Smelly sustainability

The case of the 1st Polish food waste to biogas plant

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Abstract:

Poland with its long coal and landfilling traditions struggles to reach the European Union goals for both the share of energy produced from renewable sources and management of biodegradable waste. Biogas is proven to be a part of a sustainable solution addressing the problem of organic waste utilisation while providing an opportunity for renewable energy generation as well as for nutrients recycling.

This qualitative study aims to explore how Poland can transit towards more plants producing biogas from food waste based on the single case of the city of Zabrze. While being a part of the main Polish coalmining region, this city is on the way to change its profile and to build the first biogas plant in the country using separately collected food waste as a substrate. This study focused on problem-solving uses the multi-level perspective to explore drivers and barriers the technology meets as well as it suggests a number of recommendations to improve the situation.

The findings show that the European Union policies on waste and renewable energy are the main drivers; whereas, the barriers are formed by a lack of sufficient support for biogas from food waste and by a lock-in of Technological, User/Market, Policy and Socio-Cultural regimes related to waste, energy and agriculture. Poland and other countries could learn from this study that the abovementioned barriers should be addressed together with a goal of market creation for biogas from food waste technology. This can be done by a reduction of support for the dominating fossil fuel systems combined with a simultaneous creation of a clear and long-term support system for the desired alternative technology.

Keywords: biogas, food waste, renewable energy, waste management, Zabrze, Poland

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Abbreviations

ACB	Agricultural biogas
BSAP	Baltic Sea Action Plan
CHP	Combined heat and power
EU	European Union
GHG	Greenhouse gases
IIIEE	International Institute for Industrial Environmental Economics
MBT	Mechanical-biological treatment
MLP	Multi-level perspective
MOSiR	Miejski Ośrodek Sportu i Rekreacji refers to Local Centre of Sport and Recreation in Zabrze
PIMOT	Przemysłowy Instytut Motoryzacji refers to Automotive Industry Institute in Warsaw
SPSEP	Swedish-Polish Sustainable Energy Platform
WWTP	Wastewater treatment plant

1 Introduction

1.1 Research background

Poland is one of the biggest coal producers in the world. This fossil fuel dominates the country's energy sector. Polish coal industry has a long history, a significant number of employees and wide public acceptance. At the same time, this industry is causing climate change globally and is responsible for air quality problems locally, which result in premature deaths and a wide range of respiratory problems.

When it comes to waste management, Poland is heavily relying on landfilling. This waste treatment strategy among other leads to methane emissions due to the decomposition of biodegradable waste. Municipal solid waste holds the third place for methane emissions generated by human activities and corresponds to 11 % of all global emissions of this gas (Singh, Kumar, and Roy, 2018), which is much stronger greenhouse gases (GHG) than carbon dioxide.

Being a member of the European Union (EU), Poland would need to revise its strategy both for energy generation and for waste management in order to fulfil the targets set by the EU. These targets include a significantly increased share of energy coming from renewable sources as well as a drastically decreased amount of biodegradable waste sent to Polish landfills.

Biogas production from food waste can be seen as a part of a future solution, which is addressing both the waste and energy areas. This solution is successfully applied in another EU country Sweden, but in Poland, there are currently no biogas plants using such kind of waste. However, the city of Zabrze, located in the very heart of Polish main coal mining region, has decided to take on a challenge and to make the first steps towards its own biogas plant based on food waste. Other Polish municipalities follow Zabrze's progress with great interest.

Due to its ability to consider the complexity of real-world technological transitions (Geels, 2002), the transition theory is seen useful in order to provide insights on how a shift towards biogas from food waste could happen in Polish energy and waste management systems.

1.2 Research objective and research questions

This thesis aims to provide an insight on the biogas from food waste production in Zabrze, Poland and based on this to give recommendations on how to improve the situation on both local and national levels. Thus, my contribution is mainly practical and focused on problem-solving.

General research question:

How can Poland achieve a transition to more biogas from food waste plants?

Subquestions:

1) What are the drivers for biogas from food waste production in Zabrze?
2) What are the barriers against biogas from food waste production in Zabrze?
3) How can the change be facilitated? (How can barriers be overcome and how can success factors be strengthened?)

1.3 Outline

The next chapter describes the research methodology, following by chapter 3, explaining the complexity of biogas system. Chapter 4 provides the background information for the case of Zabrze, while the subsequent chapter presents the transition theory. Chapter 6 combines the data analysis and discussion when answering the research question. Finally, chapter 7 draws the conclusions and gives suggestions for further research.

2 Research Design/Methodology

2.1 Ontological and epistemological considerations

2.1.1 Epistemology

This study is based on the epistemological position of interpretivism that recognises the difference between the subjects of social and natural sciences, and therefore "requires the social scientist to grasp the subjective meaning of social action" (Bryman, 2012, p. 30). Such type of research implies a triple interpretation of the phenomenon (Bryman, 2012). In this thesis, I as a researcher interpret people's perception of Polish waste management and energy systems and then apply the theoretical framework to my findings.

2.1.2 Ontology

From an ontological perspective, this study follows the approach of constructionism, which views the social world as a construct and acknowledges the role of individuals in the constant process of shaping this construct (Bryman, 2012). Thus, the actors related to waste management and energy systems in Poland are believed to have an active role and the capacity to influence the transition of the abovementioned systems. At the same time, the pre-existence of these systems is not declined.

2.2 Research strategy and research design

Qualitative research strategy and single case study design have been chosen in order to achieve a deep understanding of the possibilities for the development of biogas production system based on separately collected food waste in Zabrze. Moreover, according to Yin (2009), case study design is the most suitable for investigations with a combination of the following three conditions:

- "How" and "why" questions are to be answered;
- There is a little to no control over events;
- A contemporary phenomenon is in focus.

This study falls under all three of the conditions, which justifies the choice of the research design.

In spite of the fact that there is a lack of consensus on the criteria for qualitative research evaluation, the common critique is mainly derived from the assessment criteria for the quantitative strategy (Bryman, 2012). Qualitative research is accused of being subjective, difficult to replicate and hard to generalise. Furthermore, there is an additional criticism for lack of transparency in the research process (Ibid.). Being able to provide holistic and meaningful characteristics of the studied phenomenon, case study design is often used for conduction of qualitative research (Bryman, 2012; Yin, 2009). In such a case, it shares the same critical considerations (Ibid.).

However, this study attempts to respond to some of the critiques. As a response to external validity criterion, it can be stated that statistical generalisation is not considered to be a purpose of such research design and chosen single case is not viewed as a sample (Bryman, 2012; Yin, 2009). Single case study instead seeks analytic generalisation by contributing to the theory expansion (Yin, 2009). The credibility criterion (Bryman, 2012) or construct validity (Yin, 2009) is addressed by the employment of data triangulation approach, which implies the use of multiple sources of data (Bryman, 2012; Yin, 2009). The data analysed in this research consists of documents, direct observations and interviews. Created case study database of collected data contributes to the reliability of the research (Ibid.).

2.2.1 Case selection

Zabrze has been chosen as a case for the investigation due to a combination of several reasons. First of all, according to the field expert (Interview 2), it was the only place in Poland, which intended to implement a model of biogas production based on separately collected food waste and with the purpose of the future usage of biogas for transport. Moreover, the idea of Zabrze biogas project is to become a pilot case for Poland and to show that it is a possible and feasible model in Polish reality.

Secondly, Zabrze was selected as a case based on convenience sampling. I have been involved in the biogas project in Zabrze and therefore have easy access to many actors related to it. Furthermore, due to my work, I had an opportunity to observe the development of the project from its initiation and during at least three years' timeline.

2.3 Data collection methods

In order to ensure high quality of case study research, three different types of data were applied. Data was collected by conducting semi-structured interviews with actors, involved in Zabrze project, reviewing the available literature on the topic (articles, policies, reports), and by personal observations.

2.3.1 Interviews

Semi-structured interviews were conducted as they allow for deeper understanding of the respondents' perceptions about the topic, while still maintaining a focus (Bryman, 2012). For the latter, an interview guide was prepared (see Appendix A. Interview guide.), covering the topics of Zabrze biogas project history and its overview, drivers and barriers, success factors and possible threats in the future, actors involved, ways to overcome barriers and to strengthen the success factors as well as lessons learnt. The exact questions, which were asked during the interviews and their order, were adjusted depending on the interviewee's relation to the biogas project in Zabrze as well as on the received replies (Bryman, 2012).

The respondents were chosen based on purposive sampling, with a goal to cover all the actors relevant to the biogas project in Zabrze, including among others people responsible for waste management, ecological education, international relations in Zabrze municipality (see Appendix B. List of interviewees.). In addition, a snowball sampling approach was used to identify the experts related to different parts of the biogas system in Poland. Interviews were held until the theoretical saturation was reached. In the thesis, I will refer to the interviews by their number in Appendix B.

Each interview started with the short introduction of me and the purpose of my study with the purpose of obtaining the informed consent of the research participants (Kvale and Brinkmann, 2009). The respondents, who were involved directly in the biogas project in Zabrze together with me, were asked to ignore this fact and to provide full answers, including the information, which in their opinion I might already know. Further, in order to address possible ethical issues of confidentiality, I asked for permission to record audio and to refer to the names and answers in my thesis (Kvale and Brinkmann, 2009). Most of the interviews were conducted face-to-face and were mostly held at the offices of the respondents, ensuring familiar settings for them (Bryman, 2012). Other interviews were taken via Skype and one via email correspondence. In total 13 persons were interviewed, some of them few times. Interviews with each respondent in total lasted from 41 to 165 minutes. The majority of the interviews were conducted in English, however, in Poland, almost all of them were in Polish with consecutive interpretation to English. Since Polish belongs to the same language group as my native languages and due to the fact of being involved in the biogas related activities intended for Polish people for few years, I could check both if my words were interpreted to Polish correctly and if the reply was interpreted fully and correctly to English. For most of the interviews, it was the case. All of the interviews were audio-recorded and transcribed afterwards.

2.3.2 Documents

Documentation was used as one of the data sources to crosscheck and complement the information gathered by interviews and observations. In order to avoid an overabundance of data only the documents most relevant to the research questions were reviewed (Yin, 2009). Moreover, Scott's (1990) quality criteria of authenticity, credibility, representation and meaning were applied for the source evaluation (Bryman, 2012). The selected documentation sources consisted of EU as well as Polish national and local Zabrze municipality's policy documents and reports related to the questions of waste management and energy; official statistics, and peer-reviewed articles on biogas related developments in Poland. Due to my involvement in Zabrze biogas project, I also had access to the administrative documents connected to it, including project application for funding, project schedule, reports from consultants, permits and minutes from Managing Board meetings. The insider's position provided me with the knowledge needed to understand the context and the aim, in and for which the documents were produced (Bryman, 2012).

2.3.3 Observations

Direct observations in the form of field visit and observations of meetings were employed in order to provide a better understanding of the settings for Zabrze biogas project (Yin, 2009).

The field visit of Zabrze landfill, where the future biogas plant is planned to be located, took place on the 5th of September 2012. The trip was organised by Miejski Ośrodek Sportu i Rekreacji (MOSIR - refers to Local Centre of Sport and Recreation in Zabrze), the municipal company, which owns the landfill and plans to build a biogas plant. The visit lasted about 30 minutes and was conducted mostly by a vehicle with two stops: one at the planned location for the biogas plant and one next to the current combined heat and power (CHP) plant, which runs on the gas collected there at the landfill. Photographic documentation (See Appendix C. Pictures from the landfill belonging to MOSiR.) was taken during the field visit with the purpose of conveying the characteristics of the location for the readers of this thesis (Yin, 2009).

2.4 Data analysis

Analytic induction strategy was employed for carrying out data analysis. Collected empirical evidence was examined, categorised and finally used as a basis for drawing conclusions (Yin, 2009). Transition theory with multi-level perspective was used as a theoretical framework to structure the case study.

2.5 Research limitations

2.5.1 My involvement in the project

Due to my work for Swedish-Polish Sustainable Energy Platform (SPSEP), I was involved in the biogas project in Zabrze from its initiation. Altogether, SPSEP, MOSiR and Zabrze municipality wrote a project application for funding from Baltic Sea Action Plan (BSAP) Fund in order to develop the pre-investment documentation for the pilot biogas plant using separately collected food waste. I participated both in the application development and some of the project meetings, thus getting the access to most of the project documentation. With two groups of students, I took part in the studies related to substrates investigations and possible biogas usage in Zabrze in 2012 and 2013 (Generosi et al., 2012, Černiauskaitė et al., 2013). During these studies, we held a number of interviews with the possible substrates providers, energy and gas buyers, as well as municipality representatives in Zabrze. Furthermore, we conducted a number of study visits in Sweden to study best practices of biogas from food waste production. In addition, I participated in a number of biogas related conferences, study tours and study visits both in Sweden with Polish delegations and in Poland. A full list of relevant activities I was involved during 2011-2015 can be found in Appendix D. List of biogas related activities I participated in.

