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Innovative Bioenergy Systems in Action

The Mureck bio-Energy Cycle: Synergistic Effects and Socio-economic, Political and Sociocultural Aspects of Rural Bioenergy Systems

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Abstract

This thesis aims to offer insights into the initiation and development of modern (rural) bioenergy systems. For this reason, the thesis explores the formation, evolution and regional effects of three bioenergy projects – a biodiesel cooperative, a biomass district heating plant and a biogas plant – that are co-located within the small rural community of Mureck, in Austria. It finds that the three projects form an industrial ecosystem that is founded on a unique and innovative architecture, and that is characterised by a more efficient use of materials and energy. By adopting a system dynamics perspective, the thesis explains the gradual evolution of this industrial ecosystem, influenced by the closed-loop philosophy and the broad bio-ecological vision of one developer, and emerging as all actors have sought to minimise transaction costs. It further shows that much of the innovative character of this system was largely due to the formation of a regional cooperation triangle among research institutions, technology suppliers and implementers. Next, the thesis explores the favourable policy context that has fostered the evolution of this system. A socio-economic section analyses the regional benefits generated by this industrial ecosystem and shows that these range from increased heating convenience and prestige among local residents, to increased self-sufficiency and to value added to the region. Finally, a socio-cultural analysis explores why this system, as well as other bioenergy projects in the region, were essentially driven by endogenous forces. It finds that bioenergy projects have represented over time a considerable income-alternative for farmers, and that such projects may fit well within rural communities. By highlighting the features of the (regional) rural culture, the section provides an additional means of interpreting the formation of the industrial ecosystem in Mureck, and stresses that bioenergy projects play an important role for the development of rural regions. Based on the innovative Mureck case, the study indicates general preconditions for the successful diffusion of bioenergy systems.

Executive Summary

In this thesis the development of three bioenergy projects within the Austrian province of Styria is discussed. The projects – a biodiesel cooperative (SEEG), a biomass district heating plant (Nahwärme) and a biogas plant that produces 'green' electricity (Ökostrom) – are co-located on the outskirts of Mureck, a small rural community on the border with Slovenia. The projects, jointly referred to as the *Mureck bio-Energy Cycle*, are explored in terms of interaction with each other, interactions between key stakeholders and political support. The thesis also adopts a system dynamics perspective and investigates the historical development and evolution of the Mureck bio-Energy Cycle over time. The objective was to discover cornerstones that have led to the present result in Mureck.

The study was justified by the innovative character of the case, which promised to offer valuable insights into the initiation and development of bioenergy systems. The Mureck bio-Energy Cycle enjoys an outstanding reputation. In 2001, the biodiesel cooperative SEEG has received the International Energy Globe Award for its success regarding biodiesel production from used frying oils, and as recognition of the efficient cooperation that was taking place between SEEG and Nahwärme.

To explore this case, the embedded case study method was chosen. Five factors were selected for analysis: (1) the synergies and complementarities between the three different bioenergy projects comprising the Mureck bio-Energy Cycle (for instance when the biogas plant uses by-products from the biodiesel fabrication process), (2) economies of scale due to integrated deployment of the three systems (such as specialisation, knowledge-transfer and integration of certain activities), (3) local cooperation that allowed the formation of reliable supply chains, (4) the attitude of authorities and (5) the existing local opinion and the benefits associated by residents with the Mureck bio-Energy Cycle. The objective was to find out whether these factors have played a crucial role for the development of the Mureck bio-Energy Cycle, and to discuss how they contributed to the development of the system.

The thesis builds upon three stages: the first stage corresponds to the initial phase of the research, during which relevant information was collected, essentially from secondary sources and from literature review. Reflected in Chapter 2, this stage introduces the reader to the Mureck bio-Energy Cycle and offers a general picture of the case. The second stage was founded on the data obtained from the empirical study. It corresponds to Chapter 3 and to the actual analysis of the case. To enhance the integration of knowledge and to facilitate the analysis, this chapter is divided into four separate parts – the techno-economic, the socio-economic, the political and the socio-cultural subsystems of the Mureck bio-Energy Cycle. Finally, the third stage, reflected in Chapter 4, integrates the insights from each analysed subsystem and tries to develop a more valid case understanding. It formulates the conclusions and gives suggestions for further research.

A first important finding of this research is that the three bioenergy projects in Mureck have gradually evolved into an industrial ecosystem that is characterised by a more efficient, closed-loop use of materials and energy, and in which by-products from one process serve as feedstock for other processes. This evolution was triggered by glycerine – an important by-product that occurs during the transesterification process for biodiesel production at SEEG. Over time the deployers of the three projects sought to make the best economic use of their materials and energy. This enlarged their cooperation basis, which gradually came to include the sharing of additional resources, such as the joint use of premises and machines, the integration of certain departments and the cyclical deployment of Ökostrom and Nahwärme as heat suppliers of the town. It is also shown that the Mureck bio-Energy Cycle has benefited

continuously from a natural system vision and from a management philosophy of closing loops.

The socio-economic section discusses the complex relations between the Mureck bio-Energy Cycle and its most important stakeholders. It describes the complex systems that supply the three bioenergy projects with resources and stresses that although the Mureck bio-Energy Cycle takes up a large part of renewable resources from within the immediate agricultural setting, the system is neither self-sufficient, nor limited to a pure local economy. Next, a series of benefits are found to be related to the Mureck bio-Energy Cycle. Among them, the most important are employment generation, increased heating convenience and prestige for residents in Mureck, additional income opportunities for farmers and ultimately increased self-sufficiency and value added to the region. The analysis also highlights potential negative impacts, such as land use competition.

A significant finding from the analysis of stakeholders is that the Mureck bio-Energy Cycle was made possible through the close cooperation with centres of knowledge excellence (such as the University of Graz and Vienna) and with plant constructors in the region. These partnerships have facilitated the development and early adoption of innovations, permitting the co-located bioenergy projects in Mureck to systematically benefit from technological underpinning by both technology developers and suppliers. Cooperation has either taken the form of joint R&D activities, or that of joint planning, construction and optimisation of processes and installations through a 'trial and error' process.

The analysis of the political subsystem argues that each individual project in Mureck has benefited from considerable local, regional and federal support, because at the time of establishment of each project *opportunities for action* on given initiatives were present at the political level. This assertion is demonstrated by using the concept of 'policy windows' that was developed by Kingdon. It is further shown that some of the governmental promotion was rather limited in time and does not necessarily continue to exist under present conditions. An important and related finding is also that Austrian and in particular Styrian authorities have deliberately sought to establish bioenergy projects as an alternative form of revenue for farmers, since it became clear that farmers have few chances to compete with their better adapted colleagues on the European agricultural market.

Finally, the socio-cultural analysis, seen as an additional means of interpreting the formation and evolution of the Mureck bio-Energy Cycle, shows that bioenergy projects within the larger Radkersburg district (to which Mureck belongs) have evolved gradually, as farmers were subjected to an increasing competitive pressure from outside actors. Ecological theory is used to show that farmers in Radkersburg have faced a *niche overlap* with their better adapted competitors. In this context bioenergy projects have come to be associated by farmers as new income opportunities that could reduce their dependence on the volatile European agricultural market. Self-sufficiency and closed-loop thinking are two features of the philosophy of one developer of the Mureck bio-Energy Cycle. It is shown that they are partly rooted in the traditional farming culture that exists in the region, and partly a result of the general economic pressure on farmers in Radkersburg.

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1 Introduction

1.1 Background

Energy is inextricably linked to social and economic development (Hektor, 2005; UNDP, 2004). Since the beginning of the industrial era more than two and a half centuries ago, energy generation and utilisation have experienced a sharp and steady increase (IEA, 2004; Grubb, 1990). However, serious concerns over resource depletion, energy security, irreversible environmental degradation and negative social and economic impacts have highlighted the vulnerability of present energy systems, demonstrating the need for fundamental reforms (UNDP, 2004; Kartha, 2000). One part of the solution is to increase the share of renewable energy sources in energy generation (UNDP, 2002; Grubb and Vigotti, 1997; Grubb, 1990).

Biomass is one such renewable energy source. Recently it has received growing attention from many actors and from the energy sector in particular due to its large application in a broad range of energy systems.[1] Its importance has increased since the oil crisis in the 1970s, and recent record-levels of oil prices[2] are fostering the diffusion of new biomass technologies. Even so, modern bioenergy technologies account for only a small fraction of the total energy market (IEA, 2004). The major reason for this is not the lack of technologies, but rather a series of non-technical barriers of various kinds that prevent or slow down bioenergy diffusion. Nevertheless, around the world support for bioenergy systems is increasing. In recognition of these opportunities, the European Union has set ambitious targets for the European bioenergy sector. These can only be attained through a better understanding of bioenergy systems, the support they need and the benefits they provide to communities.

However, modern bioenergy systems and their role for regional development are still poorly understood (Domac, Richards and Risovic, 2005; Austrian Energy Agency, 2003). Some authors stress the negative effects that can be involved, such as lack of cost competitiveness, disrupted or limited fuel supply or increased environmental pressure (Bungay, 2004; Rösch and Kaltschmitt, 1999; Radetzki, 1997). Others argue that bioenergy systems mainly provide benefits, ranging from job creation and improved industrial competitiveness, to environmental benefits and energy security (Domac et al., 2005; UNDP, 2004; Lettens et al., 2003; Kartha, 2000). The nature of bioenergy is extremely complex, involving different technologies and generating various social, economic and environmental effects (Domac et al., 2005, 97), and so, it is not surprising that such divergences arise. This stresses that what is needed in the first place is a better understanding of the fundamental impacts that modern bioenergy systems have upon communities. In addition, the few documented examples of how cooperation initiatives can facilitate diffusion and drive innovation of bioenergy systems highlight the need to explain in what way different bioenergy technologies can benefit from networking, partnerships and alliances.

For this reason this thesis researches the case of the Mureck bio-Energy Cycle – an innovative bioenergy system located on the outskirts of the Mureck community in Austria, which consists of three different bioenergy projects – a biodiesel cooperative, a biomass district heating plant

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[1] Applications for biomass range from small, traditional stoves to large combined-heat-and-power plants, or in the production of liquid biofuels for the transport sector.

[2] BBC News (August 24, 2005): "Oil prices have surged to fresh record highs again after a surprise drop in US petrol stocks […]. US light crude closed at a new high of $67.40 a barrel, up $1.69 on the day, topping the previous high of $67.10", but also Bloomberg (March 17, 2005): Crude oil rose to a record $57.50 a barrel in New York on concern the Organisation of Petroleum Exporting Countries can't pump enough to meet demand. (…) "It's an admission that [OPEC] don't have any spare capacity left…"

and a biogas plant that produces 'green' electricity – cooperating closely with each other. It explores, analyses and explains under what circumstances the Mureck bio-Energy Cycle came to be, what impact the system has upon the local communities, and the evolution of the system over time. Thus, this thesis aims at contributing to the knowledge about and understanding of crucial factors for bioenergy initiatives.

The Mureck bio-Energy Cycle was chosen for a number of reasons. First, of particular interest was the *co-location* of three different projects within the same site. The potential benefits for each project because of their geographic proximity, as well as the degree of cooperation existing among the projects have generated intrinsic interest in this case. Second, the *benefits* generated by these bioenergy initiatives in the rural community in which they are embedded, the established local supply networks and in general the interaction between the projects and their stakeholders, have motivated the research by promising new insights with regard to socio-economic factors that can drive bioenergy initiatives. Third, research on the type and degree of *political support*, either in the form of direct financial aid to these projects, or as the creation of a wider support framework for biomass energy, appeared to be meaningful for understanding how policy-makers can facilitate the diffusion of renewable energy systems. Fourth, it was hoped that the research of the wider socio-cultural context in the region could provide new perspectives on *why* this rural community has implemented not one project, but an interconnected system of three bioenergy projects. Last but not least, an inherent interest to research this case existed also at the level of the Bioenergy Network of Excellence – a pan-European group of eight leading research institutes in bioenergy to which the academic institution where this thesis has been produced is affiliated – that considered that the case could deliver new insights into the initiation and development of bioenergy systems in European rural communities.

1.2 Purpose and Research Questions

The purpose of this thesis is to explore the Mureck bio-Energy Cycle (MEC). By this, the main objectives are to understand and explain *how* this system functions, *what* the role of its key components is and *under which circumstances* its architecture has evolved. Consideration is given to (1) the techno-economic dimension of the MEC (e.g. synergistic effects arising from the integrated deployment of the three bioenergy units), (2) the socio-economic dimension of the project, (3) the political environment that offered support to this system and that influences the market conditions of the MEC, and (4) the socio-cultural environment in which the system is embedded. Last but not least, the study aims at discovering whether the system offers 'best-practice' information that can be used to establish similar projects in other regions.

1.2.1 Focus Problem

In spite of various social, economic and environmental benefits related to bioenergy systems, it is not clearly known how to foster development of sub-regional agro-based bioenergy networks.

1.2.2 Research Questions

The general research questions in this thesis are as follows:

- *How does the Mureck bio-Energy Cycle function?*
- *Under what circumstances did this system evolve?*
- *What are the implications of the system for the rural setting in which it has been established?*

In order to respond to these questions, I analyse and explain the role of various factors in the functioning of the system (such as resources, supply systems, technologies and operations, energy services), along with their wider effects on the Mureck community (for instance new income opportunities, added value, increased self-sufficiency). Particularly the second and third research questions address social and political aspects. Consequently, I focus on the role played by local actors, social networks, entrepreneurship, cooperation and local values.

1.2.3 Preliminary Hypotheses

A considerable number of articles on organisational theory point out that diversification, building of networks and closing of alliances are emergent strategies that lead to positive externalities, economies of scope, risk reduction or better positioning on the market for their participants (see for example Sartorius and Zundel, 2005; Argandona, 1999, 220; Osborn and Hagedoorn, 1997; Doz, 1996, 55; Malmberg, Solvell and Zander, 1996). Following from that, this thesis has as initial points of departure that:

- the cooperation of the three distinct bioenergy undertakings of the Mureck bio-Energy Cycle yields better outcomes for each project, and that

- the Mureck bio-Energy Cycle has emerged because it helps the actors to valorise synergistic effects within this overarching structure.

As such, these points guide the work from the outset.

Secondly, case studies on bioenergy in the European Union have shown that, apart from financial support, the capacity of local entrepreneurs and the support of local communities and authorities are crucial for the implementation of such projects (Tomescu, 2005a; McCormick and Kåberger, 2004; Danielsen et al., 2001; Rakos, 1998). In light of this, it seemed that the good cooperation with farmers and communities at the supply-chain level could be explained from a socio-economic and cultural perspective, while a political perspective would help understand the support of the local and regional authorities. In this regard, a working assumption for this thesis was that both policy instruments and economic incentives were likely to have played an important role in the implementation of this project.

A third guiding hypothesis for this thesis was that the successive expansion of the system in Mureck was possible due to local trust and networking on one hand, and increased knowledge, confidence and experience of deployers on the other hand.

The above formulated hypotheses and expectations have been derived from elements of *Industrial Organisation, Industrial Ecology, Stakeholder Theory, Public Policy and Ecological Theory*. These theories form the theoretical underpinning, and they are referenced throughout this work.

1.3 Methodology

This paper has resulted from intrinsic interest in the characteristics of the MEC. The objectives of this study – to explore, understand and explain the complex MEC system – were achieved by employing the *embedded case study* method (Scholz and Tietje, 2002; Stake, 1995). While holistic case study methods favour descriptive forms of writing, the embedded case study method allowed the segmentation of the MEC case into four relevant subsystems[3], and

[3] By utilising the embedded design the case was segmented into a techno-economic, a socio-economic, a political and a socio-cultural dimension.

subsequently the in-depth analysis of each of these subsystems. The insights derived from the multiple analyses of these subsystems were integrated in the final chapter, in order to develop a more valid case understanding. The embedded case design provided flexibility of data collection, allowed for both qualitative and quantitative data and the application of a different strategy of knowledge integration.

There seems to be little or no literature at all on the closed-loop deployment of independent bioenergy projects, which, ultimately, is the case of the MEC. Therefore, the lack of relevant predefined theoretical frameworks for research and analysis had to be compensated with a thorough documentation on the case study method. Scholz and Tietje (2002) provided excellent guidance in the formulation of the specific theoretical framework for analysis of the MEC. The resulting reference model will be presented under *Research Design*, while the most appropriate data collection methods have been outlined below.

1.3.1 Data Collection

For testing my hypotheses and for exploring the case I relied on data on the Mureck bio-Energy Cycle obtained through interviews, questionnaires, observations and archival data (regulations and steering documents at federal and province level), as well as written materials on the Mureck bio-Energy Cycle (i.e. annual reports and articles from the local newspapers). To increase confidence in my interpretations and to validate the results of my study, I applied triangulation at three levels: first, I compared and contrasted primary data with secondary data on the MEC and its region and with general information on bioenergy projects from the literature review (see *figure 1-1)*.

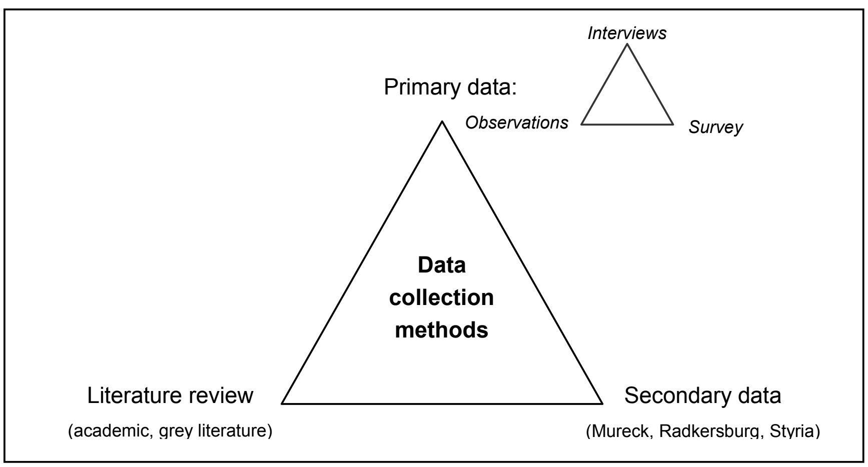

Figure 1-1 Triangulation of data collection approaches

Second, the interviews were validated using *informant triangulation* (Stake, 1995; Denzin, 1984). For this, I interviewed and compared the viewpoints of three main groups of stakeholders: (a) project deployers and experts familiar with the case, (b) farmers/residents and (c) politicians (*figure 1-2)*. The questions addressed each of the four subsystems of the case, according to the research framework defined under *Research Design*. Moreover, after each interview I administered a short questionnaire, as a method to validate the interview and to gather additional data. Third, I applied *theory triangulation* as a validation procedure for important claims, where I intended to avoid misinterpretations (Stake, 1995). In such cases the best theories for explaining certain phenomena were selected after discussing the issue with experts with alternative theoretical backgrounds, who could judge the case from a transdisciplinary point of view. The experts I consulted with have experience in sociology, rural development, ecology and bioenergy.

The interviews were designed for three major groups of actors: (a) project deployers and experts familiar with the MEC (10 interviews), (b) local farmers and residents (15 interviews) and (c) local and regional politicians (5 interviews). It was expected that these main stakeholder groups would provide the most significant information for the research. Additional interviews were held with a representative of a public material recycling yard in Mureck, who provided valuable insights about the collection system for used frying oil, and with the environmental protection officer at McDonalds Austria, who explained why his company decided to send the used frying oil from 162 restaurants in Austria to Mureck for the production of biodiesel.

