figure 2 - Preferentially attached network, influenced by path-dependency (Nikolic, 2010)

Barriers

Besides the already mentioned constraints because of Europe's search to a well-integrated system, the implementation of the telegraph network did not face a lot of problems. In this section the issues are discussed.

Legal barriers

For example from a legal perspective the implementation was hardly facing difficulties. The only legal directive that was defined relating to communication networks encouraged the project developers to construct poles 'as efficient as possible' besides railways, motorways and dikes. But this directive had no judicial foundation that urged the developers to do so. Landowners were not compensated for telegraph poles on their property, they were forced to ‘serve’ the national interest (Van der Woud, 2006, p.349). Within the Telegraph Act there was actually a sort of ‘obligation to tolerate’ the installation of telegraph lines also when they crossed private terrain (Rathenau, 1995).

Tolerate

When telephony was emerging and the discussion was raised whether or not the telephony should fall under the telegraph act. The government argued that it should fall under the telegraph line but as a consequence of that the government gained total control over construction and exploitation of the telephone lines (Van der Woud, 2006, p.358). On the other hand the civil council argued that the ‘obligation to tolerate’, could not automatically be converted to the telephone network. This network was more extensive and localized above the surface (Rathenau 1995, p.74). This lead to several claims of citizens who were confronted with telephone lines above their private property. According to the court they were not obliged to tolerate the lines, since no connection was made with the Telegraph Act. In 1904 the Telephone Act was realized, which included also the mandate for the government to install and exploit the telephone lines (Stout and De Jong, 2005).

Govern-mental role

The role of the government was remarkable. Although they created a state monopoly, due to the fact telephony was part of the general utilities, the government did not feel responsible for the realization of telephone networks in inner cities. Yet the combination of telegraph and telephone could bring a financially significant improvement of the infrastructures (Verkerk, 1883). They took a distinctive role. A reason for this could be the interest that the government had in the telegraph network, this was majorly financially. Lots of money was already invested in the unprofitable telegraph services, therefore there were plans to extend the telegraph network(Stout and De Jong, 2005). The realization of a competitive network was not heavily supported by the government. There was no state interest in the realization. There was an overall belief that only a small part of the citizens would experience the telephone as an important service (Rathenau, 1995, p.75). After some pressure from politics the government decided on state exploitation of the telephone network. This was despite the financially unfavorable prospects. According to the ministry these are necessary to expand the regional telephony (Rathenau, 1996, p.82). When technological challenges came up the government took a passive role. The connection with England was for example a financial and technical challenge. According to the ministry this was such a risky undertaking that it should be left to a private party (Rathenau, 1995, p.85).

Telephony importance

However the amount of connections was low in the beginning, that telephony would have an important role in the future was clear to lots of people. This appeared to be right, from the beginning telephony was a success. The network grew despite repression of the government and the industry. It was for example Siemens who constantly launched innovations on their telephones. Since the telephone models were not compatible or out-dated people were urged to purchase them which were relatively expensive (Van der Woud, 2006, p.364). Yet still people invested in the technology, apparently the opportunities that the telephone usage offered them outweighed the costs.

Concluding notions

The main advantage of communication networks in the beginning was that it could benefit from the characteristics of the railway infrastructures. The double function of the stations and the organizational integration in the railway company simplified the acceptance of the telegraph infrastructure. On the other hand the willingness of European countries to implement the telegraph infrastructure to be well-integrated in the environment (e.g. placing of telegraph poles) slowed down the implementation. Later on the government was careful in the telephony implementation since they wanted to protect the national mail services. Fortunately the success of communication was overwhelming in all disciplines (mail, telegraph and telephony). For this reason the public investments have not been at risk. The successful development was not foreseen on beforehand. The government privatized the railways and protected the mail service in which they invested a significantly. So in these cases it was up to a specific stakeholder to decide which public value is leading and what decision will be made. The somewhat conservative and distinctive attitude of the government caused a rather slow (compared to the American situation) but complete implementation of the communication networks that also covered low density areas. The general interest was served well by this policy. When the communication demand increased the network expanded using the reliable backbone infrastructure as a starting point. Technological challenges were avoided by the government and left to private parties in order to avoid financial risks. Table 11 gives an overview of the findings in this section.

Table 11- Situation for telegraph and communication lines

	Telegraph and Communication lines
Objective	Make communication (gather and share information) safe, secure and fast instead of dangerous and time-consuming
Pre-conditions	• Technological opportunity • Easy implementation using existing infrastructure (railway network)
Drivers	+ Closely linked to railway network (organization) + Need for safe and secure information exchange + Support from industries
Difficulties	- Government that took distinctive starting position towards telephony - National government invested already significant in postal services - Extensive trajectory to fully-integrate infrastructure in environment - Believe in heartiness for telephony (audio contact instead of information contact) - Legal position (telegraph act)
Advantages policies	Monopolize the market lead to normalized tariffs and coverage of low density areas

4 Railway connections

Within this section the situation on the railway network will be analyzed. The railway connection, it started in England in 1825 and was implemented first in The Netherlands in 1839 between Haarlem and Amsterdam(Van der Woud, 2006, p.84). As is applicable to all means of transport, the objective of the railway infrastructure was to decrease the space in time. The railway made the transport on long distance possible, faster and more comfortable.

Drivers for the infrastructure

Wind and water

In the early days transport was usually executed using barges on rivers, which was a comfortable but slow mean of transport. The fact that there was a well-functioning mean of transport available slowed down the implementation of the railway infrastructure (Schotanus, 2005). Within The Netherlands people had always benefit from wind and water. For people it is contra intuitive to move away from those foundations towards a future based on fire and steel. In this specific occasion the transition has taken at least 10 years before the Dutch felt comfortable by the implementation of the railway network (Van der Woud, 2006, p.295).

Improve above expand

It is remarkable that the first railway connections that were installed not were located between cities that were not yet connected by means of water. All connections actually doubled the already existing infrastructure, like the connection between Rotterdam and Germany. So apparently policymakers preferred to improve existing lines instead of complement the network with new connections and expand the existing network based on the waterways.

America vs Europe

In 1859 the first railway connection between Amsterdam and Haarlem existed for 20 years. Within these twenty years also other connections were established but these were not connected with each other. Still the Netherlands did not have a national railway network as was already the case in for example America. However several initiations of this network took place, problems of different nature arise: political, technological and ideological (Van der Woud, 2006, p.84). It was for example the more pragmatic culture of the Americans that created their basis for their material success. Where Europe was struggling 12 years to realize a tunnel in the Alps, the Americans realized thousands of kilometers railway network without facing any barriers. Probably the inlands of Europe were harder to prepare for railway infrastructures compared to America (Van der Vleuten, 2006).

European challenge

When the Europeans in 1870 completed the tunnel through the pas of Mount Cenis the double railway track between Paris and Turin was finished. From this moment on realization of the infrastructure was not a matter of technological challenges anymore, from now on the constraint would be financially. But however the Alp connection was of importance from a technological perspective it also had symbolic values. The connection proved the people that mobility became available to the normal citizens. This was the starting point for a broad supported and encouraged growth in mobility (Van der Woud, 2006, p.32). In 1994 the completion of the Channel Tunnel was again a good example of trans-national connections. The tunnel had political and economic priority for centuries already. Besides al kind of international bodies preceding the European Union pushed these transnational networks in order to integrate countries to one coherent, prosperous and peaceful Europe(Van der Vleuten, 2006, p.3).On the other hand also opponents of these ideas that infrastructures contribute to economic progress and social cohesion are out there. According to Proudhon en Mattelart the infrastructures were just used by powerful elites to gain economic, political or military advantages. “The length of railway lines in operation in France has tripled. Since then, we have not seen the slightest idea circulate.” This citation illustrates their vision of the situation, in which the social reform appeared to be leading above the network’s construction (Mattelart, 1996).