All these have influenced my research. On the one hand, it made the data collection process easier, since I had access to the actors involved in the project and to the related documents. Moreover, it provided me with the insider's knowledge about the project and its context. Since I was involved in the project and could rely upon already established contact network in Zabrze, my interviewees had trust in me and they were willing to share their insights. Due to our collaboration with the city of Zabrze, I got support from the International Relations Office with both organising interviews and translation. However, even as an insider I did not get the opportunity to interview the Mayor.

On the other hand, my involvement in the project might have affected the research process and findings. The roles of researcher and a project participant can be conflicting. As a researcher, I have to be objective in my analysis, cover both positive and negative sides; at the same time, it can be hard to be critical to the project and not to become subjective due to my work relations to the actors or due to me being more exposed to the opinions of some of them. Moreover, since I was involved in getting funding for the project, my interviewees could have kept too positive tone about the project in general and could have been too optimistic about its outcomes.

2.5.2 Language barrier

As I have mentioned above I understand quite some Polish; however, it is difficult for me to speak or write in it. As I have not always had the support from an interpreter or translator, it was problematic to contact or to communicate with some of the actors, which limited my data collection.

Furthermore, my incomplete knowledge of the Polish language could have affected my document search and comprehension of the collected documents, the translation of which was sometimes assisted with Google Translate. This limitation is especially valid for the specific terminology and definitions that do not necessarily have exact English equivalent or are already problematic in Polish. The examples for such terms are “food waste”, “biowaste”, “kitchen waste”, “organic waste”, “biodegradable waste”, “green waste”. They might be confusing and have different meaning even to the actors involved in the project even though they share the same native language.

3 Biogas

3.1 Biogas system

Biogas is a mixture of gases that contains 45-75 % methane (CH4), 25-55 % carbon dioxide (CO2) as well as traces of other gases such as nitrogen (N2), hydrogen sulphide (H2S) and others (Deublein and Steinhauser, 2011). This mixture of gases is the result of anaerobic digestion, the natural process of organic matter decomposition by bacteria in the absence of oxygen. Biogas can be produced at, among others, landfills (it is also known as landfill gas), wastewater treatment plants and co-digestion plants (Ibid.).

At co-digestion plants, different substrates are mixed and digested together. The list of possible substrates can include energy crops as well as various types of organic waste from agriculture, food industries, and households (Figure 1). Some of the substrates might require pre-treatment processing: for example, slaughter waste usually goes through a sterilisation process, in order to eliminate pathogenic bacteria. Food waste from households and industry might need to be unpacked, milled and mixed (Černiauskaitė et al., 2013).

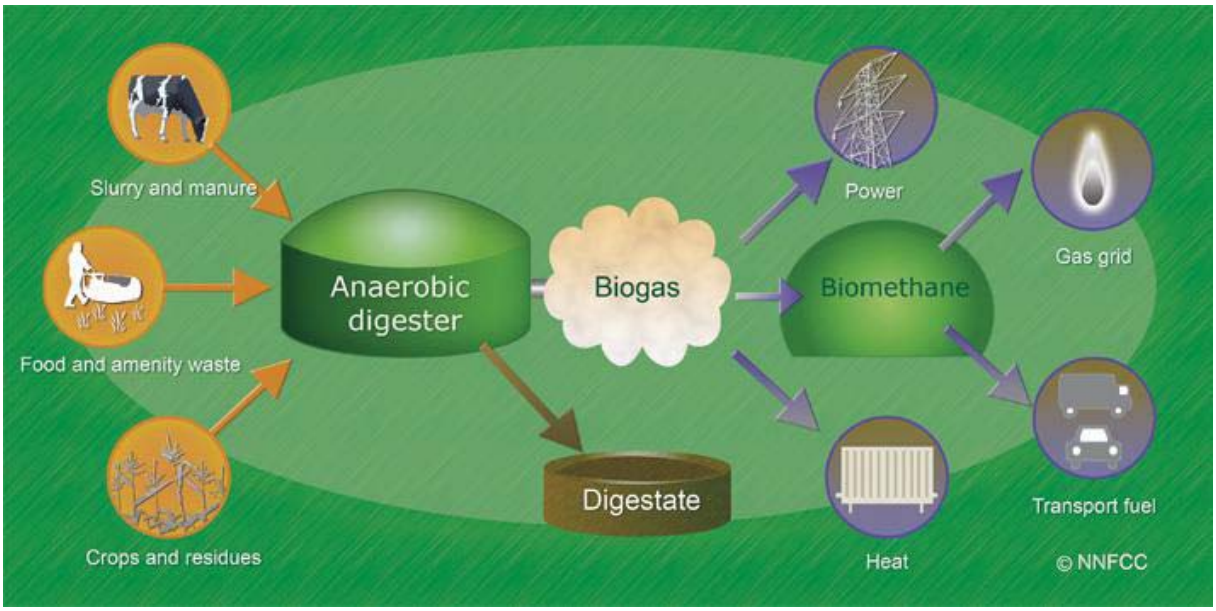

Figure 1. Biogas production process at co-digestion plants (Biogas-info.co.uk, 2015)

The fact that the digestion of substrates is done by the bacteria, which are living organisms, makes the digestion process sensitive to the type and the cleanness of the substrates. For example, manure stimulates digestion process but if digested alone does not produce much biogas (Deublein and Steinhauser, 2011). The contaminants in the substrates have a potential to stop the process completely

(Ibid.). Thus, in order to reach effective biogas production, the "right mixture" of high-quality substrates should be used.

In terms of its qualities and chemical content, biogas is similar to natural gas and can be used for energy production (heat or both electricity and heat in case of combined heat and power), as a vehicle fuel, or it can be injected in the gas grid (Ibid.). The latter two options require an additional stage of biogas upgrading in order to achieve higher methane concentration. As mentioned before biogas can have 45-75 % of methane, whereas natural gas has 85-95% (Demirbas, 2010). During the upgrading process, the methane content is increased up to 95-99 % by removing other gases from the mix (Lantz, 2013). The resulting product of biogas upgrading is also known as biomethane.

Apart from biogas production, anaerobic digestion also results in digestate formation. Digestate is rich in nutrients and can be used as fertiliser (Ibid.). For example, in Sweden, high-quality digestate is in demand and is more valued by farmers than raw manure or natural fertilisers (Emtairah, Ponte and Peck, 2011).

3.2 Biogas production as a biodegradable waste management strategy

In this thesis, biogas production is seen as a strategy for managing organic waste, focusing exclusively on separately collected food waste from households, restaurants, canteens and catering as substrates. In comparison with other approaches for treating biodegradable waste (Table 1), anaerobic digestion has many benefits. The most important is that it facilitates both energy and nutrient recovery, whereas other alternatives can only achieve one of them.

Table 1. Biogas vs other options for biodegradable waste treatment (Adopted from Deublein and Steinhauser, 2011)

Parameter	**Anaerobic fermentation**	**Composting**	**Incineration**	**Landfilling**
Energy yield	Material with high water content can be treated. Energy production more than 700 kWh/Mg	Energy consumption	Energy production depends on the water content since water has to be evaporated	Low energy production

Compliance with legal requirements	Residue odourless	Odour, toxic exhausts (NH3, CH4)	Gas purification necessary (dioxin, furans)	Odour, toxic exhausts (NH3, CH4)
Residue resulting from the process	- A small amount of the residue - Shorter time for rotting - Residue to be used as fertiliser	- Long time for rotting - Residue to be used as fertiliser	Ash as residue	Residue needs large landfill volume
Impurities in the residues	- Reduction of germs - Elimination of infectious agents (Salmonella)	Saving on fertiliser and energy (about 90 kWh/Mg)	Destruction of germs	Germs unaffected
Exhaust	Little greenhouse effect due to CO2	Little greenhouse effect	Greenhouse effect due to CO2	Stronger greenhouse effect due to CH4
Wastewater	Proportional to the amount of waste	Water remains in the residue	Water evaporates to the environment	Has to be cleaned
Investment costs	Medium	Low	High	Low

Anaerobic digestion of food waste helps to mitigate climate change from several aspects. First, it helps to reduce the GHG emissions from methane, which affects climate 56 times stronger than CO2 in the time horizon of 20 years (UNFCCC, 2018). Second, if biogas used for energy production it can substitute the energy produced from fossil fuels and thus, prevent additional emissions (Lantz, 2013). Finally, if digestate is used instead of industrial fertiliser, it helps to avoid emissions related to the production of industrial fertiliser (Ibid.).

In addition, anaerobic digestion has other environmental benefits such as bringing back phosphorus into the circulation. Phosphorus is an important nutrient, and its resources are limited (Butusov and Jernelöv, 2013). Moreover, the digestate fertiliser is easily absorbable by plans (Lantz, 2013) and has little smell in comparison with manure.

When it comes to socio-economic factors, biogas usage for energy production contributes to higher energy security with local production and all year round food waste availability (Deublein and Steinhauser, 2011).

To sum up, biogas production from food waste is a win-win-win solution for waste management, energy production and agriculture.

3.3 Biogas challenges

As shown in Figure 1, the biogas system is a very complex system with many elements and many steps. This system has a number of challenges.

First, the poor state of bacteria producing biogas might result in various problems, such as underproduction of gas and loss of income (Deublein and Steinhauser, 2011).

Secondly, biogas production from food waste requires a complex waste collection system in place. One option for such a system is to collect mixed waste and then separate it at a special plant manually or mechanically. However, this results in a questionable substrate quality. The second option is to organise waste separation at the source (where people separate waste at homes), which could give better quality but demands quite a high population involvement, education/information, control as well as special more expensive infrastructure for waste collection: bins, containers, trucks.

Thirdly, there is a threat of digestate contamination by heavy metals or harmful organic substances, coming from substrates (Ibid.). If this is the case, biogas plant might face potential problems with the utilisation of this remaining matter due to its large volumes, which accounts for 85 % from the total amount of substrates (Thorin et al., 2012).

If the digestate is of good quality, there is a need to have a field nearby of sufficient size in order to utilise all of the produced fertiliser (Lantz, 2013). In addition, the liquid state of digestate requires specialised machinery for spreading this type of fertiliser on the fields (Ibid.).

Fourthly, in order to connect all of the elements of biogas system, there is a need for transportation. Biogas production can be very transport-intensive. First, the substrates from different providers need

to be collected and delivered to the plant. Then, after the digestion process, digestate has to be stored or used in the fields, both of which can require transportation. Therefore, the plant location, planned substrates and fields for the utilisation of the digestate have to be well thought through. Furthermore, heavy transport between the locations could cause road deterioration. If the transport containers are leaking, it might cause contamination and odour release along the roads. Contamination and odour can, in turn, result in public protests.

Fifthly, due to its complexity, biogas production involves many actors (Lantz, 2013). Good collaboration between these actors is essential for a successful operation of a biogas system.

Finally, in spite of all the environmental and socio-economic benefits of biogas, its economic feasibility is quite sensitive and requires a lot of support on a governmental level. The economic aspects depend on many factors and many spheres, so the change in one of the elements of a biogas system can affect the whole process and the economic balance.

4 Case Overview

4.1 Poland as the EU member

Poland is a country in the East of Europe with and the size of 322 575 square kilometres (Statistics Poland, 2018a) and a population of over 38 million people (Statistics Poland, 2018b). The country is known in Europe by its coal traditions. Poland has several coal basins. The biggest one of them, Upper Silesia Basin is located in the South of the country and covers among other the territory of the city of Zabrze (Polish Geological Institute, 2011). Coal mining has started there as early as at the end of XVII century (Ibid.).

According to the International Energy Agency, in 2016, coal constituted to 50% of Polish total primary energy supply and 80% of the country's electricity generation (International Energy Agency, 2017). Oil was used for 26% and gas for 15% of total primary energy supply. The share of renewables was 9%, where 8% came from biofuels.

In 2012, the Polish energy sector was responsible for more than 80% of the country's GHG emissions (UNCCS, 2012). According to European Environment Agency, Polish energy use and supply (excluding transportation) caused the following shares of the country's emissions: 62 % NOx, 36 % non-methane volatile organic compounds, 99 % of sulphur dioxide, 72 % of fine particular matter (PM2.5), 75 % carbon monoxide, 48 % methane (EEA, 2014). At the same time, air pollution with PM2.5 is considered responsible for 44600 premature deaths and pollution with NO2 – for 1600 (EEA, 2015).

In 2004, the country became a member of the EU and as a member of it got an obligation to implement the EU directives into Polish national laws (European Commission, 2018b).

When it comes to the energy sector, the most important directive to the date of data collection was the Renewable Energy Directive. According to its Annex 1, Poland had to achieve a 7.2 % share of renewable energy in gross final consumption of energy by 2005 and has to achieve 15 % by 2020 (European Parliament & Council of the European Union, 2009). However, the implementation of this Directive was delayed (Abramczyk, 2014).