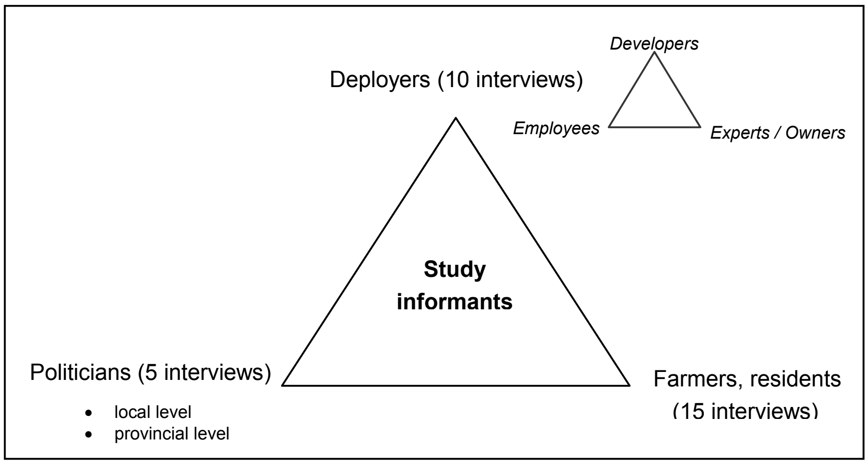

Figure 1-2 Informant triangulation

The semi-structured format of the interviews allowed the formulation of distinctive questions for each major category in advance, while providing enough liberty for open discussions on topics of particular interest. The questions for the interview were generated through brainstorming, doing this with the help of my supervisors. In this way more than a hundred questions were generated, which were then grouped around four major subjects according to the research framework, and were refined for each of the three stakeholder groups. The interviews were designed to last approximately one hour. In the end, each respondent was asked to complete a short questionnaire. Both the interview and the questionnaire were pre-tested prior to official administration.

The first interview was conducted with the founder of the MEC. Then, a snowballing technique was used for identifying other relevant persons for further interviewing. As a member of the Bioenergy Network of Excellence, the commissioner of this study, the Joanneum Research Graz offered support by pre-arranging interviews with regional politicians and with relevant experts in Graz. Altogether, 32 interviews were conducted. The focus was set mainly on why and how the MEC came into existence, how the interviewees related to the MEC system, and what the advantages and respectively disadvantages were that they perceived in relation with this system. The results from the interviews were compared against theory, providing a large part of the information used for analysis within each subsystem, as described under Research Design.

1.3.2 Research Design

The research and analysis of the MEC is structured on three levels (see *figure 1-3*), each corresponding to a different stage of the cognitive process (Scholz and Tietje, 2002, 30). The first level, reflected by Chapter 2 of this study, matches the initial phase of the research. It introduces the reader to the case as a whole, aiming to develop a general case understanding. The second level, reproduced in Chapter 3, corresponds to a systemic view of the case. On this level the MEC is decomposed into four relevant subsystems for a better integration of knowledge and subsequent analysis of each part. The analysed subsystems are: (1) the techno-economic system, (2) the socio-economic system, (3) the political system and (4) the socio-cultural system. Each subsystem ends with a *synthesis* that integrates relevant theories into the research or highlights important insights from the section. This method of 'theory integration' was preferred in this study, since it permitted to correlate each theory directly to its corresponding facet (subsystem) (Scholz and Tietje, 2002). I also feared that merging the rather diverse theories (e.g. industrial ecology, stakeholder theory or ecological theory) in a single chapter could potentially limit the explanatory power of the thesis. Finally, the third level, corresponding to Chapter 4, integrates the insights from each subsystem and tries to develop a more valid case understanding.

While the partitioning into these four subsystems was based on a broad literature review, the selection of their key components was performed at an early stage of the research. For that, a three-step procedure was adopted: first I constructed an initial list of aspects that I considered crucial for the case and its development. This was based on a literature review, on the instruments that were available for the case study, on the time allocated for the study and on the information that was available about the MEC. Several bioenergy experts from major research institutions helped with refining these aspects.[4]

Next, I grouped the aspects into a second list, which was then sent to a reference-group that was familiar with the MEC case. These people were invited to rate each aspect on a seven-point scale, and to suggest further relevant aspects that had not been included on the list. In the final stage I decided around which aspects to organise the embedded design of the MEC. My decision was based on the responses given by experts familiar with the MEC case, as well as on my personal knowledge, interests and values. As a result, I decided to investigate primarily the architecture of the system, the economy and the benefits of the case, the political factors, the human dimension and the networks of cooperation that have contributed to the realisation of the MEC. These components were then grouped into the techno-economic, socio-economic, political and socio-cultural subsystems.

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[4] Philip Peck, Kes McCormick and Tomas Kåberger, from the International Institute for Industrial Environmental Economics, in Sweden; Reinhard Padinger and Erik Daugherty, from the Joanneum Research Graz, Christine Rinesch, from the Karl-Franzens University in Austria and Christian Rakos, from the Austrian Energy Agency.

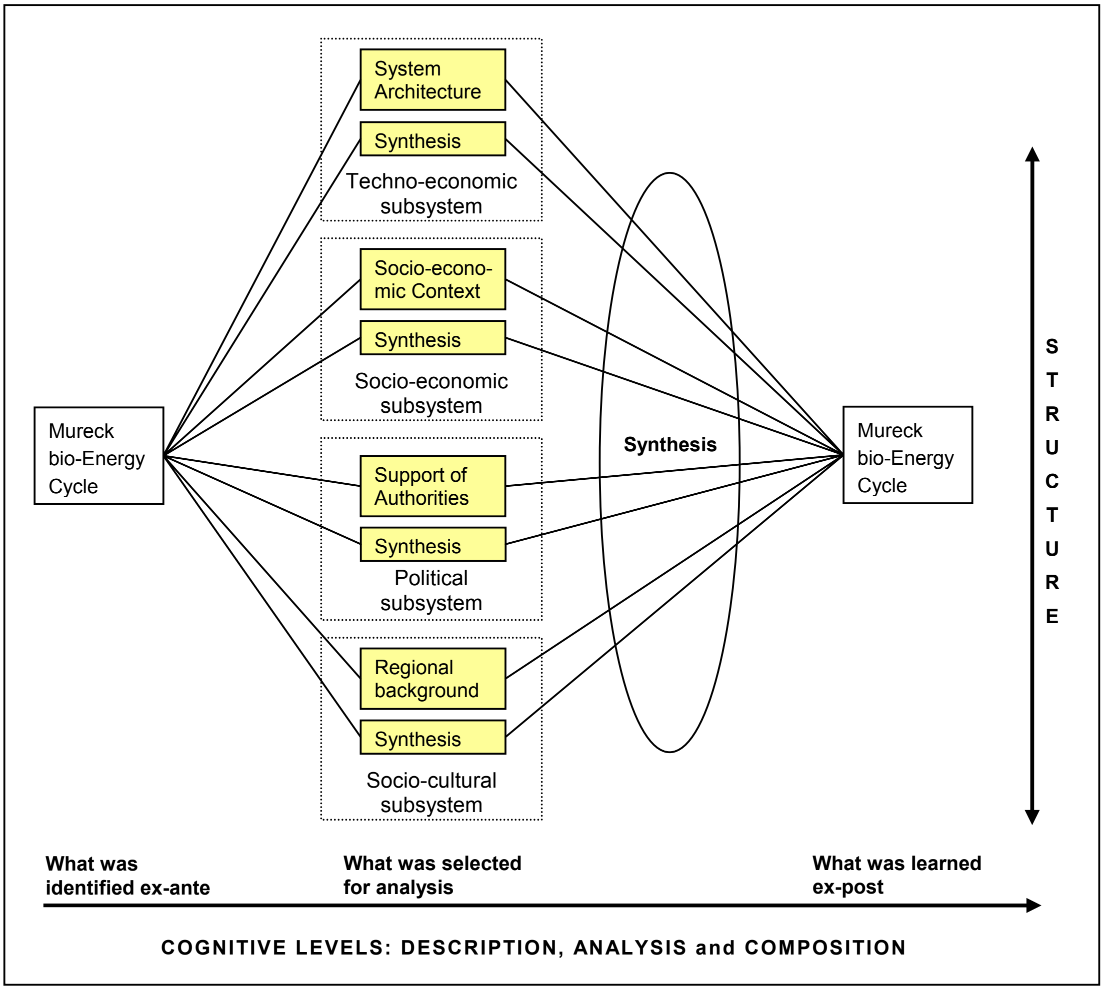

Figure 1-3 Levels and structure of the research

While usually the analysis of cases is structured according to technical, socio-economic and/or political issues, I preferred to broaden my approach and to include a further dimension: the socio-cultural context that provided important insights of the larger context. My intention was to use the concept of local culture as a complementary explanation of the location and evolution of the MEC. Nevertheless, the effectiveness and convenience of organising the analysis along similar lines is reflected by the work of previous scholars (Sartorius and Zundel, 2005; Cooperation, Networks and Institutions in Regional Innovation Systems, 2003; Bunge, 1992; Becattini, 1990). "The success or failure of a given technology is determined by political conditions, by its adaptability to a given set of technical and social norms, by scientific progress and by public perception of its risks and potentials" (Sartorius and Zundel, 2005, 32).

1.4 Scope and Limitations

In Chapter 2, the case is divided into four parts: the techno-economic, the socio-economic, the political and the socio-cultural subsystems. Though I recognise that this segmentation is only possible in theory, and that in reality the boundaries of these four dimensions are diffuse, the decision to make this segmentation resulted from the necessity to perform a more in-depth analysis of each of these dimensions.

The analysis of the MEC is performed within the system boundary of the case. This boundary includes the three bioenergy projects that compose the MEC, their key actors and the material flows that occur within this system. Hence, I adopt a territorial approach and focus on the administrative district Radkersburg, which includes the location and most of the key actors of the case.

Some findings of the study may be applicable to other regions of the world, but, as with all industrial ecosystems, the project in Mureck has very specific characteristics, even in an Austrian context. Therefore a generally valid recipe for success does not exist and trying to simply replicate the system in another context cannot guarantee any success.

Section 3.3, concerning the political subsystem, integrates a specific theory of the policy process. While I believe that this theory can provide valuable insights for the understanding of the MEC case, I am aware that my analysis is limited to rather general facts that have come to my attention during the interviews or from the review of relevant literature and of archival materials.

Section 3.4 uses ecological theory to explain the socio-cultural transformation process in the region. It adopts a unilateral perspective for explaining how farmers in Radkersburg were affected by the turbulent changes that took place within their environment. The reciprocal influence that these farmers had upon their competitors is not an objective of this study.

Last but not least it should be stressed that a detailed quantification of social, economic or ecological benefits falls beyond the scope of this paper.

1.5 Outline

Chapter 2 introduces the reader to the Mureck bio-Energy Cycle, offering a general picture of the case. In Chapter 3 the attention is shifted from the holistic perspective towards the conceptualisation of the case. For this, the case is decomposed along four dimensions (techno-economic, socio-economic, political and socio-cultural), each containing certain embedded elements for analysis, as shown in *figure 1-1*. Chapter 4 aims at developing a better case understanding by synthesising the insights obtained from each analysed subsystem and by presenting the concluding remarks, along with suggestions for further research.

DEFINITIONS

Bioenergy is the energy made available by the combustion of organic materials (biomass) such as wood and other plant matter (Kartha, 2000, 9).

Bioenergy systems are systems for the generation of useful energy from biomass; they consist of biofuel resources, supply systems, conversion technologies, and energy demands (Sims, 2002).

Biodiesel designates the production of methyl esters (ME) through a chemical process (transesterification) based on the reaction of a vegetable oil, used frying oil or waste animal fat, with methanol and a potassium hydroxide catalyst (Biofuels for Transport, 2004, 33).

- Vegetable oil is derived from oilseed crops (such as soy, rapeseed, sunflower, etc.) and leads to the production of rapeseed methyl ester (RME).
- Used frying oil (UFO) and animal fat generate 'used frying oil-methyl ester' (UFO-ME).

Biodiesel is free for use in standard diesel engines after replacing seals and fuel lines with biodiesel-persistent materials. RME can be used all year round, but UFO-ME *cannot* be used in pure form during cold periods due to its higher gelling temperature (around 0 ^{o}C).

Biofuels are any gaseous, liquid or solid fuels that contain energy and that derive from a biological source. Biofuels include ethanol, biodiesel, and methanol (Food and Agriculture Organization, 2005).

Biogas is a mixture of about 60% methane and 40% carbon dioxide, resulting from the anaerobic fermentation (digestion) of organic substances (such as liquid manure, sullage, plants, food leftovers, etc.) under the influence of bacteria. Biogas can be used by households, farms or municipalities as an energy carrier in a series of applications, ranging from the generation of heat, to the production of electricity or in the transportation sector (Miller, 2004, 404; Biofuels for Transport. An International Perspective, 2004, 44).

Biomass is an energy resource derived from organic matter, such as wood, agricultural waste, algae, other living-cell material, sewage and further organic substances that can be used to produce energy (US Department of Energy, 2005).

'Green' electricity designates the electricity produced from renewable energy sources.

Methanol is an alcohol obtained primarily from natural gas. At higher costs, methanol can also be produced from wood, wood wastes, agricultural wastes, sewage sludge, garbage and coal (Miller, 2004, 405).

Renewable energy designates the energy generated from renewable sources, such as hydro, biomass, solar, wind or geothermal energy.

Transesterification is the production process of biodiesel, during which a vegetable oil is mixed with an alcohol and a catalyst, resulting in the removal of glycerin from the vegetable oil to make the oil thinner. The products of the reaction are alkyl esters (biodiesel) and glycerin (Pahl, 2005, 32).

2 Case prospects and history

The Mureck bio-Energy Cycle (MEC) is a network of three distinct bioenergy projects – SEEG[5], Nahwärme and Ökostrom. These projects are operated in a closed-loop scheme and generate biodiesel, district heating and 'green' electricity that are derived mainly from regional resources. Biodiesel obtained from SEEG is used both locally and regionally. The majority is utilised by members of the cooperative and by the public transport sector in cities such as Graz and Bruck. The beneficiary of heating from the biomass district heating plant Nahwärme is the town of Mureck and its neighbouring settlements. The 'green' electricity generated by the biogas plant Ökostrom is fed directly into the grid.

2.1 Location

Mureck is a small town of about 1 700 people, situated in the south-eastern part of the Austrian province Styria, right on the border with Slovenia (see *figure 2-1*). The town is approximately 60 km south of Graz and is easily accessible by taking the A9 highway coming from Slovenia.

Mureck is integrated in the wider Radkersburg district – the borderland to Slovenia. The area is one of Austria's most agriculture-intensive regions. It is endowed with vast, fertile agricultural lands, which are used mostly for the cultivation of maize. In spite of the continuous restructuring of the rural economy, a large number of people are still employed in the agricultural sector.[6] However, their number is falling.

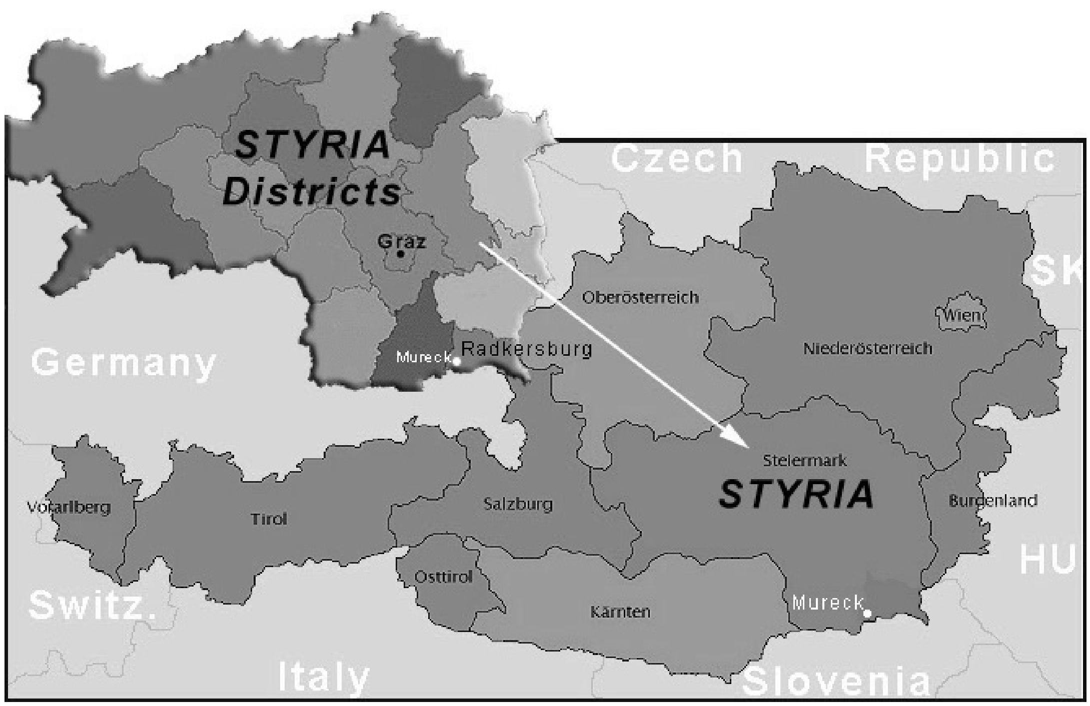

Figure 2-1 Map of Austria with Province of Styria

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[5] Südsteirische Energie- und Eiweißerzeugungsgenossenschaft

[6] See Section 3.4 on the socio-cultural subsystem.

2.2 Drivers, developers and philosophy

Austrian drivers for bioenergy projects in the agricultural setting

According to the literature, general drivers behind the development process of bioenergy projects in Austria were problems generated by *surplus agricultural production* on the international markets, *deterioration of incomes* for farmers, increased *environmental awareness*, and amelioration of *crop rotation* and *diversification* of the product range (Farar, Maurer, Preissl, Roediger-Schluga, Seubert, 1998, 26). In addition, the oil crisis of the 1970s, correlated to the country's high energy import dependency is seen as a further important driver behind the establishment of biodiesel plants in Austria (Pahl, 2005; REACT, 2004). While mentioned at this point in order to convey a general picture for the reader, the effects of these drivers are described under Section 3.3 and Section 3.4, in the political and in the socio-cultural subsystem respectively.

Developers and philosophy

The origin of the MEC can be traced back to 1985, when three local farmers envisioned the establishment of a new form of cyclical farming that would enable them to "produce their own food for their own beasts of burden – i.e. tractors" (Bio-energy Cycle Mureck. Sustainability report 2004, 2005, 3). This *cyclical farming* should help them to "become independent from the world market and all its risks, by meeting [their] personal requirements with raw materials from the local region" (Bio-energy Cycle Mureck, 2005, 4).

Karl Totter, chairperson of the SEEG, is one of these three farmers and also the motor of the initiative. His worldview as a farmer can be traced in his reasoning: "In former times large areas [of land] were needed to produce feed for draught animals. Why don't we utilise our fields to create feed for the new draught animals, the tractors?"[7] Prior to devoting himself to bioenergy, Totter was known and respected by farmers as leader of the local pig breeders. A former pig breeder in Deutsch Goritz explains that people have a lot of trust in Totter: "That's why we followed him in the cooperative. He is a fighter. Otherwise he would not have made it so far!" (Tischler Senior, 2005).[8] Moreover, almost all respondents who were asked to name key drivers of the MEC have started by mentioning Totter and his incredible energy. Since 1985 Totter has pursued his vision with great tenacity and has become the central figure of the MEC. Today Totter is an emblematic figure of the Mureck community.