Barriers

Profiteers

As already mentioned the realization of the Dutch railway network progressed slow compared to other European countries. But especially the difference with the Americans was significant. Where the Americans had slightly any problems with landownership the opposite situation appeared to be in The Netherlands. A clear example of this is the fact that people anticipated on the realization of railways by the purchase of specific grounds that would be on the potential railway route. The case of Wickevoort Crommelin is a well-known example. In this situation investors purchased a piece of land paying six times the normal price, they felt comfortable on this deal because they thought a railway company would buy them out. Unfortunately the railway company chose to construct a detour just around their piece of land, since the company refused to yield and pay such an enormous amount of money (see also Figure 3). Individuals tried to benefit at the expense of the public interest. In other countries like France or England, activities like this did not appear (Van der Woud, 2006, p.293).

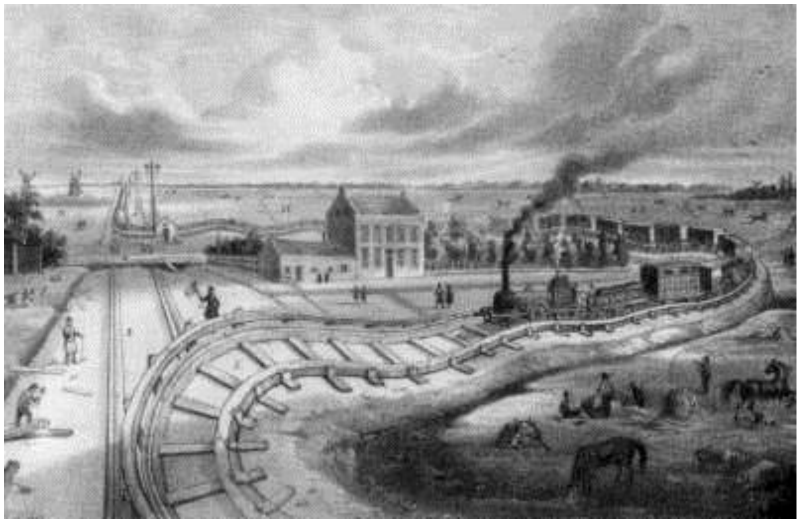


Figure 3 - The Case of Wickevoort Crommelin (Wikipedia.org)

Public resistance

The implementation of the railway network was accompanied with lots of discussion, it should have negative effects on the land- and waterways. Leather producers were for example convinced that the introduction of this train network would harm their production since the transport by horse should decrease(Van der Woud, 2006, p.393). But, as also was the case with the telegraph and mail services, transport services became increasingly popular on the whole spectrum. The growing supply of infrastructures and transport modalities had a strengthening effect to other infrastructures and modalities as well. The railway network for example benefited from an excellent additional automobile infrastructures that covered short distances. Something that can be compared with the OV bicycle concept nowadays. Commuters use the train for their long distance traveling and switch to the OV bicycle to fulfill the last part of their trip.

High initial investmen

Another difficulty to railway infrastructures was the enormous investments that were needed. Nobody was sure whether or not these huge investments could be remunerated. Yet the western part of Holland had a quiet successful business, but since the operators were all private companies they only transported people in high density areas. It was up to the government to facilitate the more risky investment and fund the low density areas (Van der Woud, 2006, p.298).

Concluding notions

The fact that the service that railway networks would provide was already available in a modest slow way, caused the difficult start of the implementation. Apparently the prove that the substitute was a significant improvement of the system needed to be clear. When small connections proved that the demand on faster and comfortable mobility was rising the investments were finally made to unroll the railway network on a national scale. Especially since the technology improved and took away physical constraints the raise of the railway network went faster. Unfortunately in The Netherlands the interference of individuals that wanted to piggyback the success of the railways. Nowadays these kind of situation cannot occur anymore due to expropriation regulations. Table 12 gives an overview of the findings of this section.

Table 12 - Situation on railway infrastructures

	Railways
Objective	Facilitation of faster and efficient transport routes throughout the country, decrease the

	space in time
Pre-conditions	• Administrative stability • Technological opportunity • Economic growth
Drivers	+ Overall increase in mobility infrastructures + Technological innovation + Availability to the 'normal' people
Difficulties	- Well-functioning alternative available (barges) - Pragmatic integrative attitude European countries - Geographical characteristics European inland - Piggybacking entities who block project developers - Business case only attractive within high-density area
Advantages policies	Expropriation regulation

5 Coal gas / Natural gas

Now an insight has been given in infrastructures in transport modalities and communication, the perspective in this section will be shifted to an energy related infrastructure, namely the coal and natural gas. The reason those two are presented together is caused by the fact that the natural gas roll out could build upon accumulated experiences from earlier period. A gas network had already been created (Correlje, et al. 2004).

Drivers of the infrastructure

Invention of light

Let us first start with focusing on the drivers of coal gas. An important innovation that accelerated the implementation of coal gas networks in the industrialized world was the production of light. Using coal gas the people accomplished to increase the amount of working hours more effectively and relatively cheap. The infrastructure needed to produce, distribute and transport the coal gas was a constraint in the take-off phase. For this reason the production of coal gas started de-central, so no extensive infrastructure was needed.

England pioneers

Only England had the capital, the technology and the entrepreneurs to start such an infrastructure throughout the inner cities. The English concentrated the responsibility of the infrastructure to one stakeholder, the Imperial Continental Gas Association (ICGA). They took care for funding, licensing, building and exploitation of the gas factory, transport facilities of the coal, pipelines in the streets and the luminaires at the clients place. The infrastructures started in the city centers since a high population density was required to a financial feasible exploitation of the system in the take-off phase. Using their expertise the ICGA started gas networks in other European cities. The Westergasfabriek in Amsterdamis for example also initiated by the British in 1883 (Van der Woud, 2006, p.70).

Positive side-factors

The successful implementation of coal gas was strengthened by the realization of the railway infrastructure. Due to the de-central production of coal gas, the coals needed to be transported to the coal gas factories. This process became easy using the railway network as a means of transport. The distribution of the coal resources became fast and affordable. Another invention that contributed to a successful implementation was that of the match. This gave people the opportunity to easily kindle the gas fueled lights.

Electrical innovation

In 1880 the electrical light bulb was invented, which put pressure on the future role of gas. Light sources could be easily facilitated with electricity cables instead of the less flexible gas pipelines. Electricity was easier in distribution and production, therefore people started to construct networks to facilitate their light production with electricity. Also these networks started in city centers and it became a direct and serious competitor of the coal gas (Van der Woud, 2006, p.73). Both, electricity and coal, could be used for the same purpose. It was actually gas that made electricity flourish. The gas engine that was developed made electricity production more efficient. Gas and electricity, became competitors but did not really counteract. It was even the availability of both that kept increase the demand. Because of this competitive element, prices decreased and both became available to more and more people. However coal was the main feedstock, from the 1950s long-distance gas was also produced by firms as DSM and Hoogovens, furthermore oil refineries started producing refinery gas (Correlje et al, 2004).

Available to all

The rise of gas and electricity networks also caused social progress. At the start of the twentieth century American social critics observed that electrical, internal combustion, and mass production technologies brought economic democracy. All classes could from that moment enjoy material abundance (Van Vleuten, 2006, p.297).

Coal to oil transition

The discovery of the Slochteren gas deposits brought a new system of gas supply in The Netherlands. The system provided a relatively cheap, reliable and clean source of energy. Yet when in 1959 the Slochteren gas was discovered already a transition from coal towards low-cost oil products was taking place. While in 1952, 80 percent of the energy supply was generated by coal, this was decreased to 50 percent in 1962. The transition to natural gas took place in the background of a general transition from coal to oil products (Correlje et al., 2004).