In 2012, Polish energy policy provided financial incentives and exemptions for producers of renewable energy (Ministry of Economy, 2010). Moreover, energy providers selling electricity to end users were supposed to have a certain percentage of electricity coming from renewable energy sources together with the certificate of its origin, or pay a substitution fee (Ibid). At the time the interviews were conducted in 2012, Poland had a certificate system, which was applicable for biogas usage:

- Electricity produced from biogas was entitled to green certificates;
- CHP below 1 MW – yellow certificates and above 1 MW – violet certificates;
- Agricultural biogas injected into the gas grid – brown certificates (Muras, 2011).

Green certificates could be combined with one of the certificates for co-generation (Ibid).

When it comes to the waste management system in Poland, the dominant waste treatment strategy for municipal solid waste in the country is landfilling. 53% of municipal solid waste has been landfilled in 2014 (Alwaeli, 2015) and more than 70 % in 2010 (European Commission, 2017).

According to the EU Landfill Directive, Poland had to reduce the amount of biodegradable waste going to landfills so that it would not exceed 50 % (in relation to the mass of this type of waste in 1995) by 2013 and 35 % by 2020 (The Council of Ministers, 2010). In 2008, the country generated 6614 thousand Mg of municipal biodegradable waste, which constitutes to 54.7% of municipal waste (Ibid.).

In 2012, a new waste management law came out in Poland, following the targets set by the EU. Apart from its focus on reducing the amount of biodegradable waste going to the landfills, this law drastically changed the rules for the waste management sector. Firstly, Polish municipalities became owners of municipal waste and had to implement new waste management plans (Polish Parliament, 2011; Interviews 2, 4). Secondly, this ownership came with responsibilities and fines in case of non-compliance (Polish Parliament, 2011; Interview 2).

As alternatives for landfilling, in 2012, the country had one working incineration plant in Warsaw and six planned (European Commission, 2012). In addition, there were 90 composting plants in 2009 (Ibid.).

Poland has a very low share of 23% for separately collected municipal waste, and currently, its waste management system relies heavily on mechanical–biological treatment plants for processing municipal residual waste (den Boer and Jędrczak, 2017). These plants aim for material recovery as well as for stabilisation of biodegradable fraction before landfilling (Ibid.).

4.2 Biogas in Poland

There are currently three types of biogas in Polish legislation: strongly supported by financial incentives agricultural biogas (biogas coming from a specified list of substrates: agricultural, food production and forestry (Polish Parliament 2010)), as well as less supported landfill gas and sewage treatment gas (Interview 2, 3).

Since biogas production from food waste is related to at least three fields (waste, energy, and agriculture), there are at least three different ministries regulating different aspects related to it (Interview 2). The Ministry of Environment is responsible for waste management, the Ministry of Economy for renewable energy, the Ministry of Agriculture for the use of fertiliser and agricultural biogas (ACB), including the list of allowed substrates to be used for biogas to be still qualified as ACB (Ibid).

In 2010, the share of biogas in Polish renewable energy mix was 1.7 % (Igliński et al., 2012) and the same year a development strategy has been accepted that was supposed to create a support system for the construction of 2000 agricultural biogas plants until 2020 (Cwil, 2011, PIGEOR, 2015). In 2012, there were 178 biogas plants in Poland, out of which 87 were landfill based, 67 were located at wastewater treatment plant (WWTP) and 24 were agricultural (Igliński et al., 2012).

When it comes to biogas production from food waste in Poland, it was non-existent at the time of research. The potential of biogas production from the biodegradable fraction of municipal waste was estimated to 100 million m3 (Igliński et al., 2012).

4.3 Zabrze and the project

Zabrze is a city of in the south of Poland. It is located in the heart of Silesia region. In 2016, Zabrze had a population of 176 327 people (Central Statistical Office, 2016). As mentioned above, the city is located in the Upper Silesian coal basin. The first state coal mine in Zabrze dates back to 1791 (Dulias, 2016).

In 2012, the city of Zabrze already had two biogas installations: one at a local WWTP and one at a landfill. After getting inspiration in Sweden, local actors decided upon a plan for the third type of biogas plant in the city - a co-digestion plant using separately collected food waste as one of the substrates. As mentioned before, it was supposed to be the first plant of such a kind in Poland. Below, I describe the actors involved in the project and their roles.

MOSiR, which stands for Mejski Osrodek Sporta i Rekreacji (Local Centre for Sport and Recreation), is a municipal company responsible for sport and recreation. It owns a sports complex and a stadium, but it also runs local landfill, markets and a hotel (MOSIR Zabrze, 2018). The business idea behind the company was that sports infrastructure and activities require resources, which landfill business could provide. MOSiR was making quite some money on the gate fees, which were paid for dumping waste at the landfill. This business model became threatened when in 2012 a new waste management law came into force. Even before, MOSiR was already looking for different sources of income.

Together with a Swedish company Vireo, they came up with a project (one of the above-mentioned biogas plants), where the landfill gas produced at MOSiR's landfill is burned in CHP plant provided by Vireo. Produced electricity is sold to the grid, and in addition and in addition to revenues the companies also receive financial incentives from the government (certificates). In the end, both companies share the income (Interview 8). Based on this experience, MOSiR saw the possibility to run the biogas project in a similar way (Ibid).

The idea to construct their own biogas plant came to MOSiR during their trips to Lund, organised by SPSEP (Interview 7). In Sweden, MOSiR's representatives learned about local waste management systems, the benefits of biogas production, and had the opportunity to see a working biogas plant (Ibid).

SPSEP has been promoting Swedish waste management and renewable energy solutions not only in Zabrze but also in the whole of Poland by creating connections between Swedish solution providers and Polish municipalities and ministries via conferences, study trips and meetings (Interviews 2, 4; my observations during the work time at SPSEP). The platform has also been working on supporting the development of new "more sustainable" laws in Poland (Interview 4).

A senior manager of the BSAP Fund participated in one of the conferences organised by SPSEP, where he presented the possibilities for financial support for biogas projects in Poland. SPSEP, MOSiR and the city of Zabrze used the possibility and got the funding for the pre-investment documentation for the biogas plant in Zabrze (Interview 2; I was working both with the conference and the application).

The city of Zabrze supported the biogas project by the educational activities related to waste sorting. It was also in line with the city's work in adapting to the new waste management legislation. At the time of the interviews in October 2012, the city of Zabrze was working on the development of a new waste plan as well as a system of differentiated tariffs for citizens in order to encourage people to sort waste. The tariffs were implemented and currently constitute 12 zloty per person per months for sorted waste in contrast to 20 zloty for unsorted waste. (Um.zabrze.pl, 2018). The new waste legislation also informed the new programme for environmental education, which was under development in 2012 as well and was intended to place considerable focus on waste management, and especially on sorting (Interview 10). Moreover, the new biogas project followed the objectives of Zabrze's Mayor Malgorzata Manka-Szulik, who aims to create a new profile for the city, transforming it "from a city of heavy industry" to a city of "medicine, science, modern technologies, a city of culture, sport and industrial tourism" (Mszulik.pl, 2018).

During that time, the city also had an experimental area with 500 private houses/villas, where sorted at the source organic waste was collected for composting purposes. Both collection and composting were done by a big private company called ASA. Apart from collecting waste in whole Zabrze, this company owned an mechanical-biological treatment (MBT) facility located just next to MOSiR's landfill (Fcc-group.eu, 2018). There the biodegradable fraction of mixed municipal waste is separated and composted (Ibid).

5 Theoretical Framework

This chapter will describe the framework of transition theory, which I applied in order to answer my research question and to analyse the data. This framework has been already used for the analysis of transitions towards more sustainable solutions within energy and waste management (Raven, 2004; Kemp, Rotmans, and Loorbach, 2007; Gardiner, 2012, Abramczyk, 2014; Kristjánsdóttir, 2017). Therefore, it can be useful even for my case of a transition towards more sustainable waste management and energy systems in Poland. The framework includes the concept of transition and multi-level perspective (MLP).

5.1 The concept of transition

Transition is "a gradual continuous process of change, where the structural character of a society (or a complex sub-system of society) transforms" (Rotmans, Kemp and van Asselt, 2001, p.16). Transitions vary by their scale, speed, and timeline. During the transition process, there are changes in different areas, which reinforce each other (Ibid).

The transition process can be divided into the following stages/phases: pre-development, take-off, acceleration/breakthrough and stabilisation (Figure 2). Predevelopment is characterised by the status quo when the coming changes are not yet noticeable. At the take-off and acceleration stages, both new and old systems are present, and the new one is slowly taking over the old one. At the stabilisation phase, a new dynamic equilibrium is achieved (Ibid.).

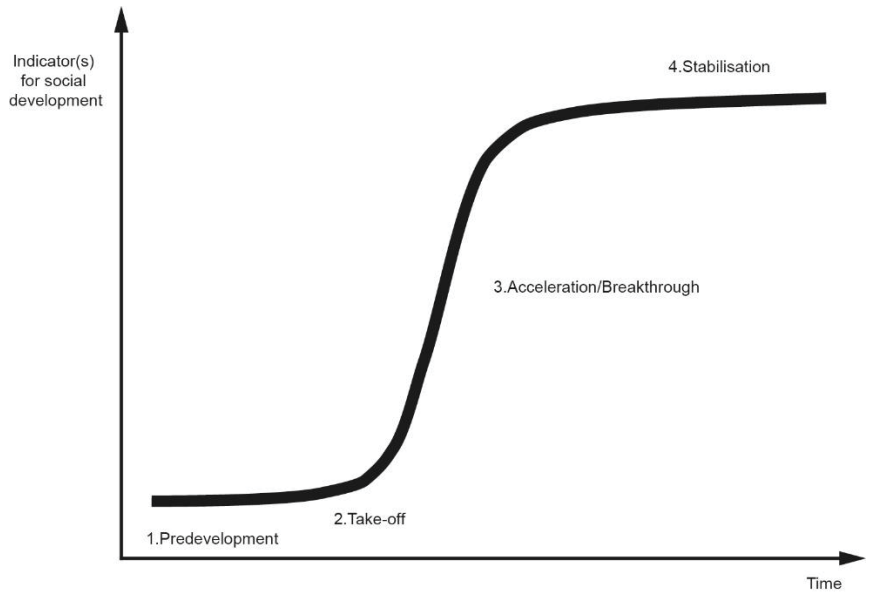

Figure 2. The four phases of transition (Adopted from Rotmans, Kemp & van Asselt, 2001).

Transitions are usually quite slow and might take a generation or more to happen. At the same time, sudden major events such as war can significantly speed up the transition process (Ibid).

5.2 MLP

The central part of transition theory is the MLP. It consists of three aggregated levels: macro or landscape, meso or regimes, and micro or niches (Rotmans, Kemp and van Asselt, 2001, Geels, 2002, 2004, 2005a, 2005b).

The macro level represents the external context in which the transition takes place. It includes such elements as political coalitions, fossil fuel prices, social values, economic paradigms, demography, environmental problems (Ibid.). The term landscape is used to describe this level in order to show the 'hardness' of its structure (Geels, 2005a). Changes do occur here, but they are usually very hard to achieve. They can be either slow, such as a change of political culture, or fast, such as economic depression (Geels, 2005b). These changes can put pressure on the meso level.

The meso level consists of five sociotechnical regimes, which "refer to the semi-coherent set of rules carried by different social groups." (Geels, 2005a, p.1260). These regimes are Science, Technological, Policy, User/Market and Socio-Cultural. The examples of rules are:

- for Science regime - research programmes, rules for government subsidies, paradigms, criteria for knowledge creation;
- for Technological – product standard and technical requirements, technical problem agenda;
- for Policy – policy goals, problem agendas, institutional commitments to existing systems;
- for User/Market – rules on market structure and functionality, subsidies and taxes, user practices and preferences, beliefs about market efficiency;
- for Socio-Cultural - cultural values, the symbolic meaning of technologies and ideas about their impact (Geels, 2004).

In reality, the regimes do not have well-defined boundaries and can have areas of intersections (Geels, 2005b). Regimes have dynamic stability, which is hard to change but it still provides room for the occurrence of incremental innovations (Geels, 2002, 2005b). However, if the system of rules is not aligned and there are mismatches, the stability of the regime is affected, and a window of opportunity for radical innovations is created (Geels, 2004, 2005b).

The micro level is a level of niches, which refers to individual actors or technologies (Rotmans, Kemp and van Asselt, 2001). Niches are usually protected from the dominant rules and thus become a place for radical innovations (Geels, 2004). There are two types of niches: technological and market niches. Technological niches can be protected by public or private investment (for example, in order to develop a prototype), whereas in market niches the technology is already developed to such an extent that there is a demand for it in within the existing market (Geels, 2005b).

The three levels represent a nested hierarchy (See Figure 3), where niches are parts of the regimes and regimes are parts of the landscape (Geels, 2005a).