Motivation

The vision is ultimately rooted in the 1973 oil crisis and its deep psychological impact on public life in Austria – a country with a high energy import dependency. In fact, the crisis had been felt so strongly that already the same year the Ministry for Agriculture initiated a research program that aimed at finding ways for securing domestic liquid fuels supply from renewable resources (REACT, 2004). As Totter (2005) explains, the oil crisis has convinced him that local systems, based on the principle of self-sufficiency, were a precondition for security. With this in mind, Totter first established a local biodiesel plant – SEEG – in 1991. Some years later, realising the opportunity offered by the availability of large wood resources in the region, Totter established a biomass district heating plant for the city of Mureck. Nahwärme, the local district heating plant, exploits the abundant wood resources and improves heating conditions in the city. Finally, the more recent decision to establish a third bioenergy project in Mureck (that is, the biogas plant Ökostrom) has taken into account a variety of factors, including local abundance of raw materials, guaranteed feed-in tariffs for 'green' electricity, the need to find a

[7] "Früher hat man große Flächen gebraucht, um Futter für die Zugtiere zu gewinnen. Warum setzen wir nicht unsere Felder ein, um Futter für die neuen Zugtiere, die Traktoren zu gewinnen." (Gib Biosprit in deinen Tank, 2005).

[8] Deswegen sind wir ihm gefolgt in der Genossenschaft. Er ist ein Kaempfer. Sonst waere er nicht so weit gekommen. (Interview Tischler senior).

suitable application for the glycerine from biodiesel production and the opportunity to replace the uneconomical deployment of Nahwärme during hot summer months.

2.3 Targets

The philosophy of Totter, who aspired to create a profitable circular process for the generation of vital resources in the region, essentially formed the mission statement. He started by asking himself "Why don't we find an economic system that brings us more security, that triggers advances in terms of ecological benefits and that will actually bring us forward in the right direction from a socio-political point of view?" (Totter, 2005).[9] The answers to this question were actually Totter's *targets*: "to become more self-reliant, more independent, to farm according to natural cycles and for the well-being of everybody within the region."[10]

2.4 History

Having heard of a bench-scale process for the production of biodiesel from rapeseed[11] that was tested by the Institute of Organic Chemistry at the University of Graz, in 1985 Totter contacted the University to inquire about the process. As the laboratory-scale tests had been completed and a larger supply of biodiesel for additional tests in a real-world setting was needed, the researchers were interested in viable partners that would help them to continue the research in a pilot project. Moreover, participation of farmers was seen as a core element, given the goal of the research – to enable farmers to "grow and use their own fuel and be independent from the fluctuations in the international market" (Pahl, 2005, 33) – but also the main resource (rapeseed) and the agricultural co-product (rapeseed cake – a protein feed for animals) of the process. Farmers would learn to cultivate rapeseed, produce biodiesel and test it with their tractors. Additionally, they could use the rapeseed cake as a protein feed for animals. For Totter the cooperation was seen as a sustainable way of producing his fuel, which entailed the potential to fulfil his vision. Moreover, rapeseed was a welcome plant in a broader crop rotation.

In 1986 the proposal received full support from the provincial government and the pilot project was started by the Institute of Organic Chemistry in cooperation with the Weinbauschule Silberberg. During an informative meeting regional farmers were told about the project and a large number of farmers agreed to participate. The first rapeseed was harvested in June 1987 from a 30 hectare plot. One month later, the first pilot plant worldwide for production of rapeseed methyl ester (RME), "constructed by [farmers] and the blacksmith of the village under the supervision of the agricultural college teacher [in Silberberg] after the instructions of the IOC", produced the first biodiesel (Totter, 2005). Nevertheless, when standing before the task of doing the field tests, many farmers became reluctant, fearing that the biofuel would damage their tractors. In the end there were about ten or twenty farmers who agreed to carry out the tests (Pahl, 2005, 34). Totter was also among these farmers. He remained fully committed to his vision and over time developed a very close cooperation with the scientists. After undergoing trials at the agricultural college in Silberberg from 1987 to 1989, Totter decided to found a cooperative for the production of biodiesel, based on the idea of cyclical farming.

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[9] Und warum machen wir nicht eine Wirtschaftsweise, die uns mehr Sicherheit bietet, die uns oekologisch um einiges vorwaerts bringt, und die bloss uns auch gesellschaftspolitisch um einiges vorwaerts bringt in die richtige Richtung

[10] ...dass wir selbststaendiger werden, unabhaengiger werden, im Kreislauf der Natur bewirtschaften und zum Wohle aller in der jeweiligen Region

[11] See Definitions/*Transesterification*.

When in 1991 the construction of the SEEG was completed, it was one of Austria's first commercial biodiesel plants to enter into operation. The initial investment, covered to a large extent by Styrian authorities, amounted to 6.15 m Euro. One year before, in 1990, major tractor manufacturers such as John Deere, Ford, Massey-Ferguson or Mercedes had offered a strong support to biodiesel production by issuing engine warranties for biodiesel use. Until 1995, the production capacity of SEEG was of approximately 500 tons of biodiesel per year, produced entirely from rapeseed. SEEG is organised as a farmers' cooperative. In the beginning it had about 300 members, while currently their number has risen to almost 600.[12] The system allows farmers to remain owners of their products throughout the entire process. Under the motto "From the field to the tank"[13], farmers grow as much rapeseed as needed to cover their own energy and protein needs. For besides biodiesel, from the production process farmers also receive the valuable rapeseed cake that serves as a protein feed for livestock (cattle and pig breeding).

Both the limited supply of rapeseed (due to declining set-aside percentages in the EU) and the consequent increase of its price triggers intensive searches for cheap raw materials in Mureck (Mittelbach, 2004). Based on the very good cooperation with the scientists, in 1992 the IOC and the Technical University of Graz for the first time produce biodiesel[14] out of used frying oils (UFO) in Mureck. Two years later, in 1994, the production of biodiesel from UFO is launched officially in Mureck and SEEG becomes the first producer worldwide of biodiesel from used frying oils, under the motto "From the frying pan to the tank".[15] For that, the plant expanded its production capacity to 3 000 tons of biodiesel and launched a complex system for the collection of used frying oils from restaurants and households. Municipalities can join the system by collecting used frying oil, for which they in return receive biodiesel. In 1994, the city of Graz for the first time adapted two city busses for the use of biodiesel of type UFO-ME. One year later, in 1995, ten city buses in Graz are already running with 100% UFO-ME.

While biodiesel produced before 1995 fulfils the existing Austrian biodiesel norm (ÖNORM C1190) without problems, the introduction of a new biodiesel norm (ÖNORM C1191) in 1995 triggers a series of technical problems in motors.[16] The new norm requires biodiesel to have a much higher flashpoint (110^{0}C in contrast to the initial 55^{0}C). As a consequence, in a first stage biodiesel is adapted to fulfil only this flashpoint-condition. Nevertheless, the combustion at such high temperatures produces a high degree of pollution with impurities (of up to 100 ppm), causing the clogging of various parts of the motors. Accumulating during two consecutive years, these serious problems have generated a negative image for biodiesel. Unfortunately, this negative image still prevails to a large extent today (Totter, 2005; Konrad, 2005), although from a scientific perspective the present fears are not grounded (Pahl, 2005; Biofuels for Transport, 2004).

In 1997 researchers from the University of Graz solved these problems by lowering the pollution level of biodiesel. By 1998 a new biodiesel norm was being introduced in Austria

[12] According to the plant's deployers SEEG has approximately 580 members: approximately 260 are local or regional farmers that cultivate rapeseed as members of the SEEG, while the rest are communities, restaurants or further organisations involved in the collection of used frying oil.

[13] Von dem Acker in dem Tank

[14] used frying oil methyl ester (UFO-ME)

[15] Von der Pfanne in dem Tank

[16] Impurities from the production process are the main reason for the sticking phenomena that would clog injection pumps (Styrian material flow management network, 2005).

(DIN 51606), which, in addition to the previous norm, set the degree of pollution (impurities) at a maximum 20 ppm (mg/kg).

The year 1998 marked the construction of the second bioenergy project in Mureck: the biomass district heating plant Nahwärme. The legal form of Nahwärme Mureck is a limited liability company, to which SEEG holds a share of 42%, while 58% belong to two local partners. The investment costs at that time represented about 7.20 m Euro, the plant received a financial aid from authorities of almost 50% (see table 3-6). The idea of constructing the plant had appeared back in 1995, when a study on the area Radkersburg showed that while the region relied mostly on fossil fuels for heating, it possessed sufficient biomass resources that could be used instead (Totter, 2001, 46). "As we had the energy carrier – vegetable oil – we thought that it could be used [together with biomass] for the production of heat and power in a cogeneration plant. The combination seemed fine", says Totter, the chairman of SEEG. In the same year he started an information campaign in Mureck, presenting the benefits of biomass for district heating and 'green' power generation with the slogan "A city meditates – a city rethinks!" The discussions were open and involved all concerned parties. "We are doing something for the city, we create added value in the region, we are offering security, comfort – for the environment it surely is better", were Totter's arguments, and they definitely bore fruits. After about three years he had earned the confidence of all four fractions in the municipal council, along with contracts closed in advance for heating services for the public buildings in Mureck. When the plant was put into operation in 1998, a connection rate of 50% was achieved. This, in spite of record low oil prices that required customers to pay an additional 25% conversion cost over a conventional oil-fired heating system (Bio-energy Cycle Mureck, 2005, 27). Today, Nahwärme operates two 2-MW heating furnaces which supplies heat to about 80% of all objects in Mureck and the surrounding area. The plant is located in the immediate proximity of the SEEG. The total length of the network is of about 12 km. Totter's objective is to reach a 100% supply of the town.

Aiming to also generate power, Nahwärme ran tests for about two years with a prototype motor based on glycerine from the production of biodiesel. As the experiment failed, in 2000 the decision was taken to construct a biogas plant for electricity generation. During the same year the production capacity of the biodiesel plant SEEG was raised to 4 000 tons of biodiesel per year, due to the high success of the collection system for used frying oils.

In 2001 the city of Graz decided to operate 40 more city busses with 100% UFO-ME, raising the total number of biodiesel-run busses to 55 (one half of the whole fleet). In the same year, Totter won the World Energy Globe Award, as recognition for his achievements with biodiesel from used frying oil, and for presenting his innovative concept on the Mureck bio-Energy Cycle.

One year later, in 2002, the production capacity of the biodiesel plant was increased by 1 000 tons to a total of 5 000 tons biodiesel per year. During the same year, tests for processing of waste animal fat into biodiesel were started in cooperation with researchers from the Graz University.

In 2004 the production capacity of SEEG, the biodiesel plant, was raised to 7 000 tons. This year marks also the starting date at the construction of the biogas plant Ökostrom. The investment costs for Ökostrom were about 5.40 m Euro. The plant was organised as a limited liability company, to which Nahwärme and seven other farmers act as partners. Totalling an output of 1 MW that can generate some 8 000 MWh of 'green' electricity per year[17], Ökostrom became operational in May 2005.

For 2006 a further expansion at SEEG is planned, which will raise the production capacity of the plant to 10 000 tons biodiesel a year. The works have already started.

Timeline	1987	1990	1992	1994	1995	1998	2000	2001	2002	2004	2005
SEEG expands to 10 000 t BD/year											◈
BoKu Vienna-University researches the effects of glycerine in biogas manure										x	
Ökostrom is constructed										⦿	
SEEG expands to 7 000 t BD/year										◈	
Graz University tests UFO-ME from animal fat at SEEG									x		
SEEG expands to 5 000 t BD/year									◈		
Graz runs 55 city busses with UFO-ME								x			
SEEG expands to 4 000 t BD/year							◈				
Nahwärme's attempts to valorise glycerine fail; Consideration of a biogas plant							▣ ◈				
Nahwärme is constructed						▣					
Graz runs 10 city busses with UFO-ME					x						
SEEG expands from 500 t to 3 000 t BD/year					◈						
Graz tests UFO-ME in two city busses				x							
SEEG launches UFO-ME production				◈							
IOC tests UFO-ME at SEEG			x								
Construction of SEEG		◈									
Pilot Phase in Silberberg	x										

x Indicates an important support by authorities or research institutions

◈ Indicates the establishment or an important change at SEEG

▣ Indicates the establishment or an important change at Nahwärme

⦿ Indicates the establishment or an important change to Ökostrom

Table 2-1 Timeline of Mureck bio-Energy Cycle

[17] Estimated to the annual consumption of about 7,700 people (Bio-energy Cycle Mureck, 2005, 29).

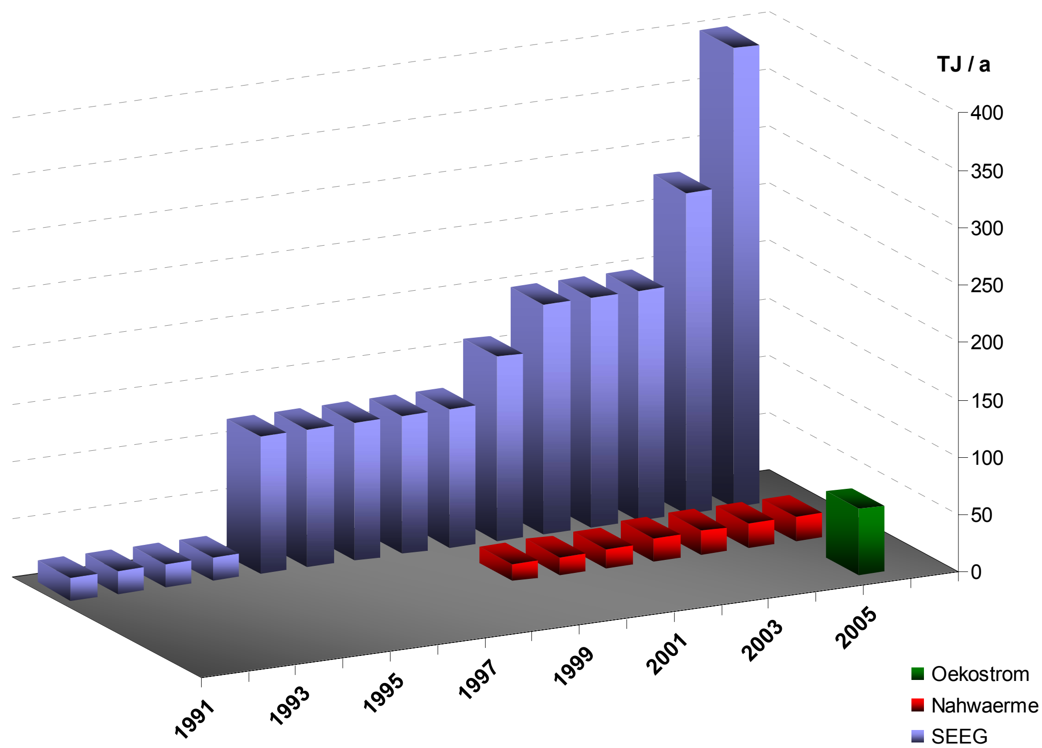

Figure 2-2 Establishment of bioenergy projects and raise of production capacity (in terms of Joules per year)

3 Segmentation and analysis

In this chapter the MEC is divided into four subsystems in order to perform a more in-depth analysis of the specific techno-economic, socio-economic, political and socio-cultural aspects of the case. First, the techno-economic subsystem shows how the MEC and its immediate stakeholders – the developers – benefit significantly from the integrated deployment of three different bioenergy projects. Second, the socio-economic dimension expands the analysis of benefits to the larger stakeholder groups of the project and presents information that can contribute to an understanding of the role played by the MEC in the local community. Third, recognising the role of public authorities as drivers of bioenergy projects, the analysis is directed towards the political dimension in order to gain insights over how and why authorities have contributed to the realisation of the MEC. Fourth, the final section performs an analysis of the socio-cultural context within which the case is embedded, and tries to explain how the project could emerge in this context.

Each subsystem ends with a *synthesis* that aims to provide important general insights, often derived from the application of relevant theories to the researched subsystem. This perhaps less typical approach to theory integration is more common in embedded case studies (Scholz and Tietje, 2002); it was preferred in this thesis since it did not disconnect the theories from the context, rendering them more meaningful to the reader.

3.1 Techno-economic subsystem

Contributing significantly to the success of the MEC, the techno-economic subsystem basically aims to analyse and explain *how* the three technologies composing the MEC have evolved and *how* they are operated at present. However, an in-depth analysis of each individual bioenergy project in Mureck is beyond the goal of this section, given that the strength of each project roots in the integrated, closed-loop deployment within the larger frame of the MEC. Instead, a perspective at system-level seems to be more useful for understanding the case in its complexity. For that, this section researches the benefits that the MEC case derives from its unique architecture and from the distinct way in that it can be operated. It focuses on both – the pressure towards cooperation exerted by SEEG out of necessity to valorise its by-product, glycerine, and the gradual evolution of this cooperation up to the present, where the three projects are sharing a large part of their resources, such as materials, technologies, people or relationships. Subsequently, this close cooperation is analysed from a theoretical perspective within the *synthesis*-part of the techno-economic subsystem.

An overview of the parameters of each conversion technology has been given in Appendix I and II.

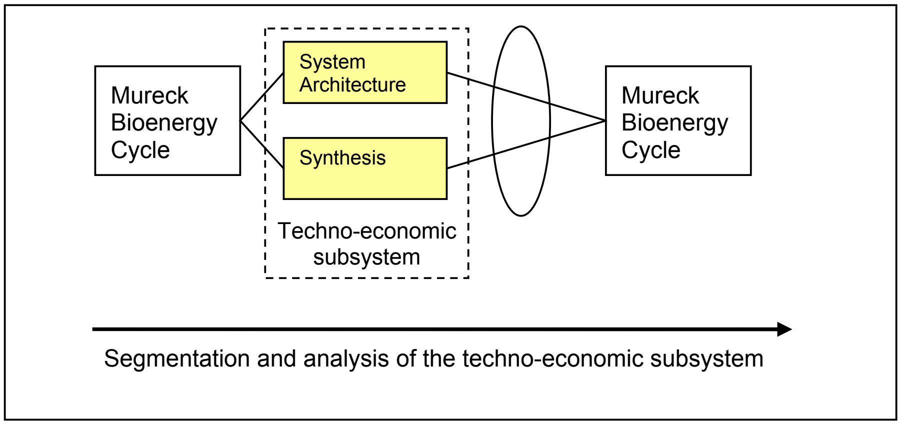

Figure 3-1 Techno-economic subsystem of the MEC

3.1.1 System Architecture

The Mureck bio-Energy Cycle is based on three different conversion technologies: a biodiesel plant (SEEG), a biomass district heating plant (Nahwärme) and a recently inaugurated biogas plant (Ökostrom). Separated from the MEC, each technology impresses through its innovative character, the efficient use of renewable resources and the energy services provided. Nevertheless, their most distinctive feature is their 'roundput deployment'[18], which allows a technology to use as feedstock industrial by-products generated by another technology. In turn, this enables thermodynamically efficient energy utilisation within the whole system. This has not always been the case: as shown in *figure 2-2*, in 1991 SEEG was the first-established bioenergy project in Mureck. The small initial size of the plant (producing about 500 tons of biodiesel in a year) would generate a fairly small amount of glycerine[19], its valorisation not being an urgent demand for the plant's operators. But when in 1995 the plant's capacity shot up with 500% (and reached 3 000 tons of biodiesel) due to the production of UFO-ME, so did the amount of glycerine, pressing the operators to search for a valorisation option for their by-product. This challenge formed the starting point and basis of the strategic cooperation between SEEG and Nahwärme and that subsequently included also Ökostrom, leading to the formation of the Mureck bio-Energy Cycle. Over time, additional ties were established with further stakeholder groups, including farmers in the region, the city of Mureck and neighbouring communities. All these actors may participate in the MEC system as members of the biodiesel cooperative, as suppliers of raw materials or as receivers of energy services. Their role is further assessed in Section 3.2, on the socio-economic subsystem.