Master plan

An essential moment in the transition was the development of the master plan for national-scale transition to natural gas proposed by Exxon (the former name of ExxonMobil). Instead of a focus on large customers the Exxon plan argued that small users could yield the highest revenues (Correlje, 1998). This required the availability of gas to domestic users on a very large scale through a countrywide high-pressure transmission system that would link all local distribution systems. From an economic point of view the market-value principle was introduced to generate maximum revenue. This made consumers never pay more for gas than alternative fuels and additionally ensured that they would not pay less. Because of the involvement of two major multinational oil companies insight and experience in energy markets was widely available (Correlje et al., 2004).

Quick roll-out

Despite the large size of the project and the many difficulties the network was constructed quickly. This was caused by the already existing local gas networks. The revenues of households in the high-density areas were used to finance further rural expansion. This offered a strategy that allowed utilities to connect users to their gas network in a profitable way. Furthermore a big advantage was that the quality of gas and the characteristics of gas appliances became standardized all over the country (Correlje et al., 2004).

Government objective

The objectives of the national government were diverse and include a quick and complete exploitation of the gas reserves, the provision of comfort and luxury to their citizens and the use of gas prices as a valuable instrument for industrial policy. Furthermore they compensated the losers of the process (Correlje et al, 2004).

Barriers

Reluctant govern-ment

Until the discovery of the Slochteren gas the national government hardly interfered in the energy supply. This task was appointed to the local municipalities who had, in imitation of (foreign)entrepreneurs, started building and exploiting local gas and power plants. Private investors needed to apply for concessions to start such a plant. Unfortunately to them the municipalities were reluctant due to the protective strategy towards the plants they had in ownership (Stout and De Jong, 2005).

Cumber-some gas

Before 1959, the year the Groningen field was discovered, the Nederlandse Aardolie Maatschappij (NAM) was mainly searching for oil instead of gas. This was also discouraged by the Shell board, which is a shareholder of the NAM, since gas was a real utility. In these days the local city networks were relative expensive and because the gas prices were low, gas was financially less attractive to produce (Madsen, 2007). The gas that was discovered now and then was sold to nearby municipalities. The national government wanted to stimulate the exploration and production, since this was an opportunity to switch from the de-central gas factories towards a national gas system of gas supply. Contractual agreements were made with the NAM that saw an opportunity to get rid of their cumbersome by-product, natural gas (Correlje et al, 2004).

DSM mandated

The exploration of the Groningen field in 1959 made clear that natural gas offered opportunities for the use in the Dutch economy. At the same time it was evident that the development of such huge resources would put the existing system of energy supply under strong pressure. For example the coal gas sector would suffer from the proposed gas supply system. A main stakeholder from that sector, DSM, was mandated to negotiate on behalf of the state with Shell and Exxon about the further development of a concessionary regime, the elaboration of the marketing policy and the role of the Dutch state. This could be considered a form of compensation (Correlje et al., 2004).

Public ignorance

Stakeholders realized that injection of the gas from one central point instead of the former de-central gas producers could bring some challenges, for example the a broad implementation would harm the Dutch coal industry. Also the perception and habits of the public needed to be changed. Information about heating, cooking in the oven and the price setting mechanism needed to be explained by a public campaign (Correlje, 2006). Some citizens expected the gas price to be nearly free, “the gas comes out of the ground for nothing”, was their argument. But the Dutch government and Gasunie had four mean reasons to keep the gas price on a significant level. The initial investments that were made to explore, distribute and win the gas had to me remunerated. Secondly the shareholders wanted to make profits. The third reason was the already mentioned protection of the oil and coal market. And furthermore the market value of the high calorific gas should be in balance with competing fuels. But the use of gas over the traditional fuels had several advantages like, the absence of dust after burning, easy adaptation, no need for storage and a high security of supply(Van Overbeeke,2001, pp228).

Out-dated regulatory framework

Besides Shell also the American oil company Esso had a major interest in the NAM. When the company send out their employees to roll-out the natural gas supply there was some amazement about the Dutch oil regulations. The property rights of domestic resources originated from the Napoleonic period, since 1810 the state had inalienable rights over the resources on Dutch soil. Therefore the state had a remarkable advantageous position in the negotiations to issue a production concession (Madsen, 2007). The eventually large state share was something new to the oil companies. Only countries like Mexico and communist countries did have such large stakes in the oil and gas industry (Correlje, et al., 2004).

Concluding notions

The production of light, the invention of the match and the rise of the railway network all contributed to a strong coal gas network. So it was because of several coincidences on the right moment that the growth of the coal gas network was this strong on a local level. It is remarkable that the fact that a functional important substitute, in this case electricity to generate light instead of gas, is available and contributes to the development of both infrastructures. The same occurred at the telegraph and postal services and the rail- and waterways. Of course this was in the middle of the industrial revolution and it is questionable whether or not this mechanism also could be applied in modern times. When considering the emergence of natural gas it appeared that it could build upon accumulated experiences from the earlier period. The physical network existed already for the major part. Furthermore the role of the national government is remarkable here. They had e.g. a relative pro-active role in the development of the economic agreements. But probably the most ingenious idea was to mandate the former state mine company DSM to the negotiation table. However they would experience negative effects of the rise of natural gas as a company, the negotiation power gave them the opportunity to evolve their own company to a solid entity under the new circumstances. Table 13 gives an overview of the findings in the section.

Table 13 - Situation on coal and natural gas infrastructures

	Coal gas / Natural gas
Objective	Efficient and affordable fuel, comfort and luxury, complete exploitation of the natural gas reserves
Pre-conditions	• Availability also on long-term • High-density necessary in take-off phase to reach financially feasible situation
Drivers	+ Production of light – extended working hours + Development of the railway infrastructure + Development of the match + Development of the gas engine + Transition of coal gas towards oil-based products (natural gas) + Complete exploitation of gas reserves (natural gas) + Involvement of two major international oil companies (natural gas)
Difficulties	- Introduction of electricity - Transport of coal to de-central gas generators - Competition with established markets in oil and coal - Harming existing industries, as e.g. coal mines (natural gas)
Advantages policies	One central supervisor for the whole chain (from funding, building, exploiting, to the luminaries at people's places) One of the main stakeholders that should experience negative effects of the rise of natural gas (DSM) was mandated to negotiate about the new situation. Focusing the market plan on small users, using market-value principles (natural gas) Standardization of gas appliances related to quality and characteristics (natural gas)

Appendix 3 Transition Process as defined by Rotmans (2004)

The transition process is divided in 4 main activities as there are:

A. Design a transition arena
B. Develop long-term vision and transition pathways
C. Steer on learning and knowledge
D. Monitor and evaluate of the process

The main activities can be split in ten individual steps where an important notion is that this does not automatically mean that the steps will be executed in this sequence. The steps are mutual interdependent and feedback loops will occur between the different steps, all steps combined will end up in a cyclic whole. Yet the overview of these steps could help for a better understanding of the transition management approach. The letters behind every step explain in which main category we could find the activity.

1. Design of the transition arena (A)
   - Create permanent support
2. Organize a multi-actor process(A)
   - Creation of innovation- and steering space
3. Demarcate the transition situation(A)
   - Multi-domain, multi-scale, multi-actor
4. Formulate the different problem perceptions (B/D)
   - Communication and negotiation
5. Develop long-term vision(B/C)
   - Innovative, ambitious and evolutionary
6. Explore the transition pathways with the transition purpose(B/C)
   - Keep options open
7. Develop and apply the right instruments(B/C)
   - Instruments derived from responsibilities
   - Setup and execution of experiments
8. Formulate temporary purposes(B/C)
   - Assessment framework for current policy / make use of the current initiatives
9. Evaluation of temporary purposes and learning effects within development phases(B/D)
   - Learning-by-doing, doing-by-learning, learn-to-learn
10. Organize the follow-up transition round(A)
    - Reorientation and redevelopment of the process

Now we have listed the activities we will explain the steps in more detail.