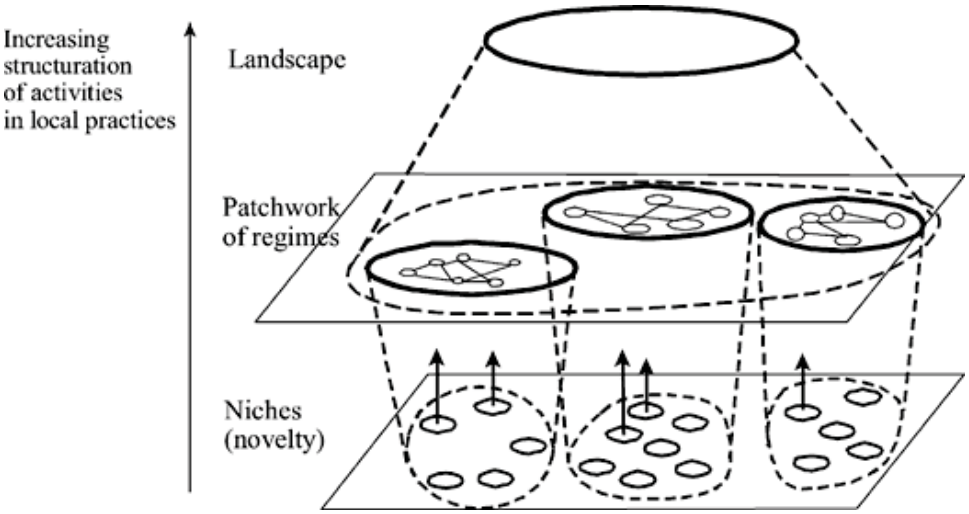

Figure 3. Multiple levels as a nested hierarchy (Geels, 2004, p.913)

There is a dynamic interaction between the three layers during the phases of the transition, as shown above. At the predevelopment stage, technological niches try to address problems in existing regimes (Geels, 2005a), whereas the regimes aim to maintain the status quo (Rotmans, Kemp and van Asselt, 2001). At the take-off, the innovation is further improved by market niches with resources (Geels, 2005a) and regimes either resist innovations or adapt small improvements in the existing routines (Rotmans, Kemp and van Asselt, 2001). At the acceleration phase, new technology is already competing with existing technologies (Geels, 2005a). The success of the breakthrough is based on the availability of a window of opportunity, created by either landscape pressure on the regime level or by the changes within regime level (Ibid.). At the stabilisation stage, new technology gradually substitutes the previous regime (Ibid.). Due to the interrelated nature of the regime elements, changes in one of the elements lead to changes in others (Geels, 2002). At the later stages of transition, regimes have a facilitating role, as they have both financial and institutional resources to speed up the transition (Rotmans, Kemp and van Asselt, 2001).

5.3 Theory application

The presented theory has been shown to be useful in studying technological transitions. Moreover, it highlights the role of the society in such kind of transitions (Geels, 2002, 2004). The theory provides a complex perspective that helps to analyse the complexity of real-world technological transitions (Geels, 2002).

In my thesis, I will use this theoretical framework to organise and analyse my findings on drivers and barriers for a technological transition towards more biogas from food waste plants in Poland. I will then suggest improvements to the situation referring back to the framework.

Due to the fact that biogas from food waste technology in Poland is in its predevelopment phase, I will mostly apply the MLP.

6 Data Analysis and Discussion

This chapter combines the presentation of my data, arranged according to the MLP, together with insights on it. In this way, data, analysis, and discussion are combined. Each of the subchapters is focused on one of the research questions: the first one describes drivers for biogas from food waste production; the second one presents barriers, and the third explores what can be done to improve the situation.

6.1 Drivers

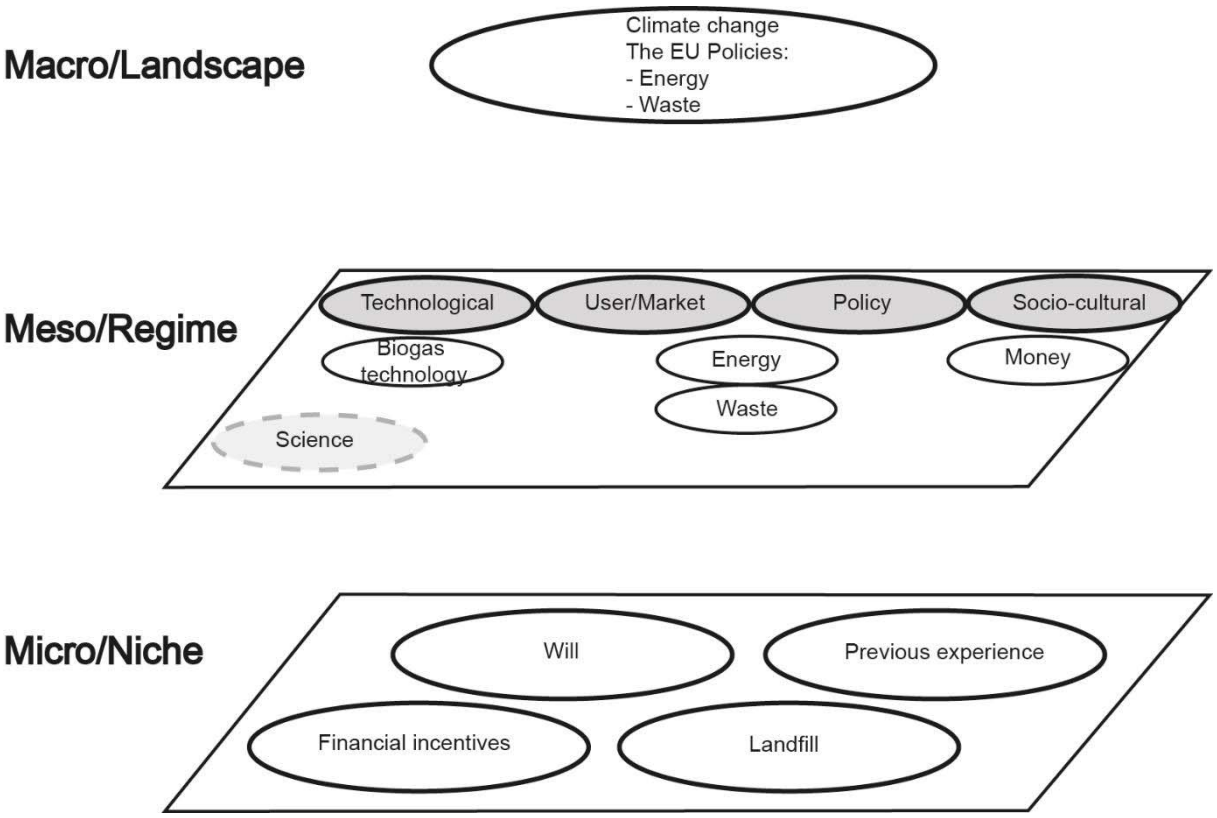

Figure 4. Drivers for biogas from food waste production in Zabrze (own construction)

In this subchapter, I map out and describe level by level the drivers (Figure 4) that facilitated the biogas project in Zabrze.

6.1.1 Macro level

On the macro level, the phenomena of climate change as well as world and the EU legislation aimed to address it have been identified as main drivers.

6.1.1.1 Climate change

Climate change and commitment to international agreements related to it, such as the Kyoto protocol, have resulted in a climate and energy package for the EU. The package for 2020 is based on three goals, two of which are a 20% reduction of GHG emissions and achieving a 20% share of renewable energy in total energy production in the EU by 2020 (European Commission, 2018a).

6.1.1.2 The EU policies

The EU policies play a dominant role in Poland's development towards more sustainable solutions when it comes to both energy (Abramczyk, 2014) and waste (Interviews 1, 5). As the former Swedish Counsellor on Business promotion said, "The EU and obligations that Poland has to the EU is the big driving force to create sustainable waste management in Poland." (Interview 5).

More specifically, Polish energy and waste sectors have been affected by the EU Renewable Energy Directive setting targets for renewable energy production and the EU Landfill Directive restricting landfilling of biodegradable waste (Interviews 1, 11).

6.1.2 Meso level

Below I present drivers on the meso level from different regime perspectives. Since my collected data did not show any drivers related to the Science regime, I start with the Technological regime, continue with common points for both the User/Market as well Policy regimes, and then finish with Socio-Cultural one.

6.1.2.1 Technological regime

The technology required to produce biogas from food waste is well established, especially in Sweden (Swedish Energy Agency, 2011). Even though the technology is not deployed in Poland in exactly same way, it can be obtained, and there are, for example, Swedish companies that are interested in exporting their solutions (Liu.se, 2017). During my engagement with SPSEP, together with other Swedish partners and companies, we organised many events focused on showing the technology of utilising food waste to generate biogas and transferring it to the Polish context. One interviewee pointed out that the components for the biogas plant might even be available locally in Poland (Interview 1).

6.1.2.2 User/Market and Policy regimes

Since both the User/Market and Policy regimes had energy and waste as common themes, I address these regimes together. As mentioned in the case introduction, Polish membership in the EU led to the obligation of implementing EU directives among others for waste and energy into the country's national laws. This represents a strong top-down connection from landscape level to the regime level.

At the time of the data collection in 2012, the new Polish renewable energy legislation was still on its way but the certificate system that was in place already provided some support for renewable energy sources. In those conditions, the most profitable option for biogas usage was the production of electricity (Interview 2).

When it comes to waste, the new Polish legislation opened a window of opportunity for biogas as "the most useful and efficient solution" for treating biodegradable waste (Interview 7). For those who produced landfill gas, the new law would result in smaller gas production as landfill gas is formed from the degrading of organic remains (Swedish Environmental Protection Agency, 1999). In this way, both landfilling and landfill gas production as waste management strategies became problematic.

6.1.2.3 Socio-Cultural regime

The importance of financial aspects such as saving and making money was a recurrent theme of the interviews. For example, money has been named as the main driver for people to sort waste (Interview 5). In the context of biogas, the deputy director of MOSiR states: "For us, as the company, we need to make a profit, so this is the most important [driver], but in the way, we also learn how to love environment." (Interview 8).

6.1.3 Micro level

When it comes to the niche level, biogas production from food waste in Zabrze was driven by the will from different actors (the city's Mayor, municipality, MOSiR, and Swedish partners), financial incentives, previous experience as well as the availability of a location for the future plant.

6.1.3.1 Will

First, one of the important drivers for the project in Zabrze was the political will of the Mayor Malgorzata Manka-Szulik (Interview 10). As mentioned in the case introduction, the biogas project could be a part of a new city profile.

Secondly, the city of Zabrze has been affected by the change in waste legislation, which came all the way from the EU level and via national level reached Polish municipalities. Anaerobic digestion could have been one of the strategies to meet the requirements of this legislation and to reduce biodegradable waste going to landfill. Moreover, the city was already taking measures for increasing the amount of sorted waste at the source: new tariff system, new educational programme and an experimental area for testing it.

Thirdly, due to their business model, MOSiR was affected by the new waste law as well. This legislation would mean decreased income from both landfill gate fees as well as from electricity production from landfill gas. Therefore, the company was forced to look for new alternatives to diversify their incomes (Interview 11). At the time of the interviews, the president of the company was convinced that biogas production was a good solution to that problem (Interview 7). Similar to their business model of landfill gas installation, MOSiR was planning to get additional income by producing electricity from biogas at the future co-digestion plant (Interview 8). Both business models relied on financial incentives provided by Polish renewable energy legislation (Ibid).

Finally, connection to Swedish actors such as SPSEP inspired the project and facilitated its implementation. In the context of the biogas plant, the Director of MOSiR specifically mentioned that they were counting both on the Swedish experience and on collaboration with SPSEP (Interview 7). In order to research how Swedish experience can be applied to the context of Zabrze, students from Lund did the groundwork to document Swedish best cases, meet stakeholders in Zabrze, as well as map out possible substrates for the future plant (Interview 1, Generosi et al., 2012, Černiauskaitė et al., 2013).

6.1.3.2 Financial incentives

As mentioned, MOSiR was looking for a way to diversify their incomes and saw the biogas plant as a solution to this. The company was hoping that, due to the sales of electricity produced from biogas, they would be able to pay back the investment (needed to construct the plant) quickly (Interview 1). An important part of their projected economic model was producing biogas from waste. MOSiR's deputy director explained it as follows: "The reason why we decided on municipal waste was that for agricultural waste you would need to pay. This is why we decided to explore municipal waste, which is free." (Interview 8) Moreover, the company also expected the delivery of this waste to be free (Ibid). Yet another facilitating factor for the biogas project in Zabrze was the possibility to get funding from the BSAP Fund (Interview 11).

6.1.3.3 Previous experience

Apart from the inspiration from Sweden, MOSiR's previous experience with waste management facilitated the biogas project in Zabrze. "[The company] could use their know-how, their contacts, their logistic system" (Interview 11). Moreover, MOSiR already had a successful project on landfill gas with the Swedish company Vireo (Interview 8). Based on this experience, MOSiR saw the possibility to run the biogas project in a similar way (Ibid).

6.1.3.4 Landfill location

When planning for the biogas plant, MOSiR had already a specific location in mind on their landfill (Interview 7). The location at that time seemed to be quite good as landfill already produced odours and wastes has been already transported there (Interview 2).