The central part of the MEC is the biodiesel plant, SEEG[20], which is organised as a farmers' cooperative. With a current production capacity of 7 000 tons, the plant produces biodiesel both from rapeseed (RME) and from used frying oil (UFO-ME), of EN 14214 quality.[21] As highlighted above, a considerable amount of glycerine results as a by-product in the

[18] According to Korhonen (2004, 41), the "concept of roundput" (as opposed to "throughput") is applicable to systems, the operation of which is achieved based on recycling of matter, cascading of energy and sustainable use of renewable natural resources.

[19] Glycerine has a large application as a valuable product in the chemical industry, i.e. for the fabrication of cosmetics, medicines and food. Nevertheless, since in many cases the market for glycerine use is limited, biodiesel plants can have a problem with capitalising on this valuable product (Biofuels for Transportation, 2004, 33).

[20] SEEG - the South Styrian Cooperative for Energy and Protein Production

[21] European Biodiesel Fuel Standard

transesterification process. Nahwärme, the BMDH plant, benefits to some extent from this by-product: given its calorific value and attractive price, glycerine is used to improve burning conditions in the two boilers operated by Nahwärme. At the time being, the remaining quantity of this by-product is sent to biogas plants in the region, other than Ökostrom.[22] Nevertheless, starting with 2006, one third of the total glycerine volume resulting in the transesterification process will be used by the biogas plant Ökostrom. This application will increase the efficiency of the biogas plant by approximately one fourth[23], adding at the same time value to the fertilizer that results as a by-product in the process. Research that is carried out for Ökostrom by the University of Natural Resources and Applied Life Sciences (BOKU) in Vienna suggests that the addition of glycerine to the fermentation process turns the final biogas manure into a stand-alone fertilizer that can replace mineral-based fertilizers (Bio-energy Cycle Mureck, 2005, 29). The measure entails significant profits for the biodiesel plant too, not least due to savings on transportation costs and on time that is currently spent to find customers for this by-product.

In contrast to more common biogas plants, Ökostrom employs a complex biological fermentation process (see Annex II) that is initiated in a hydrolysis container to which glycerine will be added in future. The hydrolysis container requires a constant temperature of about 40°C, while temperature fluctuations can damage especially the methane-producing bacteria. Although the fermentation process is exothermic and generates heat, the hydrolysis container needs to be heated during colder days. The plant is equipped with a combined heat and power (CHP) motor for the generation of 'green' electricity. This motor produces enough heat for the hydrolysis process. Yet, as a security-measure to guarantee continuous heat supply to the hydrolysis unit even when the CHP motor is switched off (for instance due to strong storms that affect the generator, service activities or insufficient biogas supply due to previous fluctuations in the fermentation process, etc.), Ökostrom can be supplied with heat directly by Nahwärme. Thus, while the biogas plant has found a reliable heat-supplier in Nahwärme, this application increases the operation efficiency of the BMDH plant. Within the larger system the efficiency of energy utilisation increases.

Maybe the most important reciprocal benefit for Nahwärme and Ökostrom resides in their cyclical operation as heat suppliers of the Mureck community. As a district heating plant, Nahwärme is designed to be operated in a heat-guided mode – that is, heat is produced to match the demand of its more than 250 customers. Thus, its total capacity has been determined by the maximum heat demand on the coldest winter days in Mureck. As a consequence, Nahwärme, similar to other heating and cogeneration plants, is faced with insufficient heat sinks during hot summer months. Yet, since heat is needed in Mureck even during summer for producing hot water, Nahwärme must be operated, though at a low load factor. Even though during summer the plant would normally operate only one of its two 2 MW boilers, the low load factor would lead to a very low efficiency, rendering the operation quite uneconomical for Nahwärme. However, this shortcoming was solved through close cooperation with Ökostrom: from April to September Ökostrom switches roles with the biomass plant, supplying heat to the grid from its CHP motor. To make this application feasible, the plants are connected with a piping system and Nahwärme continues to look after the district heating grid. Thus, the links between Nahwärme and Ökostrom not only aim at improving the digestion control of the biogas plant, but also at raising the general efficiency of

[22] This is so because (1) more time is needed to stabilise the biological process in the recently commissioned biogas plant in Mureck, and (2) so far glycerine is not an officially authorised input material for 'green' electricity plants that receive the highest feed-in tariff, as in the case of Ökostrom. However, it is expected that the upcoming amendment of the legislation will regulate the use of glycerine in biogas plants.

[23] According to the deployers, it will raise the total gas yields with some 25%.

each bioenergy project: while the cyclical deployment generates substantial savings for Nahwärme by raising the overall efficiency of the plant, by reducing the year-round consumption of wood chips with more than 30% and by "sparing the plant's boilers", as the deployers put it, for Ökostrom the measure raises the heat-use efficiency to some 85% a year, generating additional income. Within the larger MEC system this measure triggers a *positive feedback loop:* the relatively cheap price that households in Mureck and its vicinity have to pay for their heat has increased the connection rate to the district heating grid, which further allows both plants to operate simultaneously during cold winter months. For the MEC as a whole, this deployment scheme has once again raised its overall energy efficiency.

The close cooperation of the projects, as well as their geographic proximity, entail additional benefits for each of them, and also for the MEC. For instance, Nahwärme is equipped with an emergency power generator (140 kW), to which both Ökostrom and SEEG are connected. The generator runs on biodiesel, which is supplied directly by the neighbouring SEEG. Given the reliable source of fuel, this measure increases the autonomy of and confidence in the device, while representing for all three bioenergy projects the most simple and cost-efficient alternative to securing their emergency power supply.

Another important benefit results from the joint use of machines and sharing of premises: not only do the three units jointly operate a tractor, a large scale and some smaller machines on the common site, but they also pool the cars in a common car fleet. One common building (heated by Nahwärme) serves as headquarter for all the three projects. The offices are integrated to the extent that they are using a single call centre and telephone exchange, and that they partly run the same software programs. Missing feedback with regard to the processes and within the close-loop deployment is hardly a problem. In fact, the two companies and the cooperative are "connected both physically and spiritually", as Totter (2005), their founder and Chairperson at SEEG explains: the employees cooperate strongly, working regularly together and complementing each other whenever it is needed. According to the operators, the resulting synergistic effects are so great, that squeezing all three structures into one single unit would not yield additional savings or benefits to the whole. To the contrary, says Totter (2005): "had we implemented only one structure, that structure would have probably become too large, too unmanageable. And this we wanted to avoid. Our philosophy is *small*, *manageable units, each motivated to be better than the other*, and this was our guiding thought when we opted for these structures. Besides, small, manageable units are substantially more efficient than a large hierarchy".

There are, however, also weaknesses resulting from this architecture. Namely, by choosing to locate all three plants at the same site, Nahwärme had to develop a longer heating grid (12.5 km), given the fact that the site is situated outside the community. This fact slightly affects the efficiency of the plant. The same is applicable to Ökostrom, where longer transportation distances have resulted for the transportation of maize and liquid manure, due to the chosen location next to SEEG and Nahwärme. Nevertheless, deployers of both plants strongly agree that the benefits and complementarities that result from the current architecture significantly outweigh these few disadvantages.

	SEEG	**Nahwärme**	**Ökostrom**
Founding:	1989	1998	2003
Legal form:	Farmers' cooperative	Ltd. Company	Ltd. company
Type of partners:	Farmers, communities, local authorities, manufacturing companies, waste disposal federations	SEEG, two farmers	Nahwärme, seven farmers
Number of partners:	580	3	8
Date of construction:	1990	1998	2004
Commissio-ning date:	1991	1998	2005
Production:	Biodiesel	District heating	Biogas, Electricity, Heat
Production capacity:	7 000 tons (under expansion to 10 000 tons)	7 500 MWh	2.2 M m^3 CH_4 1 MW_{el} 1.165 MW_t
Resources:	Rapeseed, UFO, Animal fat	Wood chips, Glycerine	Liquid Manure, Renewable vegetable raw materials (maize), Glycerine
Employees	14	1.5	1.5
Customers	approx. 650	approx. 250	approx. 2 250

Table 3-1 Mureck bio-Energy Cycle – overview of the projects

3.1.2 Synthesis

In the beginning of this chapter it has been argued that it makes sense to analyse the case as a system instead of performing the analysis of each individual bioenergy project (SEEG, Nahwärme and Ökostrom). This reasoning is continued by showing that the MEC represents a system that functions according to the concept of industrial ecology (IE), and therefore it calls for a system-level perspective (Lifset, 2003, 2; Ehrenfeld and Gertler, 1997, 68). Although the size of the MEC, the number of participating actors and that of established connections are in no way comparable to those of the classical example, the Danish Kalundborg, Mureck probably is an emerging industrial ecosystem.[24]

[24] As the three projects in Mureck represent the energy sector and not different industries, one could argue that Chertow's definition on *industrial symbiosis* (IS – a local application of IE) cannot be fully applied to describe this case. However, since the projects make use of *distinctive* types of feedstock while having *completely* different processes, they are comparable to separate industries in the sense used by Chertow.

> *Industrial symbiosis, as part of the emerging field of industrial ecology, demands resolute attention to the flow of materials and energy through local and regional economies. Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity.* (Chertow, 2000, 313)

For this reason it is believed that Chertow's definition of IS offers too a suitable instrument to explain this case.

Defined for the first time by Frosch and Gallopoulos (1989, 95), the industrial ecosystem is seen as an analogy to the biological ecosystem and represents the transformation of the traditional throughput model of industrial activity into a more sustainable, integrated model characterised by an optimised use of materials and energy, and in which by-products of one process serve as feedstock for another process.

Most industrial ecosystems have evolved gradually, as their actors sought to make the best economic use of their materials, by-products and energy, and/or to find cheaper ways to comply with existing regulations (Ehrenfeld and Gertler, 1997, 69). In other words, firms engaged in symbiotic arrangements and cooperation, exploiting a given geographical space, in order to minimise transaction costs (Pilon and DeBresson, 2003, 23; Desrochers, 2002; Williamson, 1979). While these features are all applicable to Mureck, they did not represent the central motivation of this case. Indeed, the MEC is more than that: it is an evolutionary system driven by a natural ecosystem-vision.

First, already at an early stage SEEG cooperated with Nahwärme in an attempt to develop a CHP motor that would run on SEEG's by-product, glycerine. This application would have been convenient for Nahwärme given the price and the calorific value of glycerine. For SEEG, the measure would have led to better valorisations of its by-product. Even though the development of the motor has failed, currently Nahwärme uses some glycerine as a substitute to more expensive primary materials. Second, the successively raised production capacity of the SEEG (from only 500 tons of biodiesel in 1991 to the foreseen 10 000 tons in 2006) has increased the pressure on the cooperative to find a market outlet for its valuable by-product, glycerine. Seen in connection with a potential valorisation of glycerine, the suggestion of establishing a biogas plant in Mureck was put forward for the first time by SEEG, in 2000 (Totter, 2005). As soon as it has been agreed to construct a biogas plant, an intensive, two-year site-visit-phase of installations all over Europe was started in order to identify technologies that would enable the integration of glycerine as feedstock in the process. The close cooperation between SEEG and Ökostrom was concluded with a benefit for both projects: the use of SEEG's by-product, glycerine, as a catalyst in the fermentation process of Ökostrom. The new technology of Ökostrom is complementing SEEG and Nahwärme, making it possible for all three actors to maximise their working, economic and environmental efficiency. Third, the decision to *co-locate*[25] the projects on the same site "has resulted after many calculations and many financial considerations" as Totter (2005) explains. The location-related, positive externalities within the industrial ecosystem in Mureck range from the deployment by stages of Nahwärme and Ökostrom, to the inter-firm division of labour, the common use of the infrastructure, the pooling of tools and machines and the exchange of valuable information, ideas and management practices between participants.

Studies on existent industrial ecosystems show that participating firms engage in mutual relationships based on their immediate interests, thus, mostly *without a vision at the system level* (Korhonen, von Malmborg, Ehrenfeld, 2004; Korhonen, 2004; Seuring, 2004; Desrochers 2002; Boons and Roome, 2001; Ehrenfeld and Gertler, 1997). However, the strong metaphoric value based on the analogy to bio-geological cycles makes IE "a source of inspiration and creativity in the transformation of management and strategic visions towards a new sustainability culture" (Korhonen et al., 2004, 289). Having a prescriptive dimension[26], IE serves best as a *management philosophy* or mission statement, using nature as a role model or

[25] *Co-location* is a prerequisite for IE (Lowe, 1997).

[26] This issue has triggered numerous debates over the right to make prescriptive suggestions and to derive policy implications from the IE concept. For more details, see for example Korhonen, 2004; Desrochers, 2002; Boons and Roome, 2001.

vision to move society towards a new sustainability culture (Seuring, 2004, 314; Korhonen et al., 2004, 290; Boons, 2001, 50).

The architecture in Mureck has evolved gradually and path-dependently, while the present structure of the system could neither be foreseen from the beginning, nor designed from scratch. As one informant simply explained, "When the SEEG was founded, we never thought of biogas or district heating. Ten years ago Totter had not even dreamt about these projects [Nahwärme and Ökostrom] being created!"[27] Many of the present forms of synergies and symbioses in Mureck have appeared in changing and evolving circumstances, being seized and exploited *at the right time* by the MEC's deployers. Yet, the evolution of the system has benefited continuously and from the very start from Totter's *natural system vision* & *management philosophy*: "I have been a farmer myself […] and I remember very well when, as a child, […] I collected hay for the draught animals with my father. When the mechanisation began, we abandoned this cycle and confided entirely in technology and energy supply based on fossil fuels. And this has distracted us completely from renewable energy, from the circular flow economy and the closed-loop thinking and the closed-loop acting – we have abandoned it completely and we have simply put too much trust in the fossil fuels. It is high time to return to nature's cycle, if we want to preserve an environment that is worth living in."[28] This philosophy has resulted from a combination of system level bio-ecological cycle and from a regional self-sufficiency and community theme, as discussed in Section 3.4, on the socio-cultural subsystem in Mureck.

The findings from this section are that the MEC has evolved in the direction of an industrial ecosystem guided by the closed-loop philosophy and the broad nature of an ecological vision of its architect – Totter. The increased confidence of the projects' deployers, their excellent cooperation as well as financial considerations – all have driven the successive expansion of the system up until the present dimension. The transformation process for the MEC has not ceased yet. The next objective on the list is to initiate a further cycle that would render the system more self-sufficient: it is planned to replace the commercial methanol, which is currently used for the production of biodiesel, with a bio-methanol obtained by Ökostrom from the surplus of biogas.

The system offers best-practice information especially by showing the important role of industrial ecology as a management philosophy. Yet, attempts to literally copy the MEC in order to establish a similar system in another region are likely to fail, as "[favourable] conditions today, like the ones that existed for the Mureck bio-Energy Cycle, do not exist anymore, because the circumstances have changed" (Puchas, K., 2005).[29] This 'change of circumstances over time' is highlighted within the following sections, particularly in Section 3.3, concerning the political subsystem of the case, and in Section 3.4, concerning the socio-cultural context.

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[27] Wie die SEEG gegründet worden ist, haben wir nicht gedacht, vom Heizwerk oder von Biogasanlage. Der Totter noch vor zehn Jahren hätte nicht geträumt, dass diese Projekte entstehen werden!

[28] Ich bin ein Bauer selbst gewesen [...]und kann mich noch gut erinnern, als ich als Kind [...] dabei war, mit meinem Vater das Futter fuer die Zugpferde zu holen. Wir sind dann mit der Technisierung ausgestiegen, aus diesem Kreislauf, und haben vollstes Vertrauen geschenkt, der Technik, und der Energieversorgung von der Fossilenergie. Und sind voellig weggekommen, von der erneuerbaren Energie, von der Kreislaufwirtschaft und Kreislaufdenken, von dem Kreislaufhandeln – sind wir voellig weggekommen und haben eben zu viel Vertrauen geschenkt der fossilen Energie. Es ist höchste Zeit zum Kreislauf der Natur zurückzukehren, wenn wir eine lebenswerte Umwelt bewahren wollen.

[29] Möglichkeiten heute wie es für den MEC gegeben hat, die kann es nicht mehr geben, weil sich die Rahmenbedingungen auch geändert haben. (Puchas, K., 2005).

Next to the flows of matter, information and energy within the MEC, the actors involved within these flows and their socio-economic system are a key part for understanding the case. Therefore, Chapter 3.2 explores the wider relations between the MEC and its regional actors.

3.2 Socio-economic subsystem

This section is divided in three parts: first, the larger MEC system is presented to the reader. Next, the socio-economic implications of the MEC are discussed. Third, the final part synthesises the most important findings for the socio-economic system.

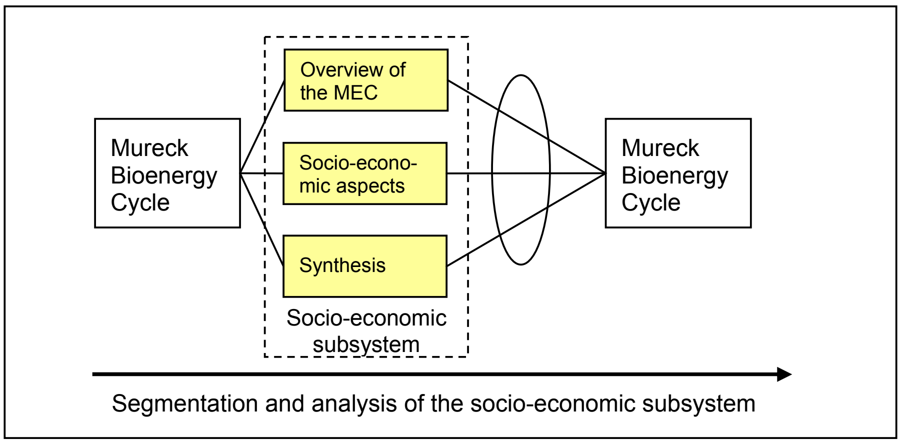

Figure 3-2 Socio-economic subsystem of the MEC

3.2.1 Overview of the larger MEC system

Although the techno-economic subsystem has covered aspects related to the system's structure, it did not include resources and supply networks. Suppliers of the MEC are mostly local actors who harvest and supply the system with renewable resources. Since they are integrated in the local or regional system, their role is presented within this chapter.