1. Design of the transition arena

Here the different stakeholders will be brought together within an innovation network focused on a central transition theme. The group of stakeholders will be limited to the leading class, based on competence, interests and backgrounds. Yet variety is desirable, for example in the proportional representation of the societal pentagon: government, private parties, social organizations, knowledge institutes and intermediaries (project organisations, consultancy bureaus). The leaders of these actors should commit to the process and spread it throughout their organization. Within the transition arena beneficial conditions need to be created to achieve this.

2. Organize a multi-actor process

Step two directly overlaps with the previous step, since the organization of beneficial conditions is one of the main targets here. Within the transition process there should be: (i) possibility to meet each other and stimulate innovative experiments, (ii) remove institutional barriers and stifling regulations, (iii) create an independent organization that supports the innovation process, (iv) launch transition teams within the actor organizations to improve communication between them.

3. Demarcate the transition situation

The third step tends to be difficult, since the situations of transition are always part of complex situations, spreading several sectors and domains. When these can be demarcated into several concrete sub themes, relations between transitions and system innovations, project-, process, en and product innovations could become clear. This offers the opportunity to select the right experiments.

4. Formulate the different problem perceptions

In this step the problem will be extensively investigated from different perspectives. It is important that all stakeholders ventilate their motives, when these converge towards each other agreement can be reached. Uncertainties should be listed, since they can play a major role in the further process of transition. Stakeholders should come to a joint agenda (Dirven, et al. 2000)

5. Develop long-term vision

The development of transition goals that should be reached in the coming decades will function as a useful guideline. These end goals should not be abstract, but should include innovative, inspiring and ambitious elements and finally end up in several end situations. Which end situation will be most likely will evolve during the transition process, that will probably also change the proposed end situations. This process should not be confused with back-casting, which is a process in which one final situation is considered and from that point steps will be defined that needs to be taken.

6. Explore the transition pathways with the transition purpose

For each end situations different scenarios are defined that are explorative, innovative and combine autonomous developments in policy and strategy with surprises. Stakeholders should not focus on one scenario in an early phase. Also this is an evolutionary process based on learning effects and insights some scenarios will be unsuitable after a while and which would be successful.

7. Develop and apply the right instruments

To achieve the proposed transition agenda stakeholders need to use different instruments. Here we can think of actions and processes, but also fiscal arrangements and public-private partnerships. Instrument does not have to be new instruments, especially on the short term existing instruments could be helpful. In reality we will see a mix of old and new instruments, when these are well-balanced the contribution to the transition will be most effective.

Experiments can play an important role as well. Different experiments that suit the transition objectives and that suit the transition pathways should be performed. Mind that this is not concerning demonstration projects, the experiments should contribute on a system level and they could probably end up in a demonstration project when the first experiment. Experiments have usually a high risk factor, since when failing consequences to the overall project could be significant.

8. Formulate temporary purposes

As assessment framework can be used to check whether or not the current purposes are justified. When existing initiatives of societal actors are used, no double work has to be done.

9. Evaluation of temporary purposes and learning effects within development phases

Especially the temporary purposes that will be considered as guidelines should be reconsidered and evaluated on regular basis. Also the transition process, the involved stakeholders and experiments will be monitored.

10. Organize the follow-up transition round

After the transition cycle is completed another round can be initiated. The follow-up cycle will preferably be done with more stakeholders involved and on several scale- and organizational levels. During a whole transition period about five to ten transition cycles needs to be completed.

Appendix 4 - Instruments and company values of Enexis

To perform their distribution tasks and fulfillment of their company values the DSO can use a couple of instruments which will be explained in this section. First of all a brief explanation of the company values will be given. Enexis distinguishes three values that are most important to them, which are Quality of delivery, Safety and Economy. Secondary values are Legitimacy, Customer Friendly and Sustainable.

Quality of delivery

Transportation and distribution of gas and electricity among their network is the primary activity of Enexis. It is one of the basic facilities in today's society and industry. Consumers are not wondering whether or not sufficient energy is available, they expect this to be. Therefore every decision will be evaluated on the effect this will have on the quality of the delivery, which is actually the reliability of the system.

Safety

Safety of employees and customers is of vital importance. Electricity and gas could both cause dangerous situations to human lives, industrial processes and buildings. Besides the direct damage such situations will also have economic consequences to the company itself.

Economy

Since energy resources are essential in today's society, the affordability will have a direct effect on the economic viability of these processes. However quality and safety should be guaranteed, the price of energy needs to be affordable. This will strengthen the competitive position of industries in The Netherlands and therefore the domestic economy.

Legitimacy

The DSO is obliged to operate within the legal frameworks that are designed by the ministry.

Customer Satisfaction

The services that are performed by the DSO need to fulfill the customer needs. Due to the monopoly position it is essential that the DSO pays attention to complaints. Customer satisfaction is included in the risk matrix of Enexis and therefore explicitly taken into account when alternatives are investigated.

Sustainable

The stakeholder model that Enexis is handling covers, clients, shareholders, employees and finally society. This societal interest is mentioned as most important to Enexis. Taking this into account Enexis is willing to facilitate the energy transition. Therefore the DSO is trying to improve sustainability throughout their activities. Energy losses are reduced, energy efficiency is increased and advantageous choices are made to favor renewable energy sources.

The rights and obligations

However customers can choose different energy companies to buy their electricity and gas, this is not the case for the distribution system operators. Which DSO will distribute your gas depends on the customers location. A DSO gets the concession of the authorities to perform the distribution tasks in a certain area. So they own the right to perform the distribution and transport services in a certain area.

Obligations: connectivity obligation, strategic obligation KCD

Since the renewed Gaswet of april 2011 the DSO has the obligation to connect customers to the gas network. Of course this is accompanied by some requirements like the customer should not be located in a deserted place in the country. More details about the connection obligation can be found in the strategic analysis B3.

According to article 8 of the Gaswet every distribution system operator needs to deliver a Quality and Capacity Document (KCD) by the competition authority (NMa). This document covers aspects of distribution and transport services now and in the future. The KCD gives an insight in the middle long as well as the long term horizon. Furthermore the document presents policy related to capacity planning. This involves future distribution expectations completed with policy that describes how the DSO will cope with the expected distribution load. Finally the KCD gives an insight on the quality monitoring systems.

Lobbying

The collaboration of a DSO is needed in most of the innovative energy projects that are initiated these days. For this reason the DSO's are invited to numerous taskforces. Here Enexis is in the position to make strategic alliances with other stakeholders in order to achieve their objectives. However Enexis' collaboration is necessary, it will not be advantageous to take an opposed attitude without the support of any other stakeholder. The DSO will always be dependent of other parties and should therefore maintain the connections closely.

Contacts academia

Enexis works in close collaboration with universities, especially the 3 technical universities in The Netherlands. Several employees have a part-time application at the university as well. Most of them are performing a PhD study parallel to their work at Enexis. Furthermore lots of graduate students perform their thesis project at Enexis and a part-time professor on Smart-Grids is seconded from the company to the University of Technology in Eindhoven.

Contacts governmental

Since the amount of DSO's in the country is limited the ministry uses the input of, especially the larger, companies in defining their (legal) policies. The ministries, agencies and taskforces related to green and biogas approach Enexis to involve in their processes together with other stakeholders.