6.2 Barriers

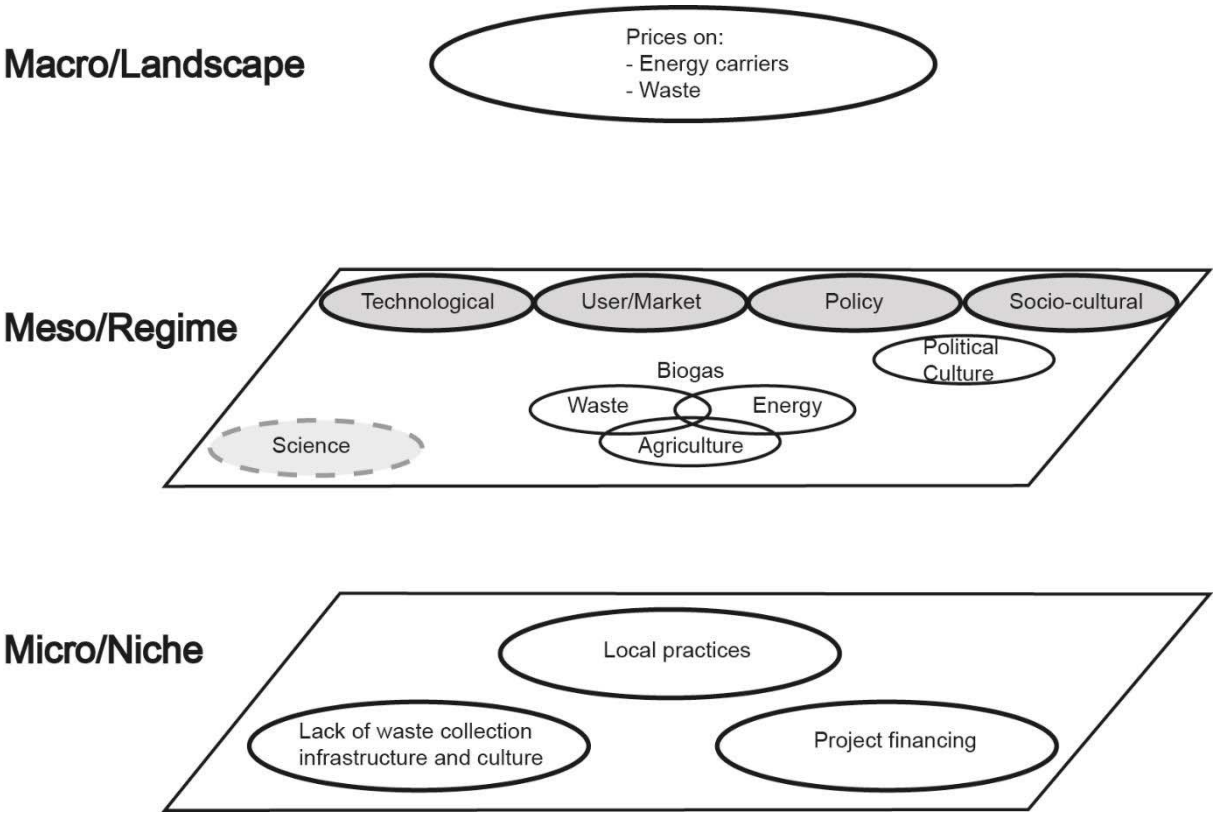

Figure 5. Barriers for biogas from food waste production in Zabrze (own construction)

In this subchapter, I cover the barriers (Figure 5) that hinder the biogas project in Zabrze.

6.2.1 Macro level

The identified barriers on the macro level are associated with the prices on energy carriers as well as to waste market.

6.2.1.1 Prices on energy carriers

One of the barriers mentioned by the interviewees was prices on energy carriers, which affect the competitiveness of biogas on the market. Biogas system is very sensitive economically, and its current profitability in Poland depends on the electricity price (Interview 1). Future changes in prices of energy carriers might be a threat to the biogas system (Interview 11).

6.2.1.2 Waste market

The changes to the waste market have been mentioned as a potential future threat to the production of biogas from waste. This kind of changes is hard to predict (Interview 2). Global or EU waste market development can affect the demand and prices for different waste streams. For example, Sweden

might want to start importing wastes from Poland for incineration (Ibid), and such a scenario might completely change the circumstances for the use of waste as a substrate for biogas production in Poland.

6.2.2 Meso level

Biogas lays on the intersection of three interrelated areas: waste, energy, and agriculture. These topics were reflected as recurrent themes in the interviews. Therefore, barriers on the meso level are structured according to Waste, Energy, Agriculture and Biogas topics. Each of these topics is covered from the perspective of Technological, User/Market, Policy as well as Socio-Cultural regimes. Similar to drivers, no barriers have been mentioned in relation to Science regime.

6.2.2.1 Waste

There are several barriers related to the current waste management system, which hinder the use of selectively collected food waste for biogas production in Poland.

First of all, landfilling and MBT-systems are dominating waste treatment. These two strategies significantly limit the incentives for creating a system for separate collection of organic waste at households.

Yet another big problem for biogas production from food waste is the selection and collection of this type of waste (Interviews 1, 2, 5). The infrastructure for it is currently missing, and its provision is quite costly (Interview 9). Food waste selection and collection can be especially problematic in the context of high-rise apartment buildings, where most of Zabrze's citizens are living (Ibid). Such buildings are equipped with garbage chutes for easy disposal of mixed waste (Ibid). Even if the new infrastructure for waste collection is provided, there is a need for control that people actually sort as they declare (Interviews 8, 9). The need for control represents additional difficulties and costs (Interview 9). Furthermore, a plant producing biogas from food waste would require a constant input of a certain amount of such waste. Moreover, this waste has to be of good quality, meaning properly separated and clean from contaminants (Interviews 1, 2) as a biogas system is very sensitive to substrates (Interview 1). "If [people] will put let's say batteries or some contaminated waste it can spoil the whole process." (Interview 11).

When it comes to the market perspective on waste, there are several competing waste management strategies. Many of these strategies: landfilling, MBT and incineration do not require biodegradable waste to be separated. The favourability of these technologies is further strengthened by the fact that

the current way of collecting waste in the mixed state is cheaper than collecting sorted waste (Ibid). Furthermore, in contrast to landfilling, MBT-option combined with consecutive composting of biodegradable waste is accepted from the viewpoint of meeting the requirement of the Landfill Directive and new national waste legislation (Fcc-group.eu, 2018). Thus, this legislation opened a window of opportunity not only for biogas.

Apart from already existing landfilling and MBT options for dealing with waste, there is also the threat of an incineration plant appearing in the area (Interview 2), yet another strategy complying with the waste legislation. In 2015, there was only one incineration plant in Poland with more to be built (Szelag, 2016).

At a local level, there might be a competitive use for organic waste. For example, people living in villas might want to use this type of waste for their own compost (Interview 10) or for animal feed.

From the Policy regime perspective, anaerobic digestion of biodegradable waste is not well covered in Polish national legislation. It has been mentioned in the waste act, "but when you are coming to […] implementing documents prepared by the ministry [of Environment], you have very well described processes and procedures concerning mechanical-biological treatment and nothing about anaerobic one." (Interview 2).

When it comes to the Socio-Cultural regime, the dominance of mixed waste collection means that there is a lack of waste separation culture (Interviews 1, 4, 5, 13). Even the possibility of teaching people to sort causes a lot of scepticism (Interview 8). It is believed that many years are required to do that (Interviews 3, 13) and "everyone will discourage you: 'Yes, it is a great idea, but it will not work. Yeah, it is fantastic, but it will not work.'" (Interview 3).

In general, waste is not usually seen as a resource in Poland (Interview 5) but rather as something difficult and dirty (Interviews 3, 5, 13).

6.2.2.2 Energy

Although MOSiR was only planning to use produced biogas for electricity generation, here I cover barriers for all of the usage alternatives: electricity, heat, gas grid injection and vehicle fuel.

From the perspective of Technological and User/Market regimes, when biogas is used for electricity or heat generation, it becomes a competitor to coal. This fossil fuel with a long tradition of use in Poland (Interview 5) dominates both the electricity and heat production areas (Worldenergy.org, 2018) and thus there is already existing infrastructure for this. In general, the energy sector seems to be

conservative and to prefer well-known solutions due to its responsibility to deliver a stable supply of electricity and heat as well as due to the high costs of new investments (Interview 5). Therefore, there is little room left for experimenting with new technologies (Ibid).

In order to inject biogas into the gas grid or use as a vehicle fuel, it has to be upgraded (interview 3). The equipment for this additional step is quite expensive (Ibid). Additionally, the gas grid connection is also expensive, and there are many requirements that upgraded biogas has to fulfil in order to be injected (Ibid). Even the Polish gas grid operator is not much interested in this option (Ibid). In order to create a local market for biogas as a vehicle fuel, an extra investment in city buses that run on gas is needed (Interview 11).

When it comes to the Policy regime perspective, coal dominates not only the Polish energy sector but also the country's energy policies. In Energy Policy of Poland until 2030 it is stated, "State energy policy assumes using coal as the main fuel for the power industry in order to ensure an adequate level of energy security of the country." (Ministry of Economy, 2009).

The Polish renewable energy policy has been unpredictable for some years. As the head of Swedish secretariat of SPSEP says: "The government can change the rules of the game quite dramatically and immediately…" (Interview 1). The country was delaying the implementation of European renewable energy legislation well beyond the deadline (Abramczyk 2014). Furthermore, the certificate system used for renewable energy is quite complicated (Interview 1). These factors make it even more difficult to calculate the profitability of renewable energy projects and make a long-term investment in it.

As mentioned in the case introduction, only ACB is allowed to be used for gas grid injection (Interview 3). Food waste from households is not included in the list of the substrates for this type of biogas (ibid), which makes it legally impossible to inject biogas from food waste into the national gas grid.

Using biogas as a vehicle fuel is also problematic due to a lack of related legislation (Interview 3). Poland has a separate act regulating bio-components and biofuels (Ibid). This act provides a specification for quality requirements for such kind of fuels and biogas is not covered there, which makes it impossible to introduce it to the market (Ibid).

From the Socio-Cultural regime, coal dominance is reflected in the public attitude: "coal […] produced in Poland is seen as Polish black gold. In Poland, they very much love their coal, and they see the coal as thesis of the wealth that they have." (Interview 5). This pride and the dominance of coal results in other technologies such as "waste to energy" being seen as potential competitors to coal (Ibid). Thus,

these technologies are regarded with a sceptical attitude as being unnecessary investments that could change the status quo (Ibid).

6.2.2.3 Agriculture

When it comes to the Technological regime perspective, as mentioned before biogas production results in the large quantities of liquid digestate. This would mean that a biogas plant should have a possibility to utilise or "get rid" of digestate, which requires huge fields nearby, a lot of transportation (Ibid), and even special equipment. Storing this amount would entail a massive facility and costs (Ibid). If an open lagoon is used, there will be emissions (as the digestion process usually is not fully finished) and smell (Ibid).

On the User/Market and Policy regimes, there seem to be legal difficulties with using digestate produced from food waste as fertiliser, which may become a problem for a biogas plant (Interview 13). According to Polish law, a digestate, regardless of origin, is categorised as waste (Interview 6). In order to change its category and introduce it to the market, it has to be certified (Interviews 3, 6). The certification process is very long and expensive (Interview 3) and using food waste from households would further complicate the process (Interview 6). "Introduction of new substrates in biogas plants requires carrying out the procedure of digestate recognition as fertiliser from the beginning!"(Ibid.)

Finally, even if the digestate can be certified as fertiliser, there are time limitations for when it can be applied on the fields (Interview 3). Between November and March, it is not allowed (Ibid), which reinforces the need for a huge storage facility.

When it comes to the Socio-Cultural regime, there might be a lack of acceptance to use digestate in agriculture from the farmers' side (Interview 1).

6.2.2.4 Biogas (in general)

From Technological and User/Market regimes perspectives, biogas technology is quite expensive and quite complex (Interviews 1, 3, 5). It is a "living system" with bacteria inside of a digester, and this system is sensitive to the substrates (Interview 1). The whole process of biogas production could stop if the "wrong" substrates are added (Ibid).

One of the complex elements of biogas technology is the transportation of both the substrates and digestate, which can result in a logistical problem (Interview 3). Moreover, these substances contain a lot of water and might smell. This, in turn, can cause additional difficulties with public acceptance (Interviews 3, 9, 10).

When it comes to the Policy regime, as mentioned in the subchapter on drivers, two very important policies for biogas from food waste technology have been pushed on Poland from the EU. However, their implementation in the national law was disorganised and last minute. The laws on both renewable energy and waste have been introduced at the last moment, bringing big changes and leaving no time to find good solutions to meet obligatory indicators (Interview 3, Abramczyk 2014).