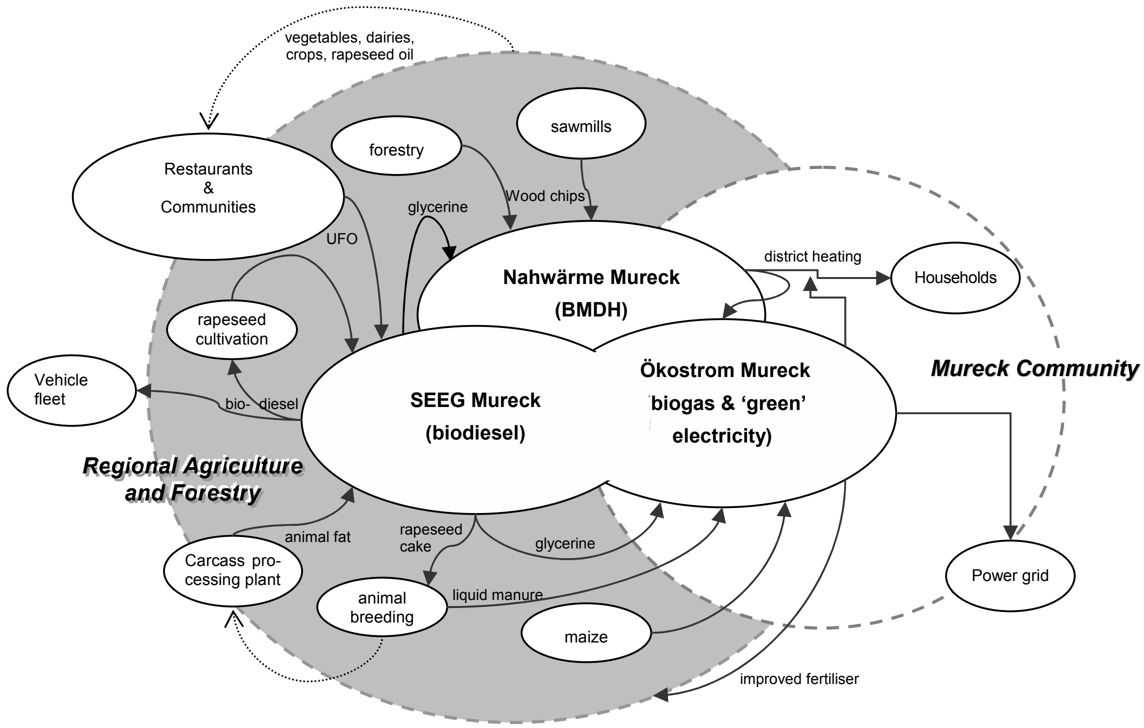

Figure 3-3 Structure of the Mureck bio-Energy Cycle

SEEG Mureck
In Mureck, 15% of the biodiesel is obtained from rapeseed, 70% from used frying oil and another 15% from animal fat.

SEEG is supplied with rapeseed by local farmers, who receive in return biodiesel plus the high-protein rapeseed cake. Some 260 local farmers are currently members of the cooperative, cultivating rapeseed on their set-aside land and processing it into biodiesel in Mureck.

Used frying oil (UFO) is the main resource for biodiesel in Mureck. Accordingly, SEEG has introduced a far-reaching collection system for UFO from restaurants and households.[30] The collection system has an operational catchment area with a radius of approximately 200 km (see *figure 3-4*), yet it reaches out to areas as far as Tyrol, Salzburg, Upper Austria and Carinthia, and it includes some additional municipalities in Slovenia and Hungary (Bio-energy Cycle Mureck, 2005, 23). The system is run through a third company (Neue Energie Niss GmbH), specialised in logistical services for this particular product. The collection is based on the distribution of specially developed 5-litres containers (called "Fatty") to households and small restaurants. When the containers are filled, they are brought to the municipal waste

[30] To some extent a collection system for UFO existed before 1994. For instance, when fresh frying oil was delivered to Austrian restaurants in barrels, many suppliers would automatically take back old barrels together with the used frying oil that the restaurant had collected. The UFO was then used either as a by-feed for animals, or else it was sent to lubricant industries. Nevertheless, the system introduced by SEEG Mureck targets simultaneously restaurants and households. Its success is largely due to the communication strategy, which stresses the environmental benefits of recycling oil. This convinced even Luxembourg to send a tank lorry with about 28,000 litres of UFO to Mureck once a month. On the way back, the lorry has its tanks filled with biodiesel. Whether the benefits of this measure were assessed in a life-cycle analysis is not known to the author.

recycling yard and emptied into a special container that is installed with the agreement of the local authorities. Larger companies and restaurants can use special containers at fixed sites, which are emptied by the collection company, upon request of the customers and free of charge. For example, already in 2002, 550 special collection containers, with a capacity of 1 000 litres each, had been placed at various fixed locations (Mittelbach, 2002, 2). In Mureck, the UFO is turned into biodiesel, at a ratio of 1 kg UFO to 0.85 l biodiesel. In 2004, approximately 6 000 tons of used frying oil and waste animal fat were processed into some 5 100 tons of biodiesel. The waste animal fat (15% of the feedstock) was collected from the carcass-processing plant of Styria, which is situated only 15 km away from Mureck. As a form of payment, participating communities receive biodiesel for use in their own vehicles. More than 100 communities and municipalities, together with numerous companies, restaurants[31] and the public transport operator of Graz are part of this cycle.

Nahwärme Mureck

Approximately 25-30% of the total wood chips needed by Nahwärme are supplied by local farmers from their own forests.[32] The rest[33] is sourced from local and regional sawmills. A small amount of glycerine is obtained from SEEG and incinerated together with the wood chips.

Figure 3-4 Collection systems and average catchment radii. R_1*=200km corresponds to the collection of UFO,* R_2*=25km corresponds to the collection of rapeseed and* R_3*=5-8km corresponds to the collection of resources for Ökostrom (adapted from Bio-energy Cycle Mureck, 2005).*

Ökostrom Mureck

Resources in the processes are maize, green forage and liquid manure from the agricultural sector (in future also glycerine from the biodiesel production). Maize and green forage are

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[31] for example, in Austria all 163 McDonalds participate in the collection system for UFO, which leads to about 1.3 m litres of collected UFO a year. In addition, 17 McDonald's restaurants in Slovenia and 14 in Hungary participate in the collection scheme that supplies SEEG with UFO. (Galle, 2005; SEEG Mureck, 2005).

[32] It corresponds to approximately 2,000 piled meters.

[33] Approximately 9,000 piled meters.

delivered by farmers within a radius of five to eight kilometres.[34] The collection of the liquid manure from animal breeders is organised by Ökostrom with its special machine.

3.2.2 Socio-economic aspects of the MEC

As it results from the previous section, the boundaries of the case are much larger than only the flows of materials, energy and information that occur strictly among the three bioenergy projects. Indeed, the real boundaries of the case ought to account for the large number of MEC stakeholders. Next to the many stakeholders, the land and labour intensity that characterise bioenergy projects in general (Kartha, 2000, 49) justifies the analysis of the socio-economic impacts of this case. Finally, from the perspective of industrial ecology the interaction of the MEC with its local and regional actors deserves particular attention too: the concept of IE focuses on "groups of firms and their stakeholders that interact to achieve sustainable development" (Boons and Berends, 2001, 115).

The socio-economic issues of the case are discussed in relation to four factors: (1) project stakeholders, (2) basic services and income opportunities, (3) development of and added value to the region, and (4) land use competition and conflicting aspects. Kartha (2000, 50) suggests a similar model for assessing the socio-economic impact of bioenergy projects.

Project stakeholders

In theory there are many definitions of stakeholders. Some scholars plead for a broad definition of stakeholders[35], other for a narrow view[36], while a third group suggests the dynamic identification of stakeholders.[37] Clarkson (1995, 106) defines stakeholders as "persons or groups that have, or claim, ownership, rights, or interests in a corporation and its activities, past, present or future". According to his view, stakeholders can be categorised as *primary* stakeholders, who are vital to the survival and wellbeing of the organisation (owners, employees, customers, actors with regulatory authority or other forms of power over the organisation), and *secondary* stakeholders, who influence or are influenced by the organisation, but who are not essential to the organisation's survival.

Figure 3-5 presents a primary stakeholder-framework of the MEC. Some actors have been identified as primary stakeholders based on their direct relation with the MEC (for instance deployers, suppliers, consumers, etc.), while other actors are perceived to be key stakeholders due to their regulatory power over the bioenergy market in general (i.e. Styrian and Austrian authorities). Challenges for stakeholder management arise when (1) secondary stakeholders oppose the project's policies and programs that were adopted to satisfy the needs and expectations of the primary stakeholders, or (2) when one or few stakeholders have excessive power and use it to harm the interests of the others (Conti, 2004; Clarkson, 1995, 107).

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[34] While maize can be transported over distances of 8 km, green forage is usually harvested within an area of 5 km (Interview with Totter Jr.).

[35] A broad definition of stakeholders is given by Freeman according to whom stakeholders are "any group or individual who can affect or is affected by the achievement of the organisation's objectives" (Freeman, 1984).

[36] Authors that support this narrow view advocate for a focus on stakeholders that are vital for the organisation's survival (Freeman and Reed, 1983).

[37] Mitchell and Wood propose a general theoretical model for stakeholder identification, based on three different attributes: power, legitimacy, and urgency (Mitchell, Agle and Wood, 1997).

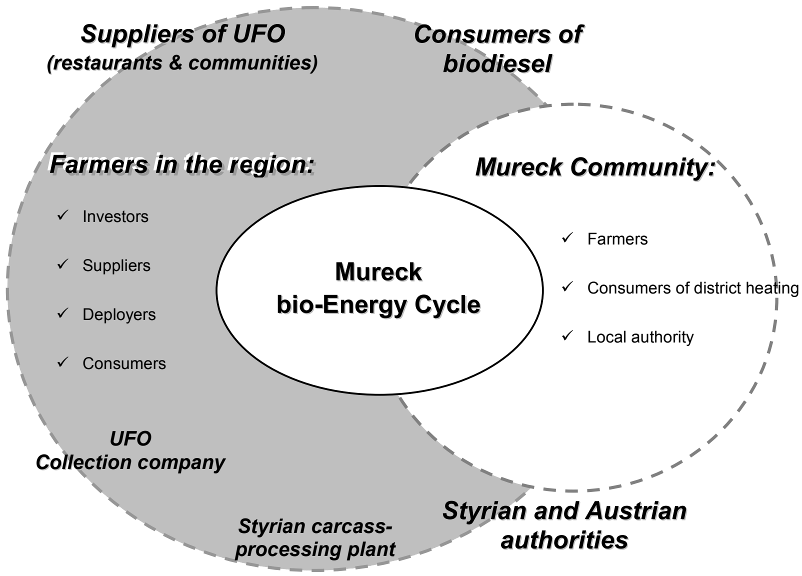

Figure 3-5 Primary stakeholders of the MEC

Based on their geographic proximity to the project it is also possible to group the primary stakeholders of the MEC in (1) local actors (i.e. local farmers, consumers of district heating and authorities in Mureck), (2) regional actors (such as farmers, settlements, restaurants and waste animal fat suppliers in the Radkersburg district) and (3) further actors in Styria and Austria (i.e. more distant communities, consumers of biodiesel, Styrian and Austrian authorities, etc.). This assemblage of actors illustrates that the MEC is basically a *local initiative*.

The natural environment in which the MEC operates represents another primary stakeholder (Driscoll and Starik, 2004; Phillips and Reichart, 2000; Starik, 1995) and it is fully recognised by the project's deployers. On one hand the natural environment is a key service provider, on the other hand it is a source of inspiration that influences the philosophy and mission level of the MEC.

Farmers. Within the group of primary stakeholders it is in particular farmers who benefit from the MEC: the system offers them diversified, reliable and long-term opportunities for income generation and protects them against price fluctuations on the international agricultural market. From a theoretical point, each independent farmer represents a distinct unit that has developed symbiotic relationships within the MEC network. This close cooperation and the sustainable use of natural resources highlights once again that the MEC represents an industrial ecosystem (Korhonen at al., 2004, 291; Korhonen, 2004, 71) that has emerged from an *agricultural setting*. The system was developed by farmers, who, over time, have come to occupy some or all functions ranging from deployers, to suppliers, consumers or owners (see *figure 3-3* and *figure 3-5*).

Developers. In the case of the MEC, the developers are both operators and owners of the projects. Many of them have continued to be farmers and this provides them the opportunity to supply the system directly with their resources. Most developers participated in hopes of improving their financial situation. However, gains in prestige within the local community were also a significant driver. From among the developers Karl Totter emerges as the leader of most initiatives and as a champion of the MEC. His implication was crucial for the implementation of the MEC and his motivation is discussed in relation with the socio-cultural subsystem (Section 3-4).

Residents. The support of local communities is essential in particular for BMDH plants, since these plants are designed to supply the largest possible part of a village. In Mureck, about 80% of all objects are connected to the district heating grid. Prior to Nahwärme, heating of living spaces was an individually performed task. Most energy systems would run on oil. Although oil-based heating was cheaper at the time when Nahwärme was commissioned, the decision of residents to connect to the district heating plant resulted from the higher comfort offered by district heating, their trust in the plant's local deployers and their understanding of the larger social, economic and environmental benefits.[38] Despite its somewhat higher price compared to individual heating, the good reputation of district heating is a national characteristic that shows that economic considerations are neither a central, nor a consistent motivation for Austrian citizens that have preferred BMDH. (Aktuelle Themen der österreichischen Fernwärmewirtschaft, 2004; Rakos, 1998). In fact, a survey performed by Rakos (1997) among residents has shown that environmental considerations were their top reason for connecting to the BMDH plant (mentioned by 95%). The following most important reasons were convenience (mentioned by 87%), while support of local farmers and local self-sufficiency was the third motivation (mentioned by 75%) (Rakos, 1997).

In Mureck some residents perceive the MEC only as Nahwärme, the plant that supplies their city with heating. However, most interviewed residents see Nahwärme as being a part of the larger MEC. It appears that residents are quite informed about the Mureck bio-Energy Cycle. The events that have been organised recently in relation with the inauguration of Ökostrom offer one part of the explanation, while another part may be the well-preserved informal communication channel within the rural setting, which works 'effectively' as the deployers belong to the regional community.

Authorities. The reliable support offered by local and Styrian authorities was crucial for the establishment and subsequent growth of the system. On one hand, authorities have understood the importance of bioenergy projects for the local economic development. On the other hand, especially since BMDH plants (and renewable energy projects in general) enjoy a positive image among the Austrian public as environmentally sound technologies, authorities have backed up the wish of the local community for a clean environment. The role played by authorities as regulators of the Austrian bioenergy market and their contribution to the realisation of the MEC will be discussed in detail under Section 3.3 on the political subsystem.

Research institutions. From among the secondary stakeholders of the MEC, the partnerships with research institutions deserve particular attention.[39] The projects in Mureck cooperate primarily with academic research institutions, such as the Institute of Chemistry at the University of Graz, the Technical University Graz or the University of Natural Resources and Applied Life Sciences in Vienna.

First of all, SEEG was a natural continuation of the pilot project in Silberberg, developed by the Institute of Organic Chemistry at the University of Graz. As such, SEEG represents a university spin-off. This feature makes it similar to many innovative projects, such as the case

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[38] Austrian citizens have expressed in a referendum their disapproval for generation of nuclear electricity, in spite of the country's high energy import dependency.

[39] Given its crucial role in the development of the MEC, it can be argued that the University of Graz is a primary, not a secondary stakeholder. Yet, in spite of the ongoing cooperation, once could say that at present the University of Graz is a secondary stakeholder, as the technologies used in Mureck are well established and mature.

of a pioneering bioenergy project in Enköping, Sweden, presented by McCormick and Kåberger (2004, 20). Second, the production of biodiesel from UFO, which assures the plant's survival these days[40], was made possible through the close cooperation with the Institute of Organic Chemistry and the Technical University Graz. Third, over time these research institutions offered freely their research potential, constituting literally an ongoing trouble-shooting service for problems related to the production and utilisation of biodiesel. For instance, it was the University of Graz that solved the technical problems related to the combustion of C1191-norm biodiesel in motors (see Chapter 2.4), managing to significantly decrease the combustion-related emissions of impurities to only 20 ppm today. Through that, the university has created a positive image for biodiesel, as it is more environmentally friendly than fossil diesel or gas. Last but not least, the partnership with research institutions has acted as a driver of innovations within the larger industrial ecosystem in Mureck: both Nahwärme and Ökostrom have benefited from top research, which practically facilitated the plants' optimal integration within the MEC. A result was the application of glycerine from SEEG as input material in the fermentation processes of the biogas plant.

Technology suppliers. The implementation of all innovative solutions proposed by the research centres necessitated a strong cooperation with regional technology suppliers. The developers of the MEC have understood this requirement very well and have deliberately pursued a strategic partnership both with the regional R&D centres, and with the technology suppliers: "We have always understood that we – that is, the cooperative here in the region of Mureck – are the 'converters'. Next [to us] there are the creative minds (meaning the know-how of the University of Graz), there is a plant engineer – the company BDI in Graz […], and this way it works out well for all of us"(Totter, 2005).[41]

Stakeholder dialogue. In Mureck communication represents an important factor to initiate dialogue with and to involve various actors in the project. Both informal and formal channels are used. The informal communication channel relies on word of mouth. It is extremely effective and suitable for spreading information, given the small village structure and existing local culture for oral communication. Within the formal communication channel information is distributed mostly through regular meetings, information campaigns of the local authority in Mureck (i.e. for the establishment of the BMDH plant), circular letters sent by the MEC (in particular to local farmers and residents of Mureck) and through the local and regional media. The farmers' regular tables are organised by the Styrian Chamber of Agriculture and represent a traditional means of exchanging information in the region.[42]

A joint marketing department is responsible for the communication with all stakeholders. Used marketing instruments are congresses, symposiums and lectures, often organised in cooperation with the research institutions and technology suppliers. Communication is in particular important for SEEG, since the plant relies heavily on the participation of communities as suppliers of UFO, and on car fleets as consumers of UFO-ME. Therefore, the marketing department has developed a sophisticated marketing strategy for UFO-ME: as regards suppliers, it gives out prizes for communities that have outstanding collection results, and it 'names and shames' communities that lag behind the average collection quota. With

[40] 70% of the total biodiesel produced in Mureck is based on UFO.

[41] Wir haben das immer so verstanden, dass wir, die Genossenschaft hier in der Region von Mureck, die Umsetzer sind. Weiter gibt es die Ideengeber (das Know-How der Universität Graz), es gibt ein Anlagenbauer – die Grazer Firma BDI [...], und so läuft es gut für alle [...].

[42] Recently, regular tables were introduced also for farmers who are running their own biogas plants. Such farmers stated that these meetings provide a good opportunity to connect people and to provide legal, strategic and technical advice to existing deployers.

regard to potential consumers, it targets mostly community services in big cities, big bus and distribution fleets, but also taxi companies and Diesel vehicles in environmentally sensitive areas.

At present, the MEC organises also regular information campaigns in schools, as an effective way to inform … *adults*: "It is very legitimate if the schoolchild returns home and says: 'Mummy, it works like this!' Then mummy or daddy believes it. Yet, if an adult would say [the same], then one does not believe it" (Totter, 2005).[43]

The result of these efforts is an ongoing dialogue process with the project's primary and secondary stakeholders, which helps address the articulated needs of the local community in a superior way.

Basic services and income opportunities

Nahwärme. The MEC provides a wide range of energy services – including many that address the need for local development. For example, Nahwärme provides convenient and reliable district heating to schools, public institutions, businesses and private households in Mureck. In 2004 approximately 250 different customers from Mureck and its neighbourhoods have opted for the district heating services of Nahwärme. According to the plant's deployers, households benefited in terms of increased standard of living (i.e. high convenience of the new system), financial savings (450 EUR per household in 2004[44]), improvement of the local environment (i.e. savings of almost 4 000 tons of CO_2 and of 3.2 tons of SO_2 per year, sustainable management of about 750 ha of forest) and increased prestige (Bio-energy Cycle Mureck, 2005). In addition, the plant generates direct revenues to 23 local forest owners – farmers who are also members of the SEEG cooperative and who welcome the long-term opportunity to sell their forest residues to the district heating plant. Additional value is generated also for the local and regional sawmills and forestry companies that supply wood chips to Nahwärme. As highlighted by another study on bioenergy projects in Austria (Tomescu, 2005, 14), in the absence of BMDH plants sawmills and forestry companies would normally supply their biomass to the large board industry, being forced to accept lower prices due to the powerful bargaining-position of the board industry.