Appendix 5 – List of Interviewees

Date	Person	Organization	Subject
4th January 2011	Jan Flonk and Michiel van Dam	Enexis	Graduation subject: dynamic gas network management
25th March 2011	Else Veldman	Enexis - Innovation	Organization of Enexis in the energy playing field
29th March 2011	Thijs van de Pas	Enexis – Infrastructural Services	Green gas and regulation
4th April 2011	Kirsten van Gorkum	Enexis - Innovation	Issues on green- and biogas
4th May 2011	Ruud van de Meeberg	Enexis - Business Development	Commercial opportunities to Enexis
29th June 2011	Robert Eenkhoorn	Provincie Zwolle – DHV	Operational approach Salland pilot
28th September 2011	Johan Wempe (by phone)	Erasmus Universiteit Chair Werkgroep Groen Gas	Chicken-Egg causality issue, tragedy of the common
28th September 2011	Mathieu Dumont	Agentschap NL – Ministry of Economic Affairs	Biogas and the governmental role
5th of October 2011	Johan Wempe	Erasmus Universiteit Chair Werkgroep Groen Gas	Biogas hub development and the challenges
30th of October	Marita Turpin (mail conversation)	University of Pretoria	On applying the Multiple Perspective Approach
9th of November	Kirsten van Gorkum	Enexis - Innovation	Reflecting upon recommendations Enexis

Appendix 6 – Scientific Article

Method to study and explore ill-defined systems

An implementation of the Multiple Perspective Approach for emerging biogas infrastructures

Frank Pijnenborg[a,b,*]

[a]*Faculty of Technology, Policy and Management, Delft University of Technology,The Netherlands*

[b]*Department of Asset Management – Innovation, Enexis N.V., Rosmalen, The Netherlands*

Available online 8th December 2011, Number of words 4447.

Abstract

System studies are used often in today's research fields. A wide variety of approaches is available, like hard and soft system methodologies. Yet while performing a general system study on a non-existing system the choice of a suitable methodology is complicated. Specific conditions and dis- or advantages of system analysis approaches urges researchers to make trade-offs. Pragmatic approaches like the Multiple Perspective Approaches (MPA) from Mittroff and Linstone (1993), could be composed in a way it meets specific requirements a specific system study needs. However this MPA is a promising framework for general system analysis it lacks some practical guidance. This paper suggests a practical guidance to the MPA. Therefore the emergence of biogas infrastructures in The Netherlands is used as a case-study. It appears that an application of MPA is a time consuming undertaking, but that by combining multiple perspectives an added value is created compared to the general system analysis methodologies. When the proposed practical guidance will be applied by other researches on different subjects, the applicability of the practical guidance could be further explored.

Key words: Systems theory, System study, Multiple Perspective Approach (MPA), methodological implementation

1. Introduction

It is obvious that a system study considers the study of a specific system. This is done by analyzing its components and the related operations. Especially in the software development the term system study is often used as part of the Systems Development Life Cycle (SDLC). Here it has the function of system analysis, describing the physical system in detail and identifying the limitations and problems which arise at a system (Weitzel et al., 1989). Nowadays the concept of system studies is widely applied, however it is not precisely defined what the concept of a 'system study' includes. There are specific technical studies available that focus on nuclear processes (Xu et al., 2008). On the other hand researches in social context arise. Their system studies consist for example out of analyzing social movements within a country during hostile occupation (Boles, 1997). However both analyses differ in the exact performance, the concept of analyzing system's components and related operations is still the core of their research. This is also the fundament to systems thinking. Within this paper a system studies exploration is presented that focuses on the selection of a suitable approach for a specific system study. Additionally a practical guidance is composed for the performance of the Multiple Perspective Approach.

Within section 2 the system approach will be explored, followed by a more specific explanation on the available system analysis approaches in section 3. Then section 4 will be used to explain when to choose which approach. Within section 5 the specific study objective of the case-study is defined. Based on this objective a system analysis approach is selected in section 6. Within the final part of the paper the Multiple Perspective Approach is the central subject. An explanation on the approach is delivered in section 7, while section 8 presents a practical guidance of the approach. Barriers and advantages of the application of the MPA will be discussed in section 9. In section 10 the final conclusion can be found.

2. Exploring the system approach

There are several developments in systems thinking. On the one hand there are researchers focusing on the development of general system theories (Klir, 1991). On the other hand there is a focus on the application of systems analysis as a means to solve complex social problems, using quantitative descriptions of social systems or organizations (Forrester, 1961; Banks et al., 1984). These are often referred to as hard systems thinking. Furthermore there is a group focusing on the process to approach the problem, this includes the systematic structuring of objectives, means, relations etc., the quantitative aspects are here less important (Van Daalen et al., 2008). This approach is often referred to as soft systems thinking.

By using the socio-technical systems perspective, a third element is introduced: namely the possible relations between the hard and soft elements. These are considered as the social elements. Hughes (1987) and Nelson and Sampat (2001) have already made this distinction; they described them as elements of non-technical nature in systems. Where Hughes emphasized on organizations and legislative artefacts, Nelson and Sampat considered social technologies besides the physical technologies. Institutions are in their view generally accepted social technologies. Both, actors (considered the physical bodies) and technical elements are subject to the law of nature, yet the difficulties within a system study will arise due to the fact that social elements and the behaviour of actors also refer to (individual) intentions and to more complex guiding principles (Ottens et al., 2006).

However each approach has specific (dis)advantages, each approach deals with complexity by means of abstraction and reduction and making a distinction between a system itself and the system's environment.

3. Which system analysis approaches are out there?

Now let us evaluate different system approaches, both hard and soft system methods, by means of their characteristics.

a. Hard systems methods

The hard system methods have a quantitative oriented basis that needs determined objectives in advance, unless purely technical problems are involved. Quantified models are a common tool within the hard system approach, as one could imagine these are designed to evaluate these pre-determined objectives such as profit or throughput times. Unfortunately the need of quantification leads to the omission of factors that are not quantitative or to the quantification of factors of factors. Furthermore hard systems approaches do apparently not offer solutions to handle different problem definitions. Examples of hard system methods are System Dynamics, System Analysis and Operational Research (Van Daalen et al., 2008).

System Dynamics: Could qualitatively describe and analyze complex system in terms of the processes, information, organization boundaries and strategies. The approach facilitates quantitative simulation modeling and analysis for the design of system structure and control (Wolstenholme, 1990). The structure contains not only physical aspects of plant and production process, but also the policies and traditions important to the decision-making process in that system (Roberts, 1988).

Systems Analysis (RAND Corporation): A systematic study of the costs, effectiveness and risks of policy alternatives or strategies. In this approach the use of models has a key role since they are used to predict consequences of alternatives (Van Daalen et al., 2008).

Operational Research (EURO, 2005): Suitable for situations related to planning and setting up logistical processes, inventory management and the allocation of (scarce) resources. It includes factors as chance and risk.

b. Soft systems methods

The soft system methods include stakeholders and their perceptions, values and interests. However especially in complex situation this can be rather difficult, since these differ a lot. The approach is based on the basic assumption that stakeholders try to reach consensus, but critics argue that it cannot handle fundamental conflicts. Another point of criticism is the belief that it is only possible to see participation as a remedy for so many organizational problems because people believe in consensus and the obstacles that might actually stand in the way of participation are not addressed (think of time investment and powerful stakeholders). Examples of soft system methodologies are the Social System Design, Strategic Assumption Surfacing and Testing and Soft systems Methodology (Van Daalen et al., 2008).