This situation also might cause lack of ambitions to reach higher goals (Ibid), as even already set goals are quite stressing. As the Mayor's Advisor, responsible for Waste Legislation implementation in Zabrze, replied to a suggestion to reduce the amount of biodegradable waste going to landfills even more: "it is against common sense to make it even harder because you need to comply with this law exactly. If you say 20% ok, looks better but if you don't comply and have 25 %, then you have to pay a fine." (Interview 9).

In this rapidly changing legislative environment, it is very hard to think in the long-term perspective, test more unconventional solutions, which are not well described in the legislation, such as biogas production from waste (Interview 3). It is hard to predict future scenarios, do long-term planning and calculations (Ibid). These factors make it very difficult for expensive biogas technology to break through (Ibid).

The situation for food waste usage for biogas production is further complicated by the complexity of the technology and the structure of the Polish legislative institution. The three ministries regulating different aspects related to this technology seem to have difficulties cooperating and coordinating their legislation (Interview 2, 3). The Ministry of Agriculture is against food waste from households to be included in the list of the substrates for ACB, and biogas from this waste does not belong to any of the three biogas categories in Polish legislation (Interview 3). The Ministry of Economy and the Ministry of Agriculture did not see the food waste from households as a possible substrate for biogas and Ministry of Environment did not address biogas (Interview 2). This way, there is a problem for biogas to be used for waste utilisation (Interview 3).

On the Socio-Cultural regime, there are concerns about the smell produced by a biogas system: starting from the food waste collection inside and outside, transport, and the biogas plant itself (Interviews 1, 5). There has been a problematic case in Poland in Liszkowo, where they needed to stop the whole process due to public complaints about the smell (Interview 3).

6.2.2.5 Policy and Socio-Cultural regimes in general

Apart from the barriers related to Waste, Energy, and Agriculture, there have been identified general obstacles related to both the Policy and Socio-Cultural regimes. These obstacles are summarised under the political culture.

The first aspect of the political culture in Poland is its focus on short-term perspective, where economic concerns come prior environmental ones. According to the former Swedish Counsellor on Business promotion, "the tendency to buy the cheapest and not the best […] is definitely true for Poland […] because they don't have the money. Also, they don't calculate their investments the right way; they don't think about life-cycle costs and things like that." (Interview 5). Price is the main criterion in public procurement, which makes it problematic to acquire products or services of high quality because high quality comes with an extra price (Interview 3) and as it was mentioned before biogas production is an expensive technology. Moreover, using waste for biogas production is difficult and might be not considered due to the lack of environmental considerations (Ibid).

Economic concerns are important not only for public institutions; they also affect the behaviour of businesses and the general population. For example, small waste companies do illegal handling of waste or residents throw away waste not in their own container but somewhere else to save money (Interview 13).

Secondly, as described above, the political culture in Poland can be characterised by problematic cooperation or lack of thereof, lack of information exchange between different parties as well as lack of common vision. This phenomenon has been illustrated for the three ministries involved in law-making for biogas from food waste. It has been also relevant to the city of Zabrze and will be described at the niche level.

The problematic collaboration gets further complicated by the bureaucracy, where different parts of the bureaucratic apparatus have shared responsibilities and compete with each other. The decision-making is top-down/centralised with a lot of intermediates (Interview 4). The process has many steps and takes a long time. The paperwork involves paper documents, stamps, and signatures, ordinary mail (Ibid).

6.2.3 Micro level

The barriers at the niche level were connected to the project and municipality practices as well as to the lack of infrastructure for and culture of waste sorting. In addition, there was a concern related to the possibility of financing the biogas plant.

6.2.3.1 Local practices

First of all, in spite of the fact that MOSiR had previous experience in waste management as well as in landfill gas, neither they nor the city of Zabrze seemed to have knowledge and experience in biogas from food waste (Interview 1). It was a new project of the type for both of them, just as for the whole of Poland.

This lack of knowledge and experience resulted in a heavy reliance on consultants. The project has been split into parts, where each part was delegated via tenders to different consultants and results from some stages has been used as an input for the next stages. Such a dependence on consultants seemed to be costly, and the results of the work of each of the consultants were too diversified (Ibid).

In my opinion, the abovementioned issues might have led to not well-formulated tenders and difficulties to understand if the delivered by consultants work was of high quality. As one of the members of the project's Management Board reflects, at least one of the hired consultants has never done a good job (Ibid).

Secondly, due to unclear leadership from MOSiR's side, SPSEP had to be involved in the project's Management Board to ensure control over the project implementation (Ibid). MOSiR's was very unstructured in their way of working, which showed itself, for instance, in sending the wrong bank account to the fund that provided the project with a grant (Interview 1, 4).

Even though the Management Board was created, at least one of its members reported a lack of communication between the meetings and contradictory information coming from project managers (Interview 1). Contradictory information and "blurry" reports (with little substance) from the Board meetings are confirmed also by my own observations.

Moreover, even though the project had funders, partners and a member of the Management Board, who did not speak any Polish, there was nobody speaking English at MOSiR (Interviews 1, 4, my observations). No professional translator was provided by the company either due to a belief that this could save money for the project (Interview 4). This, in turn, affected the project's quality and timeline (Ibid).

Finally, as mentioned at the regime level, problematic cooperation and bureaucracy with slow decision-making affect the city of Zabrze as well. Thus, the city had four different entities responsible for environmental education: Department of Education, Department of Ecology, Infrastructural Department and Environmental Education Centre (Interview 10). All of them were involved in the education of the city residents when it comes to waste sorting. On the one hand, these entities had shared responsibilities, and on the other hand, they competed with each other (Ibid). In general, their cooperation was complicated (Ibid).

6.2.3.2 Waste sorting: lack of infrastructure and culture

The barriers presented on regime level, related to the lack of infrastructure for food waste collection as well as residents behaviour in relation to waste, are relevant also for Zabrze. Even in the experimental area of the city with biodegradable waste sorting at the source, the quality of the collected waste was not very high: "People can put a tire and grass on the top." (Interview 13). According to the representative of the waste collection company, the awareness among people seemed to be low, so the collected waste had to be checked, and stuff that should not be there had to be removed at the segregation plant (Ibid).

6.2.3.3 Financing possibility

Yet another barrier at the niche level is connected to the possibility to finance the biogas plant. Therefore, the business plan had to show that such a plant can be profitable (Interviews 1, 11). In addition, as described in the project drivers, MOSiR's financial standing was affected by new legislation resulting in less income from gate fees. In such a situation, it might be hard for the company to find a partner for investment (Interview 11).

6.3 Discussion

I answer my first and second research subquestions in two previous subchapters. In sum, the main drivers for biogas production from food waste in Poland are the EU policies related to waste and renewable energy as well as financial instruments related, on one hand, to fines in case of landfilling of biodegradable waste, and on the other hand, subsidies for the production of electricity from renewables. Applying the MLP, the landscape level puts pressure on the regimes, which adjust by reconfiguring their rules and to some extent opening a window of opportunity. The niche of the biogas project in Zabrze is trying to use this possibility. The actors involved try to run this niche as if it was a market niche, which would mean that it is supposed to be able to "survive" in the current market conditions. At the same time, barriers on the regime level make "the survival" impossible. First, there

is a legislative lock-in, which makes it impossible not only to explore all the potential options for the use of biogas produced from food waste, but also hinders the possibility to operate this technology at all, due to the difficulty with digestate usage. Secondly, even if this difficulty is resolved, the existing market and policies for biogas from food waste do not provide sufficient support for this technology to be economically feasible. This barrier is reinforced by the dominance of economic concerns over environmental in decision-making. The lack of ambition to address these barriers is further strengthened by the dominance of coal in all regimes.

Below I will discuss the options for overcoming these barriers while maintaining the drivers in order for Poland to achieve a transition towards biogas from food waste plants. In this way, I will answer my third research subquestion and my main research question.

6.3.1 The position of coal

As mentioned before and shown in the previous subchapter, the coal industry represents a tremendous barrier for renewable energies in Poland in general and for biogas in particular. Coal dominates policy discourse (Ministry of Economy, 2009) and has a lot of support in the form of open as well as hidden subsidies. At the same time, the coal industry is causing climate change globally and is responsible for air quality problems locally, which result in premature deaths and a wide range of respiratory problems. These problems are not included in the price of the energy produced from this fossil fuel.

In order to address the core of the problem and not just its symptoms, it would be necessary for the Polish government to reduce or preferably totally eliminate the support for energy production from coal. Additionally, the model for the pricing has to be reviewed in order to include the negative externalities that the coal industry has in the final price of the services it provides. This step could create additional stimuli for energy efficiency and reduce the demand for energy, in contrast to just providing incentives for renewable energy, which could lead to reduced energy prices and thus overconsumption of energy. Finally, the resources from unused financial support and the income from the price increase (taxes) should be reinvested into creating better conditions for renewable energy sources. This measure has to be taken with a precaution to make sure the coal industry does not try to “pretend” to be renewable energy in order to get the benefits, as it happens, for example, in the case of coal co-firing with biomass in Poland, which is supported by the country’s renewable energy scheme (Siedlecka, Śniegocki, and Wetmańska, 2017).

The significant role in the implementation of these recommendations is seen for the EU since, as shown before, it is unlikely Poland would be willing to take these kinds of drastic steps by themselves.

6.3.2 Legislation for market creation

The second main area to be addressed is the current lock-in on the regime level in relation to waste, energy and agriculture. As mentioned in the previous subchapter, there are three different ministries, each responsible for policies related to one of these areas, and these ministries seem to have difficulties cooperating and coordinating their work.

One solution to the current situation could be improved coordination between ministries with the common goal of including food waste as a supported substrate for biogas production. This should include addressing the following issues:

- Develop waste legislation to include better documentation on biogas alternative for food waste treatment;
- Make it possible for digestate produced from food waste to be used as a fertiliser (Interview 2) and simplify the certification procedure for it;
- Develop a clear and long-term support system for electricity and heat produced from biogas from food waste;
- Allow the injection of biogas produced from food waste to the gas grid;
- Include biogas in the list of the biofuels for vehicles.

Additionally, the profitability of biogas from food waste can be redefined by including positive externalities of this technology in the financial support: reduction of air pollution and reduced influence on climate change, less waste going to the landfills, cleaner mixed waste that would be easier to separate and recycle, returning nutrients back to the soils, contribution to local energy security and others.

These suggested measures would help to create a predictable and stable market for biogas from food waste, which would make such biogas more attractive for long-term investments. Moreover, the developed support system would help to address the barrier of high technology costs for this solution. A predictable market with sufficient support in combination with profit-seeking culture would further facilitate the take-off of biogas from food waste.

6.3.3 Economic vs environmental considerations

Yet another identified barrier on the regime level is the secondary role of the environment. However, it has been shown (Islar and Busch, 2016; Busch and McCormick, 2014) that even if environmental concerns are secondary, the transition towards a more sustainable energy system is possible if the right incentives are in place. Thus, by applying the measures mentioned above to, on one hand, reduce the feasibility of coal applications and, on the other hand, increase the profitability of biogas from food waste, one can utilise the fact that Polish decision-makers will choose the more economical option, which in this case will also be more environmentally-friendly.

6.3.4 Education and waste management

Following on the previous point, in conditions where environmental concerns are secondary, it is important to create a system of support for the "right behaviour", even when it comes to waste sorting. Zabrze should make it cheaper and easier to do the right thing by addressing the education, financial incentives (in the form of lower fees and fines), and by providing the necessary infrastructure to the citizens. In addition, it is very important that there is infrastructure already in place when the educational activities are held.

In the future, the combination of education with support incentives could facilitate the shift in public opinion towards seeing waste as a valuable resource, better understanding of biogas technology and its benefits, as well as raising the value of the environment and achieving more long-term thinking. To strengthen "waste-resource" link, the city could provide people with the benefits of the employed technology, by for example running city buses on biogas, which would further improve the quality of the local air.

6.3.5 MOSiR and other niches

As mentioned in the subchapter on drivers, the project in Zabrze has had many advantages for starting biogas project, including a local political will, knowledge support from Swedish partners, financing for pre-investment documentation, suitable location on the landfill and previous experience on running landfill gas installation with an international partner. Even with all these benefits present, there are a few areas where MOSiR would benefit from improved practices in order to fully utilize these advantages.

First of all, since MOSiR did not have previous experience working with biogas plants and since biogas from food waste technology is much more complex technology than landfill gas, the company would

have greatly benefited from acquiring the necessary knowledge and competence internally. This could have helped ensure the continuity of the project, the assessment of the delivered results from consultants, or maybe even avoidance of using so many different consultants in the first place. In the future, when the biogas plant is built, internal competence would play an even bigger role.

Secondly, better project management practices could significantly improve the implementation of the project. Such practices could include a more careful approach to important tasks, such as providing the correct bank account for project funding, as well as more frequent and clear communication between the project partners.

Thirdly, since the project involved many international partners, the communication could have been further facilitated if MOSiR had an English-speaking person responsible for the project or considered hiring a professional translator. Interestingly enough, the language barrier has not been considered as a barrier by the company's representatives.