SEEG. The basic service provided by SEEG is the production of biofuels for transportation (along with rapeseed cake as animal feedstock) for local farmers. Since many farmers in the region are also pig breeders, the rapeseed cake enhances for them the prospect of participating as suppliers of rapeseed. About 260 farmers are members of the cooperative and cultivate rapeseed on their set-aside land.[45] In 2004, 400 to 500 hectares were cultivated with rapeseed. For each 1 000 kg of rapeseed brought to SEEG a farmer 'harvests' 380 litres of biodiesel and 620 kg of rapeseed cake.[46] However, the interviews have shown that farmers rarely cultivate more than two hectares with rapeseed due to the relatively small size of their

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[43] "Und es ist ganz legitim, wenn das Schulkind nach hause kommt und sagt: 'Mutti, so funktioniert es, dann glaubt die Mutti oder der Vatie es. Wenn's ein Erwachsener sagt, dann wird's nicht geglaubt."

[44] However, this gain was possible only since fossil fuel prices began to increase in 2002. As a general indicator, the price development of light fuel oil as compared to pellets has been presented in Appendix V.

[45] One hectare of land yields approximately 3,000 kg of rapeseed, which corresponds to approximately 1140 litre of biodiesel and to about 1860 kg of rapeseed cake (Totter, 2005)

[46] While on page 13 the *Bio-energy Cycle Mureck, 2005* indicates that in 2004 400 ha were cultivated with rapeseed, on page 19 the same document states that 800 ha were cultivated with rapeseed, yielding about 1.08 m litres of biodiesel (approximately 2177 kg rapeseed/ha). A quantity of 400 to 500 ha of land cultivated with rapeseed was indicated by the employees of the SEEG during the interviews, being further taken into account in the study.

farms, the higher suitability of maize cultivation in the region, the higher risks of crop damage in the case of rapeseed and ultimately the higher requirement to look after rapeseed.

SEEG is designed as a farmers' cooperative, which allows fulfilling local needs in a better way: it remedies a series of inequities especially for small farmers, who, due to unequal power relations, are often offered lower prices on the market. For this reason Kartha (2000, 54) argues that participation of small farmers in cooperatives is usually more beneficial than if these people could only sell their products on the market. Given the traditionally small size of the Styrian farms (Amt der Steiermärkischen Landesregierung, 2004, 15), small farmers have the chance to do profitable work and to improve their wellbeing especially as members of the cooperative.

A further service of the SEEG is the collection of used frying oil from communities. Initially, households would flush down the drain their used frying oil, contributing to the clogging of the sewage system and causing difficulties for the wastewater treatment facilities. Instead, by participating in the collection system, local authorities may partially decrease a part of the remediation costs of the public sewage system. Simultaneously, communities are entitled to receive biodiesel as a form of payment for their collection efforts. Though the collection of UFO from restaurants all over Austria – and even from Hungary and Slovenia – involves the transportation of the product over relatively long distances, there is still a general benefit for communities and the environment in this measure. Namely, prior to this collection system the UFO had to be sent for processing to the lubricant industry in the Netherlands.[47] This certainly involved longer transportation routes than the distance to Mureck. For SEEG and its deployers UFO represents a valuable input that raises the efficiency of the process compared to biodiesel production from rapeseed. Namely, 1 000 kg of UFO generate 850 litres of biodiesel.

Ökostrom. Ökostrom, the 'green' electricity plant, evolved as a further income opportunity for local and regional farmers, who can now act as suppliers and deployers of the plant. The construction of the plant was preceded by a large information campaign that sought to establish a participatory approach. About 60 farmers participated in the initial talks and were later on invited to join the project. The discussions facilitated both the contact and the exchange of information among participants, leading ultimately to the construction of two *additional* biogas plants in the region. Neighbouring residents were informed and included from the start in the dialogue process, which facilitated the implementation of the plant. To protect nearby residents, Ökostrom has voluntarily installed a bio-filter to lower process-related emissions (mostly odour).

[47] Because of the Bovine Spongiform Encephalopathy (BSE) crisis in Europe the use of UFO and waste animal fat as animal feedstock were restricted in Austria and in most neighbouring states.

Customers and suppliers of the MEC	*SEEG*	*Nahwärme*	*Ökostrom*
over 3 000	**650** • 260 farmers • members of the cooperative • non-member organisations that utilise biodiesel	**274** • 200 households • public institutions • 24 farmers as suppliers of biomass • regional sawmills	**2 250** • 2 200 households48 • 35 farmers as suppliers of biomass

Table 3-2 Customers and suppliers of the three bioenergy projects

Development of local communities / Enhanced local security

Generation of new income opportunities for farmers is extremely significant, not least given the rural character of the region. The MEC creates opportunities to valorise agricultural products locally, offering energy services in the region. In addition to these, the establishment of the MEC has spurred new local initiatives (such as the collection company for UFO and the establishment of two other biogas plants in the district) and the development of a new local market for farm products. Being owners, suppliers or consumers within the MEC, farmers can decrease expenditures related to bringing their products to the market. For the local community this represents increased local security, reduced import dependency in terms of energy, feed and fertilizer and an increased standard of living.

Since the unemployment rate among farmers in rural Styria is increasing (Amt der Steiermärkischen Landesregierung, 2004), the creation of permanent jobs in the region is very important. The MEC helps generate local employment opportunities, offering people an alternative to migrating into metropolitan areas in search of jobs.

Permanent jobs created:	**43-48**
Within the MEC *Jobs per mil. EUR invested*	17 *0.9*
• For the collection of used frying oil	15-20
• Within the agricultural sector (farming and/or supply of rapeseed, wood chips, maize and green fodder)	11

Table 3-3 Jobs created by the MEC (source: Bio-energy Cycle Mureck, 2005)

The MEC is not merely looking at its contribution towards customer satisfaction as the main goal of its processes. It has adopted a *broader stakeholder view* already from the start. Moreover, the *endogenous development* of the system is one additional guarantee that the project addresses articulated needs of the local community. For instance, by involving farmers in the cooperative, SEEG has pursued a totally different and definitely more equitable strategy than that of large RME plants that only act as buyers of rapeseed and as suppliers of biodiesel. In contrast with SEEG, these large RME plants can either increase the pressure on local rapeseed suppliers (i.e. unequal power relations and the fact that farmers have no ownership rights in the plant), or they may prefer to import rapeseed from cheaper sources outside the region.

[48] A household was approximated to 3.5 persons (Planungsregion Radkersburg, 2000, 4); Ökostrom covers the annual energy consumption of approximately 7,700 people (Bio-energy Cycle Mureck, 2005, 29).

Worth mentioning are also positive influences that the MEC has upon the local population. For example, one can think of the creation of awareness with regard to environmental protection and sustainable development not least due to the local seminars that were organised by the system, but also of the implication of citizens in the designing of their own living space: "The greatest achievement is that Mr. Totter has managed to convince the people that one can change and do something with the help of renewable energy within this region"[49], says Wolfgang Jilek, the Energy Representative of the Province of Styria (Jilek, 2005). For example, the large information campaign for the construction of Ökostrom has included ample informative meetings that, in turn, have spurred the establishment of two additional biogas plants, in Gossdorf and in Ratschendorf.

According to the deployers, in 2004 the MEC has added almost 1 m EUR to the region per year[50] (table 3-4). This value was calculated as the difference between *actual expenditures* on products & services provided by the MEC in the region, and *would-be expenditures* of the region on traditional products and energy services (Bio-energy Cycle Mureck, 2005; Regionale Energiegewinnung – nachhaltiger Wirtschaftsturbo für Gemeinden, 2005)

Added value:			**EUR 977 000**
○ biodiesel : fossil diesel	→	- EUR 0.08 * 7m litres ………	EUR 560 000
○ local heating : oil heating	→	- EUR 45 * 7 500 MWh………	EUR 327 000
○ 'green' electricity : maize drying	→	+EUR 300/ha * 300/ha………	EUR 90 000

Table 3-4 Added value to the region (source: Bio-energy Cycle Mureck, 2005)

The initial aim of SEEG was to meet the needs of local farmers. The bioenergy projects that followed in Mureck have contributed also to the local self-reliance. However, the MEC is not a *closed* local system. It also generates capital, resources and products inflows and outflows. Take for example UFO that is collected from outside the region, the fact that SEEG exports about 20% of its biodiesel, or the fact that Ökostrom generates four times more electricity as would be necessary for Mureck.

Land use competition / Discomfort factor

Land use competition. Among the nine federal 'Länder', Styria is the leader with regard to the number of implemented bioenergy projects. In particular biogas plants have known a boom since the establishment of the national feed-in tariffs, in 2002, through the Green Electricity Act. Since then, Eastern Styria (which incorporates a part of the Radkersburg district to which Mureck belongs) has become the region with the highest density of biogas plants in Austria (Puchas and Luttenberger, 2005). The main resource for these rural biogas plants is maize that is often cultivated directly by the plants' operators on plots rented from absentee landowners. From another standpoint, the region is characterised by numerous small farms.[51] In many cases their owners, most of whom are also pig breeders, do not have

[49] Der größte Vorteil ist, dass der Herr Totter es geschafft hat, die Leute davon zu überzeugen, dass man mit erneuerbaren Energien in der Region halt etwas verändern und gestalten kann.

[50] In this calculation of the MEC deployers, several aspects remained unaccounted for: (1) the fact that not all biodiesel is being utilised regionally (almost 3m out of 7m litres produced by the SEEG are exported to Slovenia and Germany; yet, the calculation assumes that the whole quantity is consumed locally) or (2) the fact that 100% neat biodiesel as fuel for tractors or for public busses usually leads to a 3% loss of power in motors (because of the lower calorific value of biodiesel), and to a slight increase of the specific fuel consumption (Schumacher and Van Gerpen, 2001, 3; Woergetter, 1992, 5), etc.

[51] In 2004, about 40% of all farms in the region had less than 5 ha in property (Amt der Steiermärkischen Landesregierung, 2004, 66; Federal Environmental Agency, 2004, 2).

sufficient land to produce the entire feed needed for the animals in a year. For this reason, small farmers traditionally relied on plots that were rented from absentee landowners. But presently, the local rents for these plots have increased in response to the high density of regional biogas plants. In turn, this forces all tenant farmers to pay higher prices, but the situation is in particular inconvenient for small pig farmers in the region (Moser, 2005; Steiner, 2004). Nevertheless, a fact is that *more* maize is actually produced than consumed within the region, and therefore it is expected that this situation will evolve towards a balance (Moser, 2005; Puchas, 2005).

Total use of land	**1 360 – 1 470 ha**
Used agricultural land (SEEG + Ökostrom)	610 - 720 ha
SEEG Mureck ………………………………………………………………………	400 - 500 ha
Nahwärme Mureck ………………………………………………………………	750 ha
Ökostrom ……………………………………………………………………………	210 - 220 ha
Large farms in the region are considered if the total acreage ≥ 30 ha **In 2004, approximately 40% of all farms had less than 5 ha in propriety**	

Table 3-5 Land requirements of the MEC

Although from the three bioenergy projects in Mureck Nahwärme requires the largest amount of land (approx. 750 ha of forest), in contrast to SEEG and Ökostrom the former does not compete with other local land uses. This, since the forest has always occupied a constant, undisputed geographical space.

SEEG and Ökostrom require together about 700 hectares of agricultural land (see table 3-4). However, in the case of SEEG one can speak of a simultaneous land use effect: the cultivation of rapeseed leads to co-production of rapeseed cake, as protein feed for animal breeders.

Shortage of raw materials. For wood chips, maize, green fodder or liquid manure no shortages have been induced by the MEC. A shortage exists in the case of rapeseed, but its utilisation by SEEG does not compete with alternative uses in the region. Therefore, no consequences of the rapeseed shortage are known for most actors, with the exception of SEEG. As it was shown, SEEG produces biodiesel of two types: RME and UFO-ME. Only RME is suited for winter use because UFO-ME gels at temperatures around 0^{o}C. SEEG has to store RME for the cold period, which requires fairly large storage capacities, and to distribute UFO-ME for use during the rest of the year.[52] The potential for RME production is limited to the total acreage of rapeseed fields in a year. In turn, the yearly acreage of rapeseed depends on several factors, amongst others on the traditional cultivation of maize for pig breeding, on the financial support offered by the EU for energy crops, and on the small size of the farms in the region. The high suitability of maize cultivation establishes maize as a principal crop in the region. In contrast, rapeseed is seen as a difficult crop given the risk of crop damage and consequently the higher requirement to look after this crop. As a result, rapeseed is cultivated almost entirely on set-aside land. However, the small sizes of the set-aside land, correlated to the too low financial incentives for energy crops planted on agriculture land, determine many farmers to give up the cultivation of rapeseed. In the region the trend for rapeseed cultivation is falling; apparently also the number of farmers that

[52] Members of the cooperative and farmers who harvest rapeseed are entitled to receive RME. Car fleet and transport companies such as the Public Transport Operator Graz receive UFO-ME during summer and RME during winter (Konrad, 2005).

cultivate it.[53] An open question is whether rapeseed cultivation on set-aside land competes with maize cultivation for local biogas plants. This represents an interesting issue for further research.

Discomfort factor. The establishment and subsequent growth of a new industry also entails some discomforting factors for the local community. In Mureck, these aspects mainly take the form of temporal unpleasant odour from the biogas plant, increased traffic, traffic-related vibrations and noise, due to the supply of resources with large vehicles. While the small group of neighbouring residents has been effectively involved in the dialogue process, it is rather residents located further away who complain about these aspects. For MEC, the good relation with the local community is very important. The three bioenergy projects have joined efforts aimed at a better coordination of their suppliers, in order to decrease the transport-related disturbances. Another advantage is the location of the MEC on the outskirts of the Mureck community.

Other issues

Potential negative image of biogas plants. A negative image of biogas plants has resulted in cases where, due to spatial planning-considerations, biogas plants were settled too close to communities. In such cases factors like smell, noise and transportation have turned the community against the undertaking, tarnishing also the good reputation of biogas plants and leading even to open protests against the establishment of new biogas plants (Vlodkovsky, 2005; Pfeiler, 2005; Tscherner, 2005; Moser, 2005). While Moser (2005), a representative of the Styrian Chamber for Agriculture and Forestry, considers that there are important problems related to the establishment of new biogas plants "due to massive concerns of neighbours", Jungmeier (2005), a regional expert in bioenergy projects from the Joanneum Research Graz, believes that biogas plants enjoy a rather positive image among residents. For Ökostrom the threat is that even non-serious or cumulating complaints from residents can team up with negative rumours and spoil the plant's good reputation within the community.

Negative image of biodiesel. As highlighted in the case's history (Section 2.4), the introduction of a new biodiesel norm in 1995 generated a series of technical problems in motors due to low biodiesel quality. By 1997, when the new quality of biodiesel managed to address these problems, a negative image of the product had already been formed. This bad reputation still lingers today. For example, many interviewed farmers in the region simply refuse to run their tractors on biodiesel, even where the machines are given free for biodiesel by their manufacturer. Additional difficulties are caused by garages and vehicle service stations. According to one biodiesel user, drivers of Diesel vehicles who would like to switch to biodiesel are often discouraged by garages that refuse to issue guarantees for cars that run on biodiesel (Konrad, 2005).

Legal form of organisation (ltd vs. cooperative society). Although the limited liability company (i.e. Nahwärme and Ökostrom) has a lean governing body that leads to a high speed and flexibility of decision-making, this legal form of organisation allows participation of only a relatively small number of local people in the project. Local discussions showed that residents endorse the two bioenergy projects that were established as ltd companies with considerably less trust than SEEG, the farmer's cooperative society. This fact is acknowledged also by the MEC's deployers (Totter, 2005). To remediate this issue, both Nahwärme and Ökostrom have adopted a participatory approach, involving local farmers as owners of and suppliers to the plants.

[53] For example, while acreages of up to 800 ha have been cultivated with rapeseed during past years, the total area under cultivation in 2005 is of approximately 400 ha and belongs to some 260 local farmers (Breitenhuber, 2005, Konrad, 2005).

3.2.3 Synthesis

Since the establishment of SEEG, the MEC has continuously added value to the region. This shows that bioenergy projects can generate a positive spin that is carried forward on other sectors and domains. However, one should also consider potential negative implications of bioenergy projects: namely, they are by definition land-intensive undertakings. Although the total land required by a single project may not appear significant, the accumulation of several bioenergy projects in the same region – such as the case of biogas plants in South- and South-East Styria – can induce land use competition. To avoid negative effects on small farmers, local and regional authorities should elaborate in time a development plan for bioenergy applications. In Styria, a development plan has been drafted only in 2005. Apart from Styrian authorities, local authorities, consultants and entrepreneurs have not heard about this plan yet.

From a system perspective, the MEC is embedded in the agricultural sector (see *figure 3-3*). It draws a large part of its resources from agriculture and returns services and products to the local communities and to the agricultural sector, in a cyclical flow and according to the concept of industrial ecology. Within this extended 'roundput' deployment all bioenergy projects in the MEC benefit from additional synergistic effects. Namely, they partly share the same suppliers and / or customers (which gives them the advantage of economies of scale), make joint communication efforts to reach a wider audience (through the common marketing unit and website) and benefit together from the individually established institutional relationships (i.e. both Nahwärme and Ökostrom have benefited from the close cooperation of the SEEG with the University of Graz). Further, the system relies on renewable energy sources that, with the exception of UFO, are harvested locally. This fulfils further criteria of industrial ecology, such as the sustainable use of *renewable natural resources* from *within the immediate system boundaries* (Korhonen et al., 2004).[54]

However, while the MEC helps increase the local and regional self-sufficiency, it is neither 100% self-sufficient, nor limited to a 100% pure local economy. This can be easily seen in *figure 3-4*, on the average catchment radii for the various supply systems utilised by the MEC: SEEG's main resource, UFO, is collected from as far as Tyrol and the average catchment radius of the collection system is of 200 km.

The three bioenergy projects that compose the MEC – SEEG, Nahwärme and Ökostrom – are all relatively small-sized, which does not "divorce the ownership from personal involvement" (Schumacher, 1973). The corollary is very important: in the case of the MEC, the producers stand in a *direct relation* to the community for which they produce.