Social systems design: In this approach proposed by Churchman it is the system designer's task to make the decision-makers aware of the restrictions of their own world-views. A model can only represent one possible perception of the system. When the aim is to improve the entire system taking into account perceptions of all stakeholders this could come with complications. In the case not all actors are involved in the process to generate this system, sub-optimization might be the result because the decision-makers only have a limited world-view. This approach uses thesis, antithesis and synthesis to come to a joint perception (Churchman, 1969).

Strategic Assumption Surfacing and Testing: This approach of Mason and Mittrof is a classic soft system approach in which the emphasis is focused on the stakeholders instead of the system itself. The approach starts by creating consensus in groups of stakeholders that have their objectives relatively in common. The groups are brought together in debate in order to come to reach a compromise on the basis of which a new strategy can be found (Mittrof et al., 1993).

Soft systems methodology: Checkland's methodology is aimed on managing complex, messy, dynamic, ill-defined human problem situation without clear objectives and that are characterized by multiple perspectives. The method tries to create the richest picture possible of a certain situation by generating several models. For example the system descriptions are defined in the so-called root definitions and are included in conceptual models (Checkland, 2000).

4. When to use which methodology?

When to use which method is not always clear. Flood and Carson (1988) posed a classification of several systems methodologies by means of defining different dimension. A first dimension is the distinction between simple or complex situations. This is based on the number of elements, interactions, the possibility of measurement and whether or not a system can evolve over time. Another dimension considers the nature of the decision-makers. Does some degree of consensus exist between them? In other words are they operating unitary or pluralistic? Based on this we can argue that Systems Analysis focuses on systemic-unitary problem situations and Operational Research considers mechanical-unitary cases. The Soft Systems Methodology and Ackoff's Social Systems Sciences are more systematic-pluralistic oriented approaches. Also these subdivisions are subject to discussion, since all methods can be viewed differently and different approaches contain different techniques. A pragmatic approach can be composed by choosing different techniques. In this way several perspectives could be combined. An example of a pragmatic approach is the Multiple Perspective Approach of Mittrof and Linstone (1993). This approach will be explained in further detail in section 7.

5. Objective of the considered system study

Which system thinking approach is suitable to analyse a specific situation depends on the nature of the situation but also on the objective of the research. This can for example be related to analysing, testing or design. In this section the objective of the system study on biogas infrastructures will be explored, leading to a selection of the system approach.

The applied system study is used in a research study that investigates the emergence of biogas infrastructures in The Netherlands. Despite several initiatives have been defined, no physical results have been accomplished. A biogas infrastructure is a stand-alone pipeline network that gathers biogas from several de-central biogas producers. The gathered biogas is transported to a central upgrading facility, here the biogas is upgraded to natural gas quality. This gas will be injected in the natural gas network to be distributed to the consumers. In this case the objective of the system study is to create a thorough system understanding for the technical and social elements. It is of importance that relevant issues will be taken into account. Unfortunately there is no methodology that will ensure this requirement.

What are the characteristics of this system upon a specific system approach can be selected? Let us start by taking into account the classification of Flood and Carson (1988) this system can be considered to be systematic-pluralistic. The system consists out of several elements from a mechanical perspective (production, transport, upgrading, etc.) and an organizational perspective (producer, distribution network operator, consumer, municipalities, etc.). Furthermore the objectives of these involved make them not operating unitary. This analysis suggests that soft system approaches are most suitable to our system study.

A special characteristic to our system study is the lack of a real physical system. The system needs to be analyzed as it is 'expected' to be designed. This differs from (hard) systems engineering studies that are able to design, compose, manage and use complex systems in the most efficient way (Van Daalen, 2008). Due to the fact the involved stakeholders have created already a technical elaboration of biogas infrastructures and actors already fulfill specific roles in the playing field this system study is aimed on progression based on the current systems situation.

Another characteristic of the biogas infrastructure is the fact that it can be considered to be a sustainable development and can be seen part of the energy transition. Several researches show that these developments need adjusted system analysis approaches (Rotmans, 2004, Geels et al. 2000).

6. Selecting a system study approach

Several system approaches have been presented and the objective and characteristics of our object of study have been discussed. This enables us to make a custom fit between the available approach and the required approach. As was argued in the previous section the system of emerging biogas infrastructures is most suitable to soft systems methods. Yet it appears that the discussed methodologies all have shortcomings in this case.

Ackoff's social system science focuses on learning and adapting, something that is difficult in a situation that not yet exists. Churchman's social systems design emphasis on the different worldviews stakeholders have. This is an important element of the situation, however we also have to deal with a technical system that is not covered in such an analysis. For Mittrof the same accounts. This approach tries to find agreed assumptions upon which new strategies could be defined. Finally the soft systems methodology approach of Checkland seems to be most useful in this case. It considers ill-defined, messy, complex and dynamic situations without clear objectives and characterized by multiple perspectives.

Since the objective of the system study is the creation of a thorough system understanding, the researcher wants to take all relevant elements of the system into account. Therefore the pragmatic Multiple Perspective Approach is selected using a variety of techniques provided by the soft systems methodology of Checkland. This latter seemed to be most useful related to emerging biogas infrastructures.

7. Multiple Perspective Approach explained

The Multiple Perspective Approach (MPA) was suggested by Mitroff and Linstone.). In their book, "Unbound Systems Thinking", the authors argue that: "Multiple combinations of models and observations are more likely to lead to truth than any single model or set of observations." Consequently, they introduce an approach that 'sweeps in' as many perspectives as possible while analysing: the Multiple Perspective Approach (MPA) (Mittroff et al. p.97, 1993). The combination of models will contribute positively to the overall understanding, but how do we know which techniques are most suitable. Here arises the dilemma that is also known as Kant's problem: how do we choose a set of representations that are relevant for a particular problem? No answer is provided on this dilemma. The researchers argue that it can be considered like a jury arriving at a decision, in that case the prosecutor witnesses and integrated their perspectives to deliver a summation to the jury. All executives wrestle with such questions daily – often successfully – even though they often do it intuitively. It can be argued that the selection of the proper perspectives constitutes the test of effective decision-making and implementation (Mittroff et al., 1993)?

In the article of Turpin, MPA is introduced as a general systems analysis framework that is useful for studying messy social problems in particular (Turpin, 2009). Two advantages of the method were identified.

First of all there is the underlying philosophy, which is well expressed and satisfactory from a systems point of view. The essence of MPA is that it tries to be all-inclusive in its way of addressing a problem, this is of course a fairly idealistic idea. The MPA perspectives are classified into five categories, namely: technical (T), organizational (O), personal (P), ethical (E) and aesthetical (A).

The second advantage of the MPA is that it is able to address three of the sociological paradigms that were described by Burell and Morgan(1979):

- The functional paradigm (mainly using the T perspective): considered to be the primary paradigm for
- organizational study, assuming rational human action.
- The interpretive paradigm (covered by O and P): focused on the 'on-going-process' in better understanding the individual behaviour.
- The radical humanist (E): concerned with releasing social constraints that limit human potential. This paradigm is often used for justifying revolutionary change, a side form of this paradigm, structural humanists are the fundamental paradigms to Marx, Lenin and Engels (Burell et al., 1979).

There is a belief that these different paradigms are incommensurable: when applying the functional paradigm one is essentially blind to aspects that are visible from the interpretive paradigm, and vice versa. An example: a civil engineer and a social worker at a road accident scene. The one will observe things that the other may be blind to (Turpin, 2011). The one will observe things that the other may be blind to. While the civil engineer will probably look at the traffic streams, traffic lights and accompanied risks, the social worker will put emphasis on the procedures of the emergency services. To sum up, the MPA seems to be a promising system analysis approach when applying a system study. However by applying the approach several authors determined that the approach lacks practical guidance (Turpin, 2006; Meyer et al., 2007). Therefore an attempt is made to create a basic practical guidance for using the MPA in the next section.