Finally and most importantly, even though MOSiR and the project in Zabrze would have benefited from the above-mentioned measures, the current lock-in situation on the regime level would not provide proper preconditions for the project to break through anyway. This means that even if a different actor tries to start a similar project, the probability of such a project taking off is very low, as this actor will still face similar barriers, primarily the lack of a market for biogas from food waste and necessary legislation on the national level. Thus, even if the landscape with EU-policies created the preconditions for the change on the regime, the regime level did not fully open up to it.

Therefore, although the MLP places high expectations on niches to drive changes on the regime level (Geels, 2002, 2004, 2005a, 2005b), this case shows that it is highly unlikely that a regime shift will occur unless the regime opens up for further changes from within.

As a final note, I would like to mention that even though my research is based on data from 2012, my analysis and recommendations are still relevant even today.

7 Conclusion

This research examined the drivers and barriers for the production of biogas from food waste in Poland, based on the case of Zabrze. Based on the analysis informed by the transition theory, the recommendations were given to both the Poland national authorities and the project leaders in Zabrze, as well as to actors willing to start similar projects.

The findings show that European Union policies on waste and renewable energy are the main drivers; whereas, the barriers are formed by a lack of sufficient support for biogas from food waste and by a lock-in of Technological, User/Market, Policy and Socio-Cultural regimes related to waste, energy and agriculture. Poland and other countries could learn from this study that the abovementioned barriers should be addressed together with a goal of market creation for biogas from food waste technology. This can be achieved by a reduction of support for the dominating fossil fuel systems combined with the simultaneous creation of a clear and long-term support system for the desired alternative technology.

It has also been shown that even a technology that is well-established in one EU country might not be able to break through in another EU country, due to the socio-technical conditions. In spite of the key role assigned to niches by transition theory for bringing about radical innovations, it might not always be possible if the right preconditions are not in place on the regime level.

7.1.1 Further research

This study contributed an analysis of the complex reality related to biogas from food waste and provided practical recommendations. Further research can be directed towards exploring the possibilities of how to make Poland and Polish authorities on different levels more ambitious in looking for new solutions and challenging the status quo. There could also be a need for a thorough analysis of economic benefits related to biogas production from food waste in order to find at which circumstances a breakthrough can be reached even in the current conditions.

8 References

Abramczyk, O. (2014). *A multilevel stakeholder analysis of drivers and barriers in Poland's renewable energy development.* Master thesis. Lund University.

Alwaeli, M. (2015). An overview of municipal solid waste management in Poland. The current situation, problems and challenges. *Environment Protection Engineering* 41: 181–193.

Biogas-info.co.uk, (2015). [online] Available at: http://www.biogas-info.co.uk/images/how_it_works.jpg [Accessed 4 May 2015].

Bryman, A. (2012). *Social research methods*. Oxford: Oxford University Press.

Busch, H., and McCormick, K. (2014). Local power: exploring the motivations of mayors and key success factors for local municipalities to go 100% renewable energy. *Energy, Sustainability And Society*, *4*(1), 5.

Butusov, M., and Jernelöv, A. (2013). *Phosphorus*. New York, NY: Springer New York.

Central Statistical Office. (2016). *Area and Population in the Territorial Profile in 2016.* [online] Available at: http://stat.gov.pl/obszary-tematyczne/ludnosc/ludnosc/powierzchnia-i-ludnosc-w-przekroju-terytorialnym-w-2016-r-,7,13.html [Accessed 30 September 2018].

Černiauskaitė, I., Cornwall, N., Drewitt, T. and Schlotz, A. (2013). *Energy from waste : a pilot biogas system in Zabrze*. Lund: International Institute for Industrial Environmental Economics at Lund University (IIIEE).

Cwil, M. (2011). Biogazownie rolnicze – aktualny stan rozwoju w Polsce. *Czysta Energia*. 10/2011, 42.

Demirbas, A. (2010). *Methane gas hydrate*. New York: Springer.

den Boer, E., and Jędrczak, A. (2017). Performance of mechanical biological treatment of residual municipal waste in Poland. *E3S Web Of Conferences*, *22*, 00020. [online] Available at: https://www.e3s-conferences.org/articles/e3sconf/pdf/2017/10/e3sconf_asee2017_00020.pdf [Accessed 30 September 2018].

Deublein, D. and Steinhauser, A. (2011). *Biogas from waste and renewable resources*. Weinheim: Wiley-VCH.

Dulias R. (2016) A Brief History of Mining in the Upper Silesian Coal Basin. In: *The Impact of Mining on the Landscape.* Environmental Science and Engineering. Springer, Cham

EEA. (2014). *Air pollution fact sheet 2014. Poland*. [online] Available at: https://www.eea.europa.eu/themes/air/air-pollution-country-fact-sheets-2014/poland-air-pollutant-emissions-country-factsheet [Accessed 30 September 2018].

EEA. (2015). *Air quality in Europe — 2015 report.* [online] Available at: https://www.eea.europa.eu/publications/air-quality-in-europe-2015 [Accessed 30 September 2018].

Emtairah, T., Ponte S. and Peck, P. (2011). Bottom up social and institutional innovations in renewable energy systems: Analysis from bio-gas systems in Sweden. In *Proceeding of the Global*

Conference on Renewable Energy and Energy Efficiency in Desert Regions (GCREEDER), 26-28 April 2011, Amman, Jordan

European Commission. (2012). *Country Factsheet Poland.* [online] Available at: http://ec.europa.eu/environment/waste/framework/pdf/PL_factsheet_FINAL.pdf [Accessed 30 September 2018].

European Commission. (2017). *Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the implementation of EU waste legislation for the period 2010-2012.* Brussels, 27.2.2017 COM (2017) 88 final

European Commission. (2018a). *2020 climate & energy package - Climate Action - European Commission.* [online] Available at: https://ec.europa.eu/clima/policies/strategies/2020_en [Accessed 11 May 2018].

European Commission. (2018b). *Applying EU law*. [online] Available at: https://ec.europa.eu/info/law/law-making-process/applying-eu-law_en [Accessed 10 May 2018].

European Parliament, Council of the European Union. (2009). *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.* Brussels.

Fcc-group.eu. (2018). *Oficjalne otwarcie zakładu mechaniczno-biologicznego przetwarzania odpadów w Zabrzu*. [online] Available at: http://www.fcc-group.eu/pl/Polska/aktualnosci/Oficjalne-otwarcie-zak%C5%82adu-mechaniczno-biologicznego-przetwarzania-odpadow-w-Zabrzu.html?ind=10 [Accessed 13 May 2018].

Gardiner, K. (2012). *Wasted Energy. Unlocking the biogas potential in Trinidad and Tobago. A Transition Theory perspective.* Master thesis. Lund University.

Geels, F. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, *31*(8-9), 1257-1274.

Geels, F. (2004). From sectoral systems of innovation to socio-technical systems. *Research Policy*, *33*(6-7), 897-920.

Geels, F. (2005a). Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technological Forecasting And Social Change*, *72*(6), 681-696.

Geels, F. (2005b). *Technological transitions and system innovations*. Cheltenham, UK: Edward Elgar.

Generosi, J., Machacek, E., Remigius, R. and Poderiene, Z. (2012). *Biogas Production in Zabrze: Closing the Cycle of Organic Waste*. Lund: International Institute for Industrial Environmental Economics at Lund University (IIIEE).

Igliński, B., Buczkowski, R., Iglińska, A., Cichosz, M., Piechota, G., and Kujawski, W. (2012). Agricultural biogas plants in Poland: Investment process, economical and environmental aspects, biogas potential. *Renewable and Sustainable Energy Reviews*, *16*(7), 4890-4900.

International Energy Agency. (2017) *Poland - Energy System Overview.* [online] Available at: https://www.iea.org/media/countries/Poland.pdf [Accessed 29 September 2018].

Islar, M., and Busch, H. (2016). "We are not in this to save the polar bears!" – the link between community renewable energy development and ecological citizenship. *Innovation: The European Journal of Social Science Research*, *29*(3), 303-319.

Kemp, R., Rotmans, J., and Loorbach, D. (2007). Assessing the Dutch Energy Transition Policy: How Does it Deal with Dilemmas of Managing Transitions?. *Journal Of Environmental Policy & Planning*, *9*(3-4), 315-331.

Kristjánsdóttir, R. (2017). *Towards a Neutral North. Identifying factors that drive a municipality to actively propel a low carbon transition: A case study of Akureyri, Iceland.* Master thesis. Lund University.

Kvale, S. and Brinkmann, S. (2009). *InterViews: learning the craft of qualitative research interviewing*. 2nd ed. Thousand Oaks: Sage Publications.

Lantz, M. (2013). *Biogas in Sweden: opportunities and challenges from a systems perspective*. PhD Lund University.

Liu.se. (2017). *Export of Swedish biogas technology*. [online] Available at: https://liu.se/en/article/svensk-biogasteknik-pa-export [Accessed 10 May 2018].

Ministry of Economy. (2009). *Energy Policy of Poland until 2030.* [online] Available at: https://climateobserver.org/wp-content/uploads/2014/09/Poland_EPP-2030-2009.pdf [Accessed 13 May 2018]. Warsaw.

Ministry of Economy. (2010). *National Renewable Energy Action Plan.* [online] Available at: https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans [Accessed 11 May 2018]. Warsaw.

MOSIR Zabrze. (2018). *Obiekty.* [online] Available at: http://mosir.zabrze.pl/obiekty [Accessed 30 September 2018].

Mszulik.pl. (2018). *Małgorzata Mańka-Szulik*. [online] Available at: http://mszulik.pl/ [Accessed 10 May 2018].

Muras, Z. (2011) *„Rainbow vertigo" – or a description of Polish support schemes for renewable and cogeneration sources*. [online] Available at: http://www.ure.gov.pl/download/2/241/Polish_support_schemes_for_renewable_and_cogeneration_so.pdf [Accessed 11 May 2018]. Clean Energy, No. 5.

Onet Wiadomości, (2015). *Odpady kuchenne mogą napędzić stołeczne śmieciarki*. [online] Available at: http://wiadomosci.onet.pl/warszawa/odpady-kuchenne-moga-napedzic-stoleczne-smieciarki/8nyr2b [Accessed 11 May 2015].

PIGEOR. (2015). *Cele i strategia*. [online] Available at: http://www.pigeor.pl/cele-i-strategia [Accessed 30 September 2018].

Polish Geological Institute. (2011). *Hard coal reserves and resources in Poland according to the UNFC-2009.* [online] Available at: https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc/IntWs_UNFC_Ankara_Sept2011/15_Smakowski.pdf [Accessed 29 September 2018].

Polish Parliament. (2010). *The Act of 8 January 2010 amending the Energy Law and amending some other acts*. [online] Available at: http://prawo.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20100210104 [Accessed 11 May 2018]. Warsaw, Poland: The Polish Parliament.

Polish Parliament. (2011). *The Act of 1 July 2011 amending the Act on maintaining cleanliness and order in municipalities and some other acts.* [online] Available at: http://prawo.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20111520897 [Accessed 10 May 2018]. Warsaw, Poland: The Polish Parliament.

Raven, R. (2004). Implementation of manure digestion and co-combustion in the Dutch electricity regime: a multi-level analysis of market implementation in the Netherlands. *Energy Policy*, *32*(1), 29-39.

Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: transition management in public policy. *Foresight*, *3*(1), 15-31.

Siedlecka, U., Śniegocki, A. and Wetmańska, Z. (2017). *The hidden bill for coal 2017*. [online] Available at: http://www.greenpeace.org/poland/PageFiles/763123/The_hidden_bill_for_coal_in_Poland_2017_WiseEuropa_report.pdf [Accessed 30 September 2018].

Singh, C., Kumar, A., & Roy, S. (2018). Quantitative analysis of the methane gas emissions from municipal solid waste in India. *Scientific Reports*, *8*(1).

Statistics Poland. (2018a). *Concise Statistical Yearbook of Poland.* [online] Available at: https://stat.gov.pl/en/topics/statistical-yearbooks/statistical-yearbooks/concise-statistical-yearbook-of-poland-2018,1,20.html [Accessed 29 September 2018].

Statistics Poland. (2018b). *Population. Size and structure and vital statistics in Poland by territorial division in 2017. As of December, 31.* [online] Available at: http://stat.gov.pl/en/topics/population/population/population-size-and-structure-and-vital-statistics-in-poland-by-territorial-division-in-2017-as-of-december-31,3,23.html [Accessed 29 September 2018].

Swedish Energy Agency. (2011). *Biogas in Sweden - Energy source for the future from sustainable waste management*. [online] Available at: https://energimyndigheten.a-w2m.se/FolderContents.mvc/Download?ResourceId=2569 [Accessed 10 May 2018]. Granath EuroRSCG.

Swedish Environmental Protection Agency. (1999). *Gas Emission from Landfills - An overview of issues and research needs*. Stockholm: Swedish Environmental Protection Agency.

Szelag, M. (2016). *The importance and analysis of Social Sustainability regarding new Waste Incineration projects in Poland.* Master thesis. [online] Available at:

http://projekter.aau.dk/projekter/files/239506459/Final_document.pdf [Accessed 13 May 2018]. Aalborg University.