Last but not least, we have seen that the larger Styrian province harbours resourceful R&D centres, reliable technology suppliers and project developers such as the MEC. The formation of a strategic *regional cooperation triangle* based on partnerships with centres of knowledge excellence and with plant constructors was crucial for the early transfer of knowledge and successful implementation of innovations in Mureck. Cooperation has either taken the form of joint R&D activities, leading to improvement and advancement of existing processes, or that of joint planning, construction and optimisation of installations through a slow but

[54] In practice, a clear setting of boundaries and delimitation between the local, regional and national levels has rarely been attempted. According to Simms, the local level corresponds to counties with either less than 32 km (20 miles) radius or with a population of less than 100,000 (Simms, 2000, 17). Thus, with the exception of the UFO that is collected from communities situated as far as Tyrol, the MEC would correspond to a localised system.

extremely important 'trial and error' process. "Close cooperation of science, research and practice! This is how we manage it, in spite of our small size" (Totter, 2005).[55]

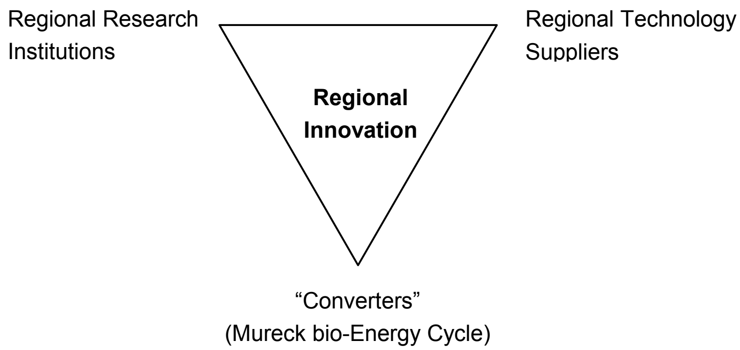

Figure 3-6 Cooperation and partnerships as drivers of regional innovation

Not surprisingly, four other case studies on innovative bioenergy projects have come to the same result: the direct and continuous flow of information between design, construction and practical operation of the plants leads to the optimisation of processes by close feedback loops (Danielsen et at., 2001, 20). In general, networking plays an important role for innovations, especially during incipient phases of industries (Tödtling, 1994), which is a trait that applies to the MEC too. The high innovation rate in Mureck compared to the relatively small size of each project consolidates Notebooms conclusion, that small organisations display a higher networking intensity and participation efficiency than large ones, in spite of a lesser participation in R&D (Noteboom, 2003, 105).

Nevertheless, without adequate support by authorities, the MEC would not have been possible in its current form. The next section discusses how authorities have contributed to the establishment of the industrial ecosystem in Mureck.

3.3 Political subsystem

From the various factors that influence the success of bioenergy systems, political aspects, especially relating to direct support for the implementation of bioenergy projects and the creation of a market framework, are known to play a crucial role. Hence, the first part of this section shows how the direct implication of the local and Styrian authorities has contributed to the realisation of the MEC. Aiming at explaining the circumstances under which each of the bioenergy projects of the MEC have benefited from political support, the synthesis in the second part adopts a (political) system dynamics perspective and discusses how and why authorities have supported the projects.

[55] Enge Kooperation von Wissenschaft, Forschung und Praxis! Dadurch schaffen wir es, trotz der kleinen Einheit, die wir hier an den Tag legen.

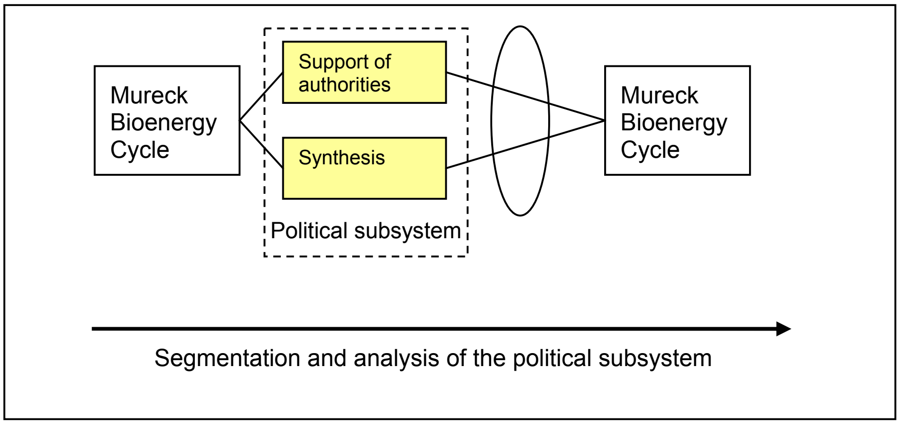

Figure 3-7 Political subsystem of the MEC

3.3.1 Support of Authorities

The support offered by Austrian authorities to the establishment of the MEC has taken various forms and was granted from different levels (i.e. local, province or national level). This section presents it in the chronological order, starting with SEEG.

	SEEG	Nahwärme	Ökostrom
Legal form:	Farmers' cooperative	Ltd. Company	Ltd. company
Investment costs:	6.15 m EUR	7.20 m EUR	5.40 m EUR
Direct aid	75%	48%	30%

Table 3-6 Investment costs and direct subsidies

Support for SEEG

SEEG, the biodiesel cooperative, is a special case that has received strong support both from the provincial and federal levels of government. As a natural continuation of a pilot project in Silberberg, SEEG represented a demonstration project for authorities. As such, it has benefited from two of the most essential instruments of innovation policy – R&D and subsidies.[56] Indirectly, SEEG has benefited through the five-year subsidy program for rapeseed cultivation that was initiated by the Federal Ministry of Agriculture in the 1980s. The program provided important subsidies for rapeseed cultivation (approximately 500 EUR per hectare at that time[57]), which motivated many farmers to plant rapeseed instead of the more traditional maize crops. Hence, the program has established the basic conditions for farmers to get organised in cooperatives for RME production. The subsequent development and implementation of standards for RME and the exemption of biodiesel from the petroleum tax has supported the development of the market for biodiesel as a fuel for transportation. In turn, this has convinced many tractor manufacturers to issue engine warranties for biodiesel use during an early phase.

At present, rapeseed cultivation on agriculture land receives 45 EUR/ha as EU-subsidies for energy crops. In correlation to the traditionally small size of Styrian farms and to the amount of work that is necessary to cultivate rapeseed, the present subsidy motivates only a few

[56] About 75% of the initial investment costs of SEEG were covered by direct aid (see Table 3-6).

[57] 7,000 ATS, according to the farmers that were interviewed.

farmers (mostly those with large farms) to cultivate this crop. Still, rapeseed cultivation is expected to increase in the coming years due to foreseen higher prices for rapeseed in the near future. The higher prices might result from the transposition of the European Biofuels Directive into Austrian law, which requires that a quantity of 2.5% of biofuels, calculated on the basis of the energy content of all petrol and diesel for transport purposes in a year, shall be placed on the market in 2005.

A further considerable support for SEEG nowadays is the participation of over a hundred local authorities in the collection program of used frying oil. Not only do these communities organise local and regional information campaigns to explain the benefits of UFO collection to residents, but they are also providing, free of charge, a series of services that are crucial for UFO collection. A very important support for the development and expansion of the SEEG is the participation of numerous public authorities as consumers of UFO-ME. For instance, the participation of Graz as an important long-term consumer of UFO-ME was crucial for the expansion of the production capacity of the SEEG (see *Table 2-1*). Consecutively, this relatively stable market-outlet has encouraged SEEG to improve and intensify the collection system for UFO.

Support for Nahwärme

Since the introduction of the first district heating technology in rural areas in the 1980s, the biomass district heating sector has experienced a rapid development in Austria (Rakos, 2001, 14). At the time when Nahwärme was constructed (1998), a well-established institutional support mechanism for BMDH plants was already in place. The plant received a substantial direct financial aid covering 48% of the total investment costs.[58]

Since Nahwärme was designed to supply the entire village with district heating, the support of the local community was of particular importance. In Mureck, the sense of solidarity was established with the help of the local authority: the opportunity of establishing a BMDH plant in Mureck "has been discussed in the municipal council and has been signalled [to the Mureck community] by all fifty representatives of the municipal council"[59], recalls Galler, the Mayor of Mureck (Galler, 2005). Procurement was another form of support that was offered by local authorities to Nahwärme. It guaranteed in advance the connection of all public buildings in Mureck to the district heating network. Given that the city hall and the schools are among the largest heat-consumers in Mureck, this measure has contributed significantly to the implementation of the plant.

Additional indirect benefits at national level have also played a crucial role. The most important ones concern the low VAT on wood (of only 10% compared to the general 20% VAT), financial aid for households to connect to the district heating grid[60] (equalling approximately one fourth of the average household costs for connection), development of standards for the BMDH technology and training and establishment of qualified consultants as focal points for BMDH-related issues (Kofler, 2005; Jilek, 2005; Rakos, 2001).

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[58] Nahwärme received a 46% subsidy from the federal level and an additional 2% aid from the province level (Table 3-6).

[59] [...] ist in dem Gemeinderat besprochen worden und es ist von allen fünfzig Gemeinderäten auch hinausgetragen worden.

[60] At present, these subsidies for households have been replaced with state allowances in the form of credits over a 10 to 14 year period (Kofler, 2005).

Support for Ökostrom

Ökostrom has received direct financial subsidies that covered 30% of its initial investment (see Table 3-6). Second, being authorised before the end of 2004, Ökostrom benefits from high feed-in tariffs for 'green' electricity over a 13-year period.[61] Third, farmers who cultivate maize or green fodder in order to valorise them in a biogas plant receive the EU-subsidy for energy crops.[62] Fourth, another indirect support for Ökostrom has mainly taken the form of lower transaction costs for plant developers due to the existence of a well-organised support framework for biogas plants. Like in the case of BMDH plants, this support framework includes well-trained public and private consultants that offer qualified advice to developers of biogas plants, standards for biogas technologies and an effective and ongoing quality control system for implemented projects.

3.3.2 Synthesis

Public authorities have traditionally played an important role in the diffusion of bioenergy projects in Austria. Their active implication can be explained through (1) the large availability of biomass resources in the country[63], (2) the desired and anticipated outcomes of bioenergy diffusion (such as value added to rural regions, job creation within the agricultural sector, development of an innovative and competitive bioenergy industry, setting the basis for export of biomass know-how and technology, etc.) and (3) the central political objectives of the national energy policy (i.e. energy security, energy efficiency and renewable energy promotion) (IEA, 2004; Zacherl, 2004; Clement et al., 1998).

However, general conditions of political support for the projects in Mureck have changed over time, since the establishment of SEEG, in 1991, until the finalisation of Ökostrom, in 2005. This part argues that much of the governmental promotion that existed for each of the projects in Mureck was rather limited in time and does not necessarily exist anymore at present. By adopting a system dynamics perspective this part discusses *why* each of these projects, and in particular SEEG, has benefited from a considerable political support: because over time adequate *policy windows* had been open for such projects.

Developed by Kingdon (1995), the concept of policy windows is widely used in political science to analyse the determinants of political change. In order to gain a better understanding of the context from which the MEC has evolved, in this part Kingdon's model will be presented and it will be explained how this model relates to each bioenergy project in our case.

According to Kingdon (1995, 174), political change may result if a *policy window* exists, that is, if the "opportunity for action on given initiatives" exists at a political level. In turn, this opportunity for action is a consequence of the simultaneous merging of opportunities within three independent 'streams':

(a) the 'problem stream', which represents the *recognition* of the problem by relevant actors,

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[61] While the Green Electricity Act of 2002 provides that feed-in tariffs shall be paid for energy from renewable sources, the actual feed-in tariffs were regulated in a decree that has expired in 2004. Since no agreement over the size of the new feed-in tariffs could be reached, the government did not pass any new decree, leaving a vacuum legislation with regard to the generation of green electricity from renewable sources (Jilek, 2005; Moser, 2005).

[62] Subsidies fall out if the energy crops are cultivated on set-aside land.

[63] Consistent biomass resources can be found within the agricultural sector and forest cover approximately 47% of the country's surface, representing the country's most important renewable raw material (Rittsteuer, P., as cited by Wolf, M., 2005, May 7).

(b) the 'policy stream', which represents *awareness* that a politically acceptable and technically or organisationally suitable solution either exists, or else it can be developed by experts, and

(c) the 'politics stream', which consists of the *political rules of decision-making* that are rooted in a given political culture and that can be influenced by various interest groups.

Policy windows emerge from stimuli that are sent by the 'problem stream' (a), by the 'politics stream' (c), or by both (Howlett, 1998). The 'policy stream' (b) is responsible for deciding over *which* solution should be adopted in the course of the decision process (Sartorius and Zundel, 2005, 36).

For example, a policy window can emerge from the problem stream (a), in which various factors, such as crises and catastrophes, availability of new data and/or new institutional feedback have occurred. In relation, "spillover problem windows", that is, the coincidental occurrence of a problem in a related topic, often play an important role because the respective coincidence may be used for agenda-setting purposes (Howlett, 1998). In Europe, such a 'spillover problem window' is the bovine spongiform encephalopathy (BSE) crisis: the accidental occurrence of this problem constituted a chance for the reorientation of the European Agricultural Policy (Sartorius and Zundel, 2005, 37).

However, a policy window can also emerge from changes that take place first within the politics stream (c), such as elections, annual budget negotiations, the influence of interest groups, etc. As Howlett (1998) shows, institutional cycles are able to generate *systematic* changes within the politics stream, which in turn may open a policy window.

While sometimes Kingdon's 'policy window' model is debated in the political science literature under the argument that (gradual) policy changes can result from intended strategic policies (as opposed to anarchic coincidences), Sartorius and Zundel (2005, 38) argue that abrupt policy changes can be explained using Kingdon's model, as they evolve in a different way than more incremental policy changes.

These arguments seem to fit very well with the MEC case – at least by judging how events have unfolded for the biodiesel plant SEEG: in Austria, the oil crisis in the early 70's was a major event that was fully perceived within the 'problem stream' (a). Its impact was sufficiently strong to build *awareness* within the 'policy stream' (b) and to create a *policy window for biodiesel*. Since from a techno-economic perspective no feasible alternative for fossil fuel really existed, a solution had first to be developed by experts. Hence, once the 'policy stream' (b) decided in favour of biodiesel[64], the Ministry of Agriculture initiated in 1973 a basic R&D program for the production of this fuel (REACT, 2004, 3).

By 1985, benchmark tests for biodiesel production had been completed successfully at the Institute of Organic Chemistry and the institute decided to move on to real-world tests (see Section 2.4 *History*). The idea was "to persuade local farmers to use biodiesel in their tractors, creating a closed energy loop in the agricultural community" (Pahl, 2005, 33). This goal of the Institute – that is, to teach farmers how to produce their own fuel – highlights yet another key issue. Namely, that the difficult situation of Austrian farmers was perceived by relevant actors from the 'problem stream' (a). Hence, the 'problem-recognition' corresponds to a second

[64] Initially two alternative replacements for fossil fuel were considered: biodiesel for Diesel engines, and bioethanol for petrol engines. Though a consortium for bioethanol had been established, it ceased its activities after only a short period "as it did not get the required political support in Austria and feedstock supply was not assured" (REACT, 2004, 1).

policy window, not necessary for biodiesel or bioenergy but rather for farmers. This *policy window for farmers* has probably evolved concomitantly with the Austrian eco-social market economy concept[65] in the early 1980s and it probably coincided with the starting point of a more incremental and strategic policy approach aimed at supporting Austrian farmers. Awareness about the difficult economic situation of farmers in particular in mountainous areas and in areas with low tourism has determined authorities to deliberately establish bioenergy projects as an alternative form of revenues for this group (Rakos, 1998). This also explains why bioenergy projects developed by farmers are entitled to receive a 10 to 15% higher investment subsidy – a considerable support for all three projects in Mureck.

In Styria, the concerted promotion of bioenergy generation in the agricultural sector started some fifteen years ago, since it became clear that farmers have no chance to compete on the European agricultural market. "The subject biomass has always been understood as a contribution to the development of a financial basis for Austrian farmers. […] So one has to make them a new footing – this is energy. […]. Energy industry is our hope for the farmers"[66], says Jilek, the Energy Representative of the Province of Styria (Jilek, 2005).

In consequence, when SEEG was established in 1991 it benefited both from the still open policy window for biodiesel and from the targeted support offered to farmers. Hence, from a system dynamics perspective SEEG benefited from a *window of opportunity*, that is, the "temporary existence of circumstances that allow novelty to get selected" (Sartorius and Zundel, 2005, 21). This insight can explain why Styrian authorities have financed almost entirely the establishment of the agricultural cooperative in Mureck and why they further subsidised the cultivation of rapeseed. Nevertheless, over time some of these strong supportive measures have lessened: the very high Austrian subsidies for rapeseed cultivation (about 500 EUR/ha at that time) were replaced with the EU-subsidies for energy crops (45 EUR/ha at present) after Austria joined the European Union, and at present new agricultural biodiesel initiatives can hardly expect to receive a 40% financial subsidy.

In a similar way we can analyse the political measures that existed for Nahwärme. As Rakos (2001, 17) shows, the introduction of BMDH plants in Austrian rural areas was strongly promoted by agricultural interest organisations, and usually it was complemented by the top-down support of local authorities. These were accompanied by thorough support at province and federal level.

In the sense of system dynamics, the favourable policy conditions from both the province and the federal level have merged with a *local* policy window and have opened a *window of opportunity* for biomass district heating initiatives.

While the supportive measures at regional and federal level were similar to those that have been discussed in the case of SEEG (i.e. support for farmers), a partial explanation to the *local policy window* is offered by Rakos (2001, 17) and by Jilek, the Energy Representative of the Province of Styria (Jilek, 2005): since many communities have joined the 'Climate Alliance'[67],

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[65] The eco-social market economy concept promotes a development that aims to create a balance between ecological, economic and social aspects. Josef Riegler, who became Vice-Chancellor of Austria in 1989, has contributed significantly to the promotion of this concept starting with the 80s. For more details see also the site of the Austrian Eco-Social Forum (http://www.oesfo.at/osf?pid=/Root/root01/m01)

[66] Mit dem Thema Biomasse ist immer der Aufbau eines finanziellen Fundamentes für die österreichischen Bauern mitgedacht worden. [...] Also man muss ihnen ein neues Fundament machen – das ist Energie. [...]. Energiewirtschaft ist usere Hoffnung für die Bauer.

[67] 'Climate Alliance' is an organisation similar to Agenda 21. For more details see also www.klimabuendnis.org.

they feel responsible to do something about climate change, which often results in initiatives to secure long-term environmentally friendly energy solutions for their respective communities. Indeed, as Galler, the mayor of Mureck explains, the fact that the town had just joined the 'Climate Alliance' has represented an important motivation to support the district heating plant that would use renewable resources (Galler, 2005). According to him, further important drivers were the prospect of added value, of income generation for local farmers and of increased prestige for the Mureck community. In conclusion, the municipality in Mureck has decided to support the BMDH plant due to impulses from both the 'politics stream' (c) and the 'problem stream' (a). Impulses from the 'politics stream' were the (local) political culture that is still influenced by the eco-social market economy concept (Tischler, 2005; Jilek, 2005), the good lobby made by the plant's developers and the pressure on local politicians regarding good practices (i.e. successful bioenergy projects) within neighbouring communities. Impulses from the 'problem stream' were mainly the recognition of the difficult situation of local farmers.

Finally, Ökostrom has benefited from both local and federal support. While a *local policy window* for bioenergy projects is still open today, in addition to that Ökostrom has benefited from a significant *national policy window:* namely – the introduction in 2002 of national feed-in tariffs for 'green' electricity. This policy window closed in 2005 (at least temporarily), since the government did not reach any agreement over the new size of the feed-in tariffs.

In conclusion, although well-intended policies for bioenergy projects are ongoing in Austria and in Styria, it is important to understand that significant opportunities – 'policy windows' according to Kingdon's model – had been open at the time when each constituent project in Mureck was implemented. This finding suggests that attempts to establish the MEC in a different setting would require from a political standpoint similar opportunity windows to be open.

3.4 Socio-cultural subsystem

In a geographical sense Radkersburg is the region in which most flows between the MEC and its stakeholders take place. Consequently, it is important to notice that certain general environmental, economic and cultural themes are recurrent within this region, representing a common socio-cultural background for most actors.

This section aims to confer an additional means of interpreting the formation and evolution of the MEC. It adopts a perspective of macrosociology and follows a historical path of the local socio-cultural context. By this, it is not intended to give a full account of the rich local culture and history, but rather to discuss major features of the *social and cultural context*, which have contributed to the formation of the MEC. The first part introduces the reader to the regional context during the past 50 years. Part two, the synthesis, analyses the effects of the transformation process that has began in the 1950s in Radkersburg. Next, it borrows the concepts of culture from the field of anthropology and explains how the local cultural context has facilitated the development of the MEC by influencing the formation of the natural ecosystem vision and loop-closing philosophy of Totter – the main developer of the system in Mureck.

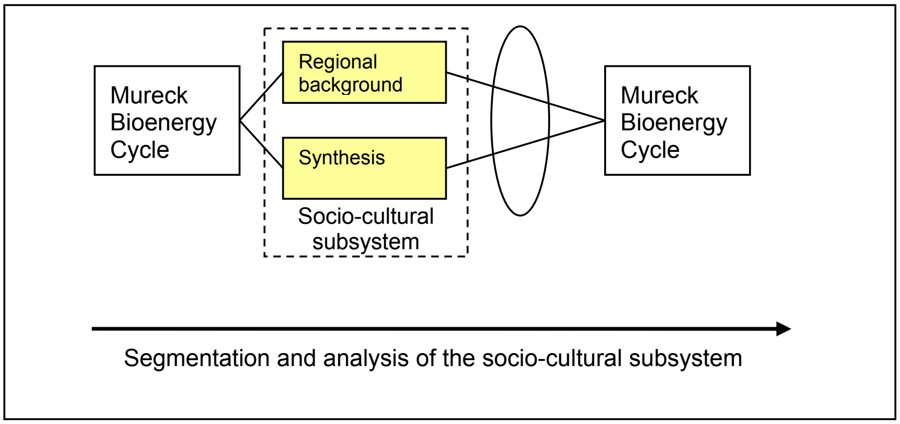

Figure 3-8 Socio-cultural subsystem of the MEC

3.4.1 Regional background

Regional context

Radkersburg has a surface of 337 square kilometres and a population of approximately 24 000 inhabitants, distributed in 19 communities. It is one of Styria's smallest districts. The capital is Bad Radkersburg. Other large communities are Mureck, Halbenrain and Murfeld, while the other communities are rather isolated and small, being not, or not easily accessible by train. [68] Settlements are fairly concentrated around the village church and the city hall, which, together with the village school(s), are usually the largest buildings in the communities. A result of the historic splitting of land among heirs is the small size of local farms.[69] Up until the 1970s the region was characterised by numerous small farms, but in the 1970s the size of farms started to grow again. A characteristic of farmers in the region is that in many cases they are also forest owners. The population is of Austrian ethnicity and there are no other important ethnic groups, although historically there has been some mixture with persons of Slovenian and Hungarian origin. The majority of the population is catholic, and church seems to play a fairly important role in people's life.[70]

Some general disadvantages have resulted from the peripheral location of the district. For decades Radkersburg was bordering the Eastern Block (Yugoslavia in the South and Hungary in the East), which discouraged cross border cooperation. For this reason the district was not particularly attractive to industry, which preferred better locations close to the marketplaces in the West. Therefore, agriculture traditionally provided most jobs in the region, which explains why Radkersburg continues to be one of Austria's most agriculture-intensive districts (Amt der Steiermärkischen Landesregierung, 2004, 36).

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[68] In 2000, Bad Radkersburg and Mureck were the only communities with more than 1000 workplaces (Statistik Austria, 2005; Planungsregion Radkersburg, 2000, 4).

[69] Currently about 40% of all farms in Radkersburg have less than 5 ha in property – scarcely anything compared to the Austrian average of 36.6 ha per farm (Amt der Steiermärkischen Landesregierung, 2004, 66; Federal Environmental Agency, 2004, 2). This highlights as well that *land use competition* in the region is a significant aspect.

[70] 10 out of 16 residents who have responded to this question in the survey have indicated that they would go to church at least once in a week.

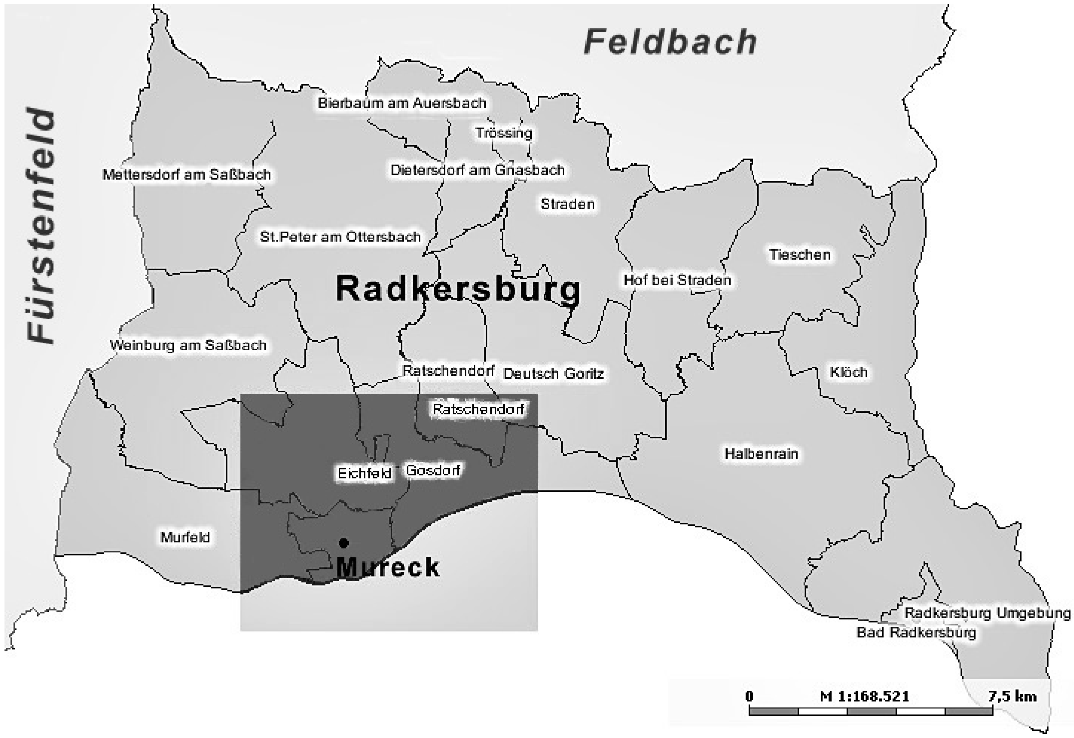

Figure 3-9 Map of Radkersburg District

In terms of economic development Radkersburg has always been around or below 60% of the Austrian average (LACE-Phare CBC, 2000, 4). This is also highlighted by *figure 3-10*, on the gross income difference between Radkersburg and the larger Austria.

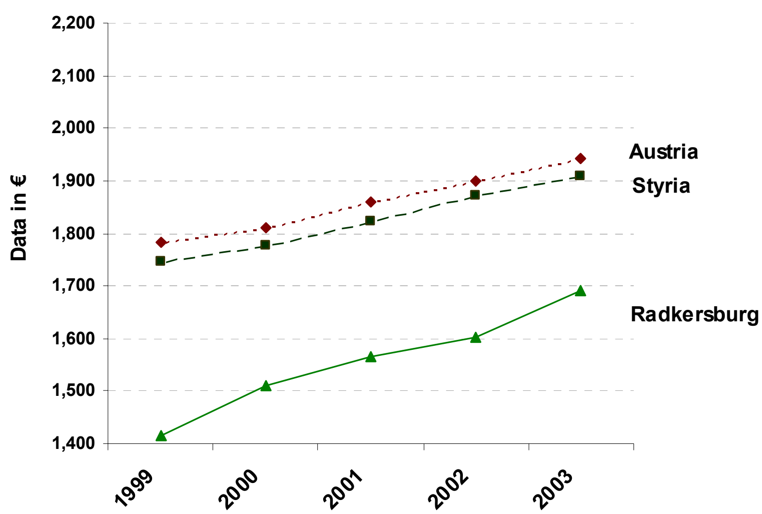

Figure 3-10 Gross income differences as compared to the Austrian average (source: Statistik Austria)

Locals in the district claim that their region is underdeveloped as compared to other Austrian or even Styrian regions. According to their interpretation, these deficiencies are due to the generally bad situation within the agricultural sector and to the structural small size of their farms. The depression and outward migration of the population from Radkersburg in response to a growing unemployment rate[71] is shown in *figure 3-11*, which depicts the decreasing population size in the district.

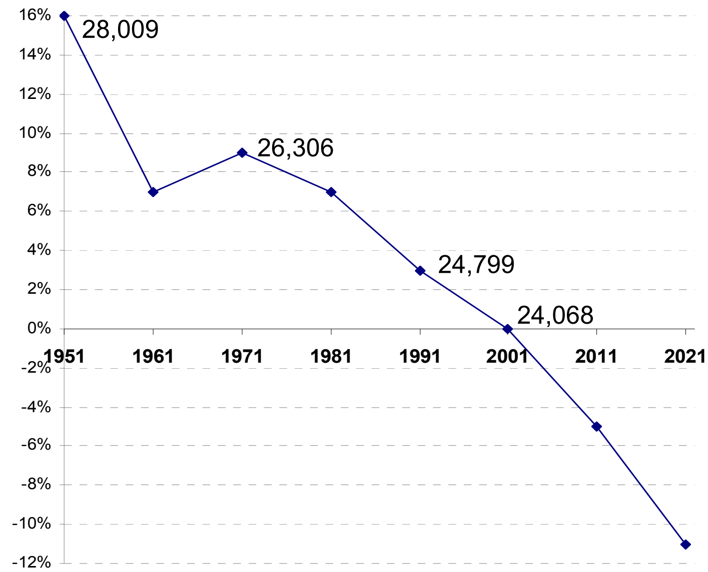

Figure 3-11 Fluctuation of residents compared to 2001 and trend (in % and absolute numbers) (source: Planungsregion Radkersburg, 2000)

From traditional farming to industrialised agriculture

Over time, good climatic conditions, adequate topography and a very fertile soil have lead to the flourishing of the local agricultural sector. All local communities were based on a farming economy that included a variety of farming products and activities, such as the cultivation of wheat, maize, pumpkins, vegetables, viniculture and animal breeding. But starting with the intense mechanisation in the 1950s agriculture became less and less used for home consumption, as farmers specialised in 'cash crops' for the market. During the 1970s *maize* became the predominant crop in Radkersburg. It was cultivated by the large majority of farmers and sold on the national market. One decade later, during the 1980s, competition toughened due to overproduction of maize at a national level. As farming conditions worsened, some farmers in Radkersburg were discouraged by the losses and eventually gave up their farms. Others switched to the less disputed animal breeding sector, specialising in *pig fattening*. Unfavourable circumstances continued to unfold for the agricultural sector, and during the past decade prices for meat became volatile, forcing more farmers out of business. The remaining farmers are adopting industrialisation for all farming processes and are seeking to *diversify* their income sources in various ways.

3.4.2 Synthesis

The synthesis is divided in two parts. First, ecological theory, as described by Abruzzi (1996), Lenski, Lenski and Nolan (1991) and Hannan and Freeman (1989), can be used to explain the adaptive strategies of farmers in Radkersburg and to show *how* this profound transformation process has favoured bioenergy initiatives in the region, contributing to the formation of the

[71] In 1999 the unemployment rate in the district was 6.5%. In 2003 it had mounted to 7.3% (Statistik Austria; Planungsregion Radkersburg, 2000, 5).

system in Mureck. Subsequently, the discussion focuses on regional socio-cultural traits, which may help understand the development of the Mureck bio-Energy Cycle.

1) **Ecological theory & transformation process in Radkersburg**

This section considers that farmers in Radkersburg face a *niche overlap* with their better adapted competitors. With the help of ecological theory this section attempts to explain the profound local transformation process that has started in the 1950s.

Ecological theory has its origins in the field of ecology, where it studies changes in populations in response to transformations that affect their environment, and describes the strategies that allow species to survive environmental change (Wilson, 1992). Nevertheless, the theory is very popular in social sciences too, where it has been applied to the 'population' of professions (Van Housen and Sutton, 1996; Abott, 1988), to 'populations' of organisations (Hannan and Freeman, 1989) and more generally for explaining social evolution (Abruzzi, 1996; Lenski et al., 1991; Barth, 1956).

A key notion for understanding ecological theory is the term *niche*, which expresses a population's *role*, or its "way of earning a living" within a community (Elton, 1927, 63). According to Bonner (1988, 100), "Ecologists often think of a community as a collection of niches, and these niches reflect different ways animals or plants can maintain a place in the community". More precisely, the niche represents the 'set of environments' within which a population can survive and reproduce itself. It can be represented graphically as a function that relates the number of individuals in a population (i.e. the fitness of the population) to the set of resources used for sustaining that population (*figure 3-12*). A population's niche may be divided into (1) its *fundamental niche*, which represents the full range of resources and conditions that a population could theoretically enjoy in the absence of competition, and (2) its *realised niche*, that is, the narrower portion of the fundamental niche that is actually filled by a population in a particular community characterised by competition (Miller, 2004, 103; Hutchinson, 1978).

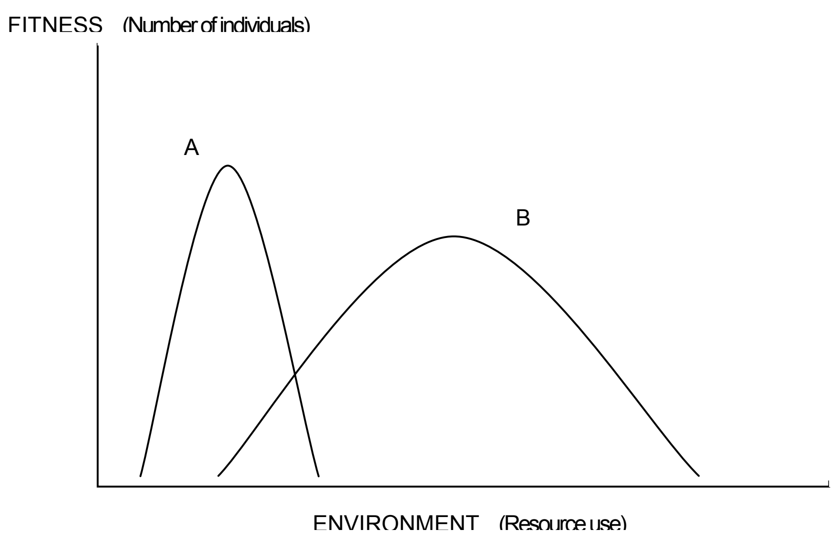

Figure 3-12 Hypothetical fundamental niches and overlap (adapted from Miller 2004; Hannan and Freeman, 1989)

Competition deserves particular attention, because its degree influences a population's realised niche breadth: if in a particular community two species compete for the same resources, the presence of the competitor "reduces the set of environments in which a population can sustain itself" (Hannan and Freeman, 1989, 97). According to Miller (2004, 174), the more the niches of the two populations overlap, the more likely it becomes that one population has to

(1) *search for resources elsewhere*,

(2) change its habits to *avoid competition*,

(3) experience a *sharp population decline*, or even

(4) cease its existence in that particular community.

Finally, the niches that exist in a particular community at a certain moment in time can be affected by three factors:

(a) the evolutionary process during which populations change partially or completely their habits or traits, or during which they split into several new species.

(b) major environmental changes, or

(c) the arrival of additional populations in that community

As its niche changes, a population must change as well in order to survive. In summary, this represents the Malthusian notion of struggle for limited resources that in the world of nature subjects populations to a continual adaptive process (Hannan and Freeman, 1989, 21).

The application of the ecological theory to explain macroevolutionary changes in human communities is sometimes disputed in the social sciences. The main argument is that natural selection is inherently different from social evolution, since the latter is characterised by (1) cultural evolution, (2) a more direct and potentially *conscious* socio-cultural adaptation and (3) the flexibility of socio-cultural adaptation in comparison to biological evolution where "Once a species becomes separate, […] it is separate for ever" (Gould 1996; Gould, 1991, 65). However, apart from poor analogies to biological systems, the ecological (evolutionary) theory has a general explanatory power of socio-cultural change (Abruzzi, 1996; Cartmill, 1994). Being responsive to the interaction of populations to their environments, human societies are "a part of the global ecosystem and cannot be adequately understood unless this fact is taken fully into account" (Lenski et al., 1991, p. 6).

This view is further adopted in this paper in order to explain the historical transformation of the socio-cultural environment of farmers in Radkersburg, and its relation to bioenergy projects. For that, a rather *unilateral* perspective on how these fundamental changes affected farmers in Radkersburg is adopted, while the reciprocal influence that these farmers had upon their competitors falls beyond the scope of this thesis.

Farmers in Radkersburg and their competitors (farmers from other Austrian districts who have specialised over time in the production of same goods, as well as outside farmers who compete with farmers in Radkersburg on the same market) are seen as two competing populations. The geographic location of the competitors is of little importance, as the competition occurs on the agricultural market.[72] Competition has increased over time, as the

[72] Initially it was the Austrian market, but since Austria's joining of the EU in 1995 the competition has shifted to the European market.

fundamental niches of these two populations began overlapping, and as their interaction on the market intensified. The reasons where that:

(a) more Austrian districts evolved as suppliers of the same agricultural products, that is, the *evolutionary process* during which other populations *changed their habits* and came to interfere with the population in Radkersburg on the same market, and as

(c) *additional* competitors arrived in the community upon the opening of the Austrian agricultural market.

Interpretation

The fundamental niche of farmers (in Radkersburg) includes the cultivation of a variety of crops, vegetables, viniculture and animal breeding. Prior to the 1950s, it corresponded more or less to their realised niche. However, once the transformation process had begun, continuous specialisation and increasing competition have narrowed the realised niche of these farmers.

The fundamental changes in Radkersburg began during the 1950s, when Styria experienced an intense mechanisation process. As everywhere, farmers in Radkersburg adopted mechanisation because it represented a labour-saving technology that entailed a more efficient exploitation of resources. In terms of ecological theory, mechanisation provided for a better adaptation of farmers to their respective environment.[73] But mechanised cultivation is done with big machines that are largely inflexible with regard to manipulation. Consequently, the cultivation of large land areas with the same crop is a must. From this, it followed naturally that farmers in the district *specialised* in the cultivation of the *best*[74] crop, maize. They basically *reduced* the breadth of their realised niche to the extent where it would mainly rely on a single income source: the cultivation of maize. In doing so, they largely ignored that a similar process had started in all neighbouring districts.

What followed was a rapid, profound and most of all *self-enforcing* transformation process. First, in the 1970s Radkersburg became famous as a maize-cultivating region that exported maize all over Austria (Tischler Sen., 2005). The more efficient exploitation of resources entailed competitive advantages that allowed farmers in Radkersburg to out-compete less efficient farmers on the national market. But then, as more districts specialised in the cultivation of maize, one decade later the Austrian market for maize became saturated and subsequent low prices started to discourage small farmers in Radkersburg (Tischler Sen., 2005; Stradner, 2005; Geissler, A., 2005). From the viewpoint of ecological theory *additional* populations with similar niches had interfered, leading to fierce competition as niches had overlapped. Their interference triggered a population decline for farmers in Radkersburg (see *figure 3-14*).

The immediate adoption of industrialised farming was largely infeasible in Radkersburg, due to the prevailing small size of most farms. For this reason, the remaining farmers in the district have tried to adapt by *searching for resources elsewhere*. Eventually they started to *avoid competition* by shifting to pig breeding, for that they used maize as feedstock (Stradner, 2005). During the 1980s, most individual farmers in the district specialised in pig breeding. This new activity not

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[73] According to Bates (1998, 117), this is