8. A practical guidance in applying the MPA

A framework is designed (Figure 4**Error! Reference source not found.**) that covers the multiple perspectives of the MPA, namely T, O, P, E and A. Using a matrix structure the three sociological paradigms that were discussed in the previous section are added. As mentioned before the one perspective will have more interfaces with a certain paradigm compared to another. But in order to get a thorough system understanding a reflection of all combinations of perspectives and paradigms will be useful. In Figure 4 the used techniques are visualized in red.

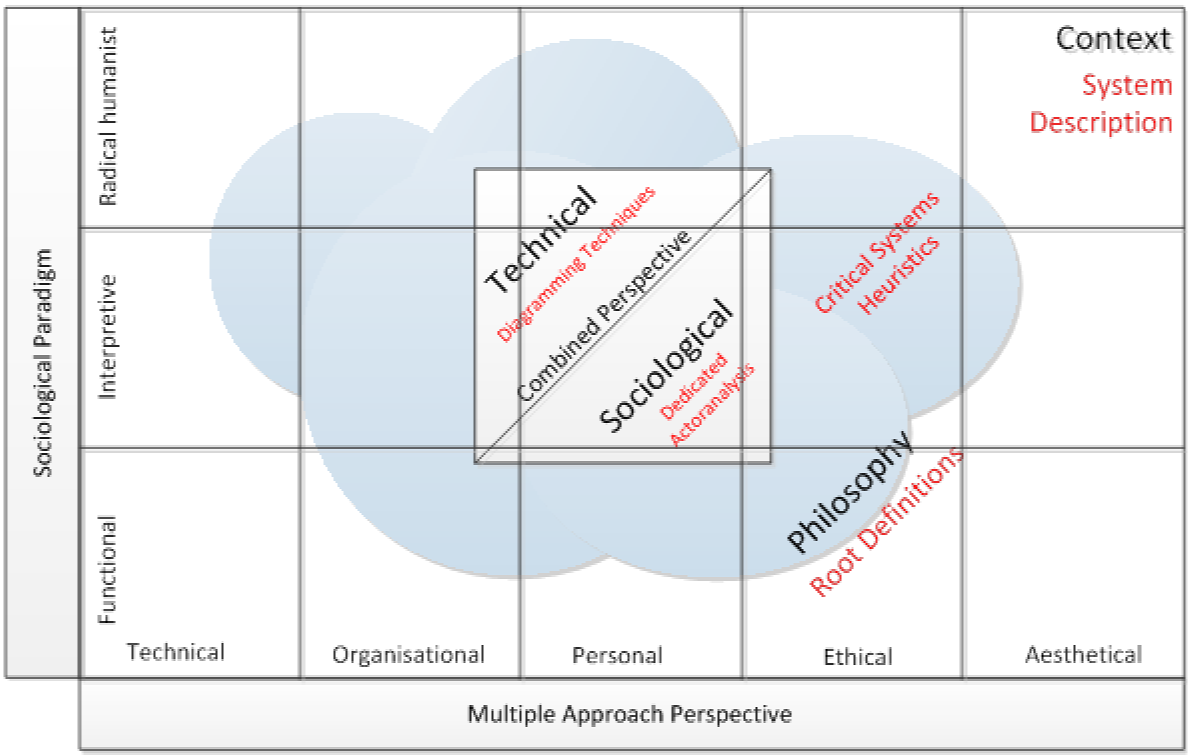


Figure 4: MPA Framework

Now our structure is defined the next step is the definition of the system itself. Two of Checkland's techniques were used that were part of the soft system methodology.

The system definition is an attempt to structure the current 'unstructured' situation. This will be done by a formulation of the system description including root definition (Checkland et al., 1990). These root definitions will sketch the philosophy and purpose of the system by distinguishing the functional, physical, economical, micro, meso and macro aspects. Furthermore the rich picture method will be used, this contains customers, actors, transformation, worldview, owner and environment. This method that originates from Checkland's SSM is used to create the system context (Checkland, 2000). The cloud in Figure 4 visualizes this system philosophy, which in combination with the root definitions functions as a demarcation of the system.

Now the system boundaries are set, the input to the five perspectives can be generated (T,O,P, E and A). As a starting point the practitioner report of Turpin et al.(2009) is used. This includes four steps divided over the categories:

- T perspective, perform an analysis using influence diagrams or a hard systems method (from systems analysis, operations research or systems engineering).
- O and P perspectives include the perspectives of as many role-players as you can find.
- E perspective, use a critical systems approach to uncover some of the ethical issues.
- A perspective: state your interpretation of aesthetics.

These steps are elaborated as follows:

1. T perspective:

Diagramming techniques will be used to identify the systems of interest and the underlying worldviews. This creates the opportunity to explore interconnection, identify emergent themes, system levels and subsystems according to key stakeholders (Collins et al., 2007). In this case the socio-technical subsystem of Chappin (2011) is taken as a starting point. This technical subsystem was originally designed for energy production, which is adapted for biogas infrastructures in this research. This step will centre mainly on the technical components, with a focus on the functional paradigm.

2. O and P perspectives

The sociological sub system will also be described using an adapted socio-technical subsystem of Chappin (2011). It considers current practices, interactions and participation related to biogas hubs. Furthermore, it describes the multiplicity of perspectives from different stakeholders. Each stakeholder that is involved in the process is discussed including their responsibilities and objectives. also In addition, overall subjects will be discussed, that do not touch upon one certain stakeholder but on multiple. This perspective focuses on the interpretive paradigm.

3. E perspective

To cover the ethical perspectives, the Critical Systems Heuristics (Ulrich, 1983) is used to reflect upon the biogas infrastructure. This technique explores the difference between a desired situation and the current situation. A tension is revealed between the two situations in case of a problem. Within this perspective the radical humanist paradigm is leading.

4. A perspective

Within the MPA the aesthetical reflection is also included. Considering the system of biogas infrastructures in The Netherlands this seems to be an unimportant aspect. The system is located mainly under the surface, furthermore involved stakeholders do not have a specific attention on aesthetics in their objectives. As was mentioned in section 1, 735 digesters will be needed when the Dutch natural gas supply is substituted by 50% biogas. In that case a similar discussion could arise as is currently the case windmills. Are there maybe too many digesters 'polluting' the landscape? Since this situation is unlikely even in the middle-to-long term the aesthetical perspective is not elaborated further in this research.

The execution of these four steps is an iterative process, for example: issues from step 3 also could have consequences for the status of step 1. In figure 6 the used techniques are visualized in red.

Furthermore the square in the middle represents both socio-technical subsystems from the T perspective and the O and P perspective. To finalize the MPA these subsystems are coupled as one coherent socio technical system (STS).

9. Results of applying the MPA

a. Barriers of applying the MPA

The MPA will take relatively more time effort compared to other system approaches. This is caused by the extensive use of multiple paradigms in parallel. Furthermore also the preparation period before applying the MPA will take time.

Since there is a wide variety of techniques available that can be applied within the MPA framework, a modeler needs to be aware of the pros and cons of the available techniques. Actually also the underlying philosophy of the methodologies these techniques originate from needs to be understand. To investigate the different methodologies and techniques will require time investment of the modeler since every system analysis will have its specific requirements.

Another barrier is the integration step that needs to be made. Without integration of the perspectives the added value of an MPA is negligible, since in that case it is just a collection of separate analysis. To make an integration step at least basic knowledge of all system components is required. According to Mittrof and Linstone the multiplicity of perspectives is vital but will for a great many introduces discomfort as well. How does one integrate perspectives? How does a decision-maker finally combine all the inputs he or she obtained to make a decision (Mittrof and Linstone, 1993). Everyone will answer these questions differently, within the chosen approach iteration was key. New developments, urged the researcher to think about consequences on other system aspects. As a consequence the choices that were made are hard to trace, which is from a scientific point of view a weak characteristic of the integration within the MPA.

b. Advantages of applying the MPA

The combination of different perspectives leads to an added value compared to the single system analysis approaches. A stakeholder analysis for example, which was in our case part of the O perspective, is usually performed as a stand-alone analysis. The MPA includes besides the individual objectives and responsibilities also the overarching themes. By combining the stakeholder analysis with the Critical System Heuristics the analyses shifted from showing the current state of the stakeholder towards the 'transition' that stakeholders need to make. This leads to a prescriptive description about the direction the stakeholders should take. Such findings would not end up from a single stakeholder analysis.

In this specific system study it was important to ensure the inclusion of all relevant issues. The MPA decreases the chance essential elements are excluded by the use of the incommensurable sociological paradigms (as discussed in section 7). In this case a complete socio-technological system description was the result.

A final advantage while using the MPA are the degrees of freedom that the researcher has available. The researcher is responsible for the selection of the sub techniques and methodologies. Furthermore the researcher's influence on the interpretation of especially the integration steps is significant. This is in convenient to the researcher; however this will also have drawbacks on the research results. These could be significantly influenced by the researcher's views.

10. Conclusion and Recommendations

The pathway between starting a system study and selecting a suitable approach is essential to the eventual outcome of the study. Therefore the objective of the study needs to be deliberately defined, based on this objective a suitable approach can be selected.

Due to the wide availability of system analysis methodologies and their minor differences selecting the most appropriate approach is a challenge. Both hard and soft system methodologies could contribute especially in case of a general system analysis. A pragmatic approach, which is composed out of several techniques, can be adjusted in such a way that it satisfies the system study objective. The Multiple Perspective Approach is a pragmatic approach and is considered to be useful as a general system analysis framework. In our case the system study subject was the emerging biogas infrastructures in The Netherlands. However unless it is considered to be a promising analysis approach, authors found out that the approach lacks some practical guidance.

This paper provides a stepwise guidance to all perspectives of the MPA. Each perspective is covered by analysis techniques, mainly related to the Soft Systems Methodology of Checkland. Within the analysis the different perspectives of T, O, P, E and A each try to surface valuable information related to the system situation that is not attainable by the other perspectives. An engineer, who is comfortable with the T perspective, may limit his assessment of a situation to rational models. Including the O and P perspectives will help him to be sensitive to "irrational" views or motivations of the role-players, which in the end may influence the outcome of a situation more than the rational forecast.

After applying the MPA it can be concluded that it requires a serious time investment to perform the MPA. This due to the multiple perspectives that are taken into account, but also the preparing understanding that is needed by selecting suitable analysis techniques. Furthermore the integration step requires knowledge on all system components, which is difficult to execute by one or a small group of people.

Advantages of the MPA reveal in the added value the incommensurable sociological paradigms have towards each other. Furthermore the MPA decreases the risk of missing essential information to the system study. The final advantage that could be addressed were the degrees of freedom the researcher will have during the system analysis. His responsibility on the selection of appropriate methodologies and techniques and his interpretation will have significant influence on the research results.

In the end, a truly multiple perspectives approach is an ideal that one can only work towards, but giving a few steps in that direction is meant to enrich one's assessment of a situation, so that decisions are based on a more inclusive set of factors.

In the case of biogas infrastructures the practical guidance lead to a well-balanced socio-technical system. Yet whether or not the added value of this specific practical guidance is applicable to more situations is unclear. The defined steps should be performed by other researchers on different subjects. That would enable us to claim with more significance if this is the case.

References

BANKS, J., CARSON, J., 1984, Discrete-Event System Simulation. Prentice-Hall

BOLES, E.E, 1997, Rebels, Gamblers and Silk: Agencies and structures of the Japan-US Silk Network

BURELL, G., MORGAN, G.. 1979 Sociological Paradigms and Organizational Analysis, Heinemann.

CHAPPIN, E.J.L., 2011, Simulations of Energy Transitions, Thesis. Next Generation Infrastructures Foundation, Faculty of Technology, Policy and Management. Delft University of Technology, The Netherlands.

CHECKLAND, P, 2000, Soft-systems methodology: a thirty year retrospective, systems research and behavioral science. System Research of Behavioral Science. 17, S11-S58

CHECKLAND, P., SCHOLES, J., 1990, Soft Systems Methodology in Action. Chichester, John Wiley and Sons.

CHURCHMAN, C.W., 1969, The Systems Approach, Dell, New York.

DAALEN, C.E., VAN, PRUYT, E., THISSEN, W.A.H., 2008, Lecture notes: Continuous Systems Modeling – System Dynamics, Delft University of Technology

EURO, 2005, What is operational research? Euro web site: www.euro-online.org

FLOOD, R., CARSON, E., 1988, Dealing with complexity: an introduction to the theory op application of systems science. New York: Plenum Press.

FORRESTER, J., 1961, Industrial Dynamics. Cambridge, MA: MIT Press

GEELS, F.W., KEMP, R., 2000, Transities vanuit een socio-technisch perspectief, Rapport voor het ministerie van VROM, University Twente and MERIT, University Maastricht

HUGHES, T.P.,1987, The Evolution of Large Technological Systems, in *The social construction of technological systems: new directions in the sociology and history of technology* (Eds, Bijker, W. E., Hughes, T. P. and Pinch, T. J.), MIT Press, Cambridge, Mass., pp. 51-82.

KLIR, G., 1991, Facets of Systems Science. New York: Plenum Press.

MEYER I, SAIDI M, MODISE M, MARAIS, M and TURPIN, M, 2007,: *National Poverty Alleviation System Case Study 1: Applying Systems Concepts to the Community Based Public Works Programme.* CSIR, Pretoria, South Africa.

MITROFF, I.I., LINSTONE, H.A., 1993, The unbounded mind, breaking the chains of traditional business thinking. Oxford University Press, Oxford.

NELSON, R.R., & SAMPAT, B.N., 2001, Making sense of institutions as a factor shaping economic performance, *Journal of Economic Behaviour and Organization* 44 (1), pp. 31-54.

OTTENS, M., FRANSSEN, M., KROES, P. and VAN DE POEL, I., 2006. Modelling infrastructures as socio-technical systems, International Journal of Critical Infrastructures 2(2–3):

ROBERTS, E.E., 1988. Managerial Applications of System Dynamics. Cambridge, MA.:MIT Press.

ROTMANS, J., 2004, Transitiemanagement, sleutel voor een duurzame samenleving.

TURPIN, M., 2009, The multiple perspective approach as a framework to analyze social systems in a developing country context, University of Pretoria, South Africa

TURPIN, M., 2011, Personal Notification by e-mail, 30th of October 2011

ULRICH, W., 1983. Critical Heuristics of Social Planning: A New Approach to Practical Philosophy. Bern: Haupt.

WEITZEL, J.R., KERSCHBERG, L., 1989, Developing knowledge-based systems: reorganizing the system development life cycle. Communication of the ACM, Volume 32, Number 4

WOLSTENHOLME, E., 1990. System Enquiry. A system dynamics approach. Chichester: John Wiley and Sons.

XU, Y, JIN, H., LIN, R., HAN, W., 2008, System study on Partial gasification combined cycle with CO2 recovery., IEEE Power and Energy Society 2008, General Meeting.

Frank Pijnenborg

Hofwijckplein 10

2515 RJ Den Haag

T: +31-628692404

M: fpijnenborg@hotmail.com

Faculteit Techniek, Bestuur en Management

Jaffalaan 5

2628 BX Delft