The Council of Ministers. (2010). *The National Waste Management Plan 2014 (Krajowy plan gospodarki odpadami 2014).* [online] Available at: http://monitorpolski.gov.pl/MP/2010/s/101/1183 [Accessed 29 September 2018].

Thorin, E., Guziana, B., Song, H., Jääskeläinen, A., Szpadt, R., Vasilic, D., Ahrens, T., Anne, O. and Lõõnik, J. (2012). *Potential future waste-to-energy systems*. [online] Mälardalen University. Available at: http://www.diva-portal.org/smash/get/diva2:583809/FULLTEXT01.pdf [Accessed 4 May 2015].

Um.zabrze.pl. (2018). *Odpady komunalne | Urząd Miasta Zabrze*. [online] Available at: http://www.um.zabrze.pl/mieszkancy/odpady-komunalne [Accessed 10 May 2018].

UNCCS. (2012). Summary of GHG Emissions for Poland. [online] Available at: https://unfccc.int/files/ghg_emissions_data/application/pdf/pol_ghg_profile.pdf [Accessed 30 September 2018].

UNFCCC. (2018). Global Warming Potentials. [online] Available at: https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials [Accessed 29 September 2018].

Worldenergy.org. (2018). *Coal in Poland*. [online] Available at: https://www.worldenergy.org/data/resources/country/poland/coal/ [Accessed 13 May 2018].

Yin, R. (2009). *Case study research*. Los Angeles, Calif.: Sage Publications.

Appendix A. Interview guide

General topic	General question	Aspects	Specific questions
Zabrze story	What do you know about this project?	History	How did the idea of the biogas plant in Zabrze appear?
	Can you tell about the biogas project in Zabrze?		Who was the initiator of the project?
		Location choice	Why Poland?
			Why Zabrze?
			Why landfill?
		Biogas	Why biogas?
		Problems addressed	Which problems does this project address?
			For whom it is a problem?
		Substrates (Household waste, manure, others)	Which substrates will be used for the production of biogas?
			Why have you decided to use waste?
		Biogas usage	For which purpose will biogas be used? Why electricity? Why as a vehicle fuel?

		Fertiliser	Who will be using the fertiliser?
			For which purposes?
		Project characteristics	What is the planned capacity? Why?
		Alternatives	Have you considered other approaches?
			Are there any Polish options?
		Long-term dynamics	How do you see the project in long-term?
			Do you think about threats/project vulnerability in the long term?
		Project in the context	How do you see the project in the wider context: Regional? National? European? Global?
Drivers	What are the drivers for the project?	Political/Institutional, Economical/Financial/Market, Social/Cultural/Behavioural, Technical, Environmental	
Barriers	What barriers do you see for the project implementation?	Political/Institutional, Economical/Financial/Market, Social/Cultural/Behavioural, Technical, Environmental	On which level (local, regional, Polish, European, global)?

		Problems along the production line (Substrates, Usage, Fertiliser, Logistics, Location, Technology, Knowledge)	
	How can these barriers be overcome?	Levels of barriers	How can Zabrze project be improved? By whom?
			What can be done on the regional level? Polish? Global level?
Success and failure factors	What are the success and failure factors in Zabrze project?	Success/Failure Evaluation	Is Zabrze project a success story? Why? How do you measure success?
			How can success factors be strengthened?
			How can failure factors be weakened?
			How can the success be replicated to other Polish cities? Other places?
Actors/Networks/Roles	Who was and who is involved in the project?	Key roles	Without whom the project would not be possible? Why?
	What are their roles?		Who else should be interviewed?

		Competitors, Disturbance (General public, waste pickers)	Who can be against the project? Why?
		Own role	What is your role in the project?
			How do you see your role in the future?
Lessons learnt	What can be learned from this project?	Lessons learnt	What can be learnt from this project? By whom?
		Gap between intentions and reality	Is there a gap? Why?

Appendix B. List of interviewees

#	Organisation	Name	Position at the Time of Interview	Date of Interview	Interview Length (min) and Type	Relation to Zabrze biogas project/Notes
1-3.	Swedish-Polish Sustainable Energy Platform, Lund/Warsaw	Mikael Backman	Head of Swedish Secretariat	22.10.2012, 19.11.2012, 24.04.2015	101, Office/Lund	Member of Managing Board for Zabrze biogas project
		Magdalena Rogulska	Head of Polish Secretariat, PIMOT, Senior Expert at Renewable Energy Department	31.10.2012	54, Skype	Member of Managing Board for Zabrze biogas project
				10.04.2015, 11.04.2015	111, IIIEE/Lund	
		Barbara Smerkowska	PIMOT, Renewable Energy Department Manager, Research & Technical Specialist	26.10.2012	52, Hotel/Zabrze	Expert, worked with biomethane

4.	Lund – Zabrze Twin City Collaboration, Lund	Joanna Nicklasson-Młynarska	Ambassador of the city of Zabrze in Scandinavia	5.11.2012	69, Home/Lund	Project facilitator, Translator
5.	Swedish Embassy in Warsaw	Gunnar Haglund	Former Counsellor (Business Promotion)	20.11.2012	56, Skype	Promoted biogas from waste in Poland
6.	Warsaw University of Life Sciences (SGGW)	Magdalena Szymańska	Assistant Professor, Department of Soil Environment Sciences, Faculty of Agriculture and Biology	8.05.2015, 11.05.2015	-, Email	Suggested by Magdalena Rogulska. I write in English, and the replies are in Polish
7-8.	MOSiR, Local Centre of Sport and Recreation in Zabrze	Zdzisław Iwański	CEO and Executive Director	24.10.2012	46, MOSiR Office	Owners of Biogas project, Interview was in Polish with consecutive interpret
		Ryszard Bęben	Deputy Director	24.10.2012, 25.10.2012	150, MOSiR Office	

						ation to English
9-11.	Zabrze Municipality	Krystyna Kurowska	Mayor's Advisor, Responsible for Waste Legislation	25.10.2012	52, Zabrze Municipality	The interview was in Polish with consecutive interpretation to English
		Czesława Węclewicz	Mayor's Advisor in Ecology Education	13.04.2012, 24.10.2012	41, Zabrze Municipality	The interview was in Polish with consecutive interpretation to English
		Marcin Lesiak	Head of International Relations Office	25.10.2012	92, Zabrze Municipality, International Relations Office	
12.	Environmental Education Centre, Zabrze	Małgorzata Góra - Wolny	Inspector for Environmental Education	24.10.2012	137, Zabrze Municipality, International Relations Office,	The interview was in Polish with

					Café	consecutive interpretation to English
13.	MPGK Municipal Waste Company/ASA, Zabrze	Zenon Doroz	Investment Director	24.10.2012	112, MOSiR Office	Collecting municipal waste; composting waste, where separately collected organic waste is currently processed. The interview was in Polish with consecutive interpretation to English

Appendix C. Pictures from the landfill belonging to MOSiR

Figure 6. Landfill gas collection and waste picking activities. Behind is the future location of the biogas plant (SPSEP).

Figure 7. Combined heat and power plant from landfill gas (SPSEP).

Appendix D. List of biogas related activities I participated in

#	Activity	Date	Details
1.	Study trip to Sweden for representatives from the Polish Ministry of Agriculture and Rural Development	May 2-6, 2011	Study trip included visits to Biogas Syd in Malmo, an association of the biogas stakeholders, NSR in Helsingborg (regional cooperation in waste management), Jordbruksverket (The Swedish Board of Agriculture), Länsstyrelsen (County Administrative Board), Lunds Energi and a sugar factory in Örtofta. The group also has visited the biogas plants in Wrams Gunnarstorp and Norups Gård.
2.	Technical trip to SYSAV, Malmo	October 20, 2011	The trip consisted of sightseeing tour of the whole building complex in SYSAV, including the waste-to-energy plant, waste site and the recycling station. It was followed by the presentation on Efficient and sustainable waste management with the focus on the organic waste treatment, following by the solutions showed by six different companies: Biomil, BioPreplant, Fvb, Optibag, Purac, Spirac.
3.	Conference in Warsaw Energy from Waste. Biogas Production - the Swedish Model	November 9, 2011	The following topics were covered: Biogas Basics – Historical Development, Production, Usage and Economic Rationale in Sweden; Municipal Waste and Waste Water at NSR Waste Management Plant and NSVA Waste Water Treatment Plant; Industrial Waste – Co-fermentation; Agricultural Waste – Manure: Farmers and Swedish Biogas International; Technology providers for design, construction, upgrading and landfill gas; Vehicle Gas and

			Biogas Production at the Waste Water Treatment Plant in Göteborg; Investing in Biogas in Sweden – How to Achieve Project Profitability; Biogas Profitability in Poland; Financing Biogas Projects; Road Map for Making Scania Region the Leading Biogas Region in Sweden until 2020.
4.	Seminar on sustainable city development with Swedish experts in Zabrze	March 6-10, 2012	Covered topics: water treatment, waste management, biogas production
5.	Seminar Innovation and entrepreneurship in the biogas area, Malmo	March 16, 2012	
6.	Biogas exhibition/seminar/study visits in Kristianstad	March 29-30, 2012	Including visit to biogas plant and biogas upgrading plants
7.	Field study on biogas from waste production in Zabrze	April 10-17, 2012	Helping students with their report ”Biogas Production in Zabrze – Closing the cycle of organic waste”
8.	Nordic Biogas Conference in Copenhagen	April 23-25, 2012	Conference Tracks: 1. Biogas production: Developments in production technologies. 2. From waste to resources: Benefits and opportunities for biogas. 3. Integration of renewable gases in the energy system: Renewable gas markets and the role of renewable gases as the backbone in the energy system of the future.

			Excursion to BioVækst and Hashøj Biogas Plants in Zealand Functions: Biovækst converts organic waste into biogas and fertiliser. Hashøj Biogas produces biogas from animal manure and organic waste.
9.	Visit to Zabrze and signing of a contract with BSAP Fund	September 4-8, 2012	Included study visit to Zabrze landfill
10.	Study visit of Polish Energy Agencies to Scania Energy Agency	September 17-20, 2012	Included a visit to Lunds Energy (projects in energy storage, plans for future energy production to district heating system), SYSAV (presentation of the Swedish waste management, study visit to waste to energy incineration plant and pretreatment of food waste for biogas production).
11.	Biogas Highway – Waste to Energy Seminar/Fair/Study tour, Gothenburg	September 18-19, 2012	Study tour on Biogas for vehicles, upgrading, injection, vehicles and liquid biogas
12.	Study trip and Waste management conference in Zabrze	October 23-26, 2012	Interviews with actors related to Zabrze biogas project
13.	Study trip to Sweden for a delegation from Zabrze	November 13-17, 2012	Including a visit to SYSAV (pretreatment of food waste), presentations on organic waste collection system and biogas production in Scania
14.	Meetings with Lunds Energi. Biogas system in Lund, Dalby	March 22 and April 3, 2013	Documentation of Swedish best practice before field study in Zabrze

15.	Meeting with plant manager and tour at Karpalund biogas plant in Kristianstad	April 2, 2013	Documentation of Swedish best practice before field study in Zabrze
16.	Meeting at SYSAV in Malmo. Pretreatment of food waste	April 4, 2013	Documentation of Swedish best practice before field study in Zabrze
17.	Field study on biogas system in Zabrze	April 9-16, 2013	Helping students with their report “Energy from Waste – A Pilot Biogas System in Zabrze”
18.	Study visit for a delegation from West Pomerania, Lund	May 17, 2013	Presentations on food waste collection system and biogas production in Scania
19.	Conference Energy from Waste – Advancements in Biogas Production, Ystad	November 13-14, 2013	The following topics were covered: Renewable energy – energy from waste. Polish experience; Biogas production as a part of a sustainable waste management system; Biogas production as a part of a sustainable energy system; Biogas production as a driver for growth, innovations and local sustainability; Sustainability aspects of biogas system; Legislative framework and recent advancements in Poland; Biogas production process and products; Biogas in public transport; Polish investments in process. Excursion to Algae Biogas Plant in Smygehamn; Presentation at Trelleborg Biogas Centre of Excellence; Presentation and visit of Jordberga Agricultural Products Biogas Plant (Under construction)

20.	Meeting at Regional Energy Agency of Scania with Polish Ministry of Infrastructure and Development	February 21, 2014	Energy Advising
21.	Study visit to Lund for a delegation from Zabrze	May 15-18, 2014	
22.	REGATEC Conference in Malmo, The first International Conference on Renewable Energy Gas Technology	May 22-23, 2014	Conference topics included: Biogas cleaning R&D and experiences, Gasification R&D, Biogas upgrading R&D and new technologies, Product gas cleaning R&D, Advances in biogas upgrading, Methanation Industrial biogas projects, Industrial bioSNG projects
23.	Biogas study tour for MOSiR, Roundtable summing up meeting at IIIEE – Lund University	April 23, 2015	Meeting with Swedish biogas related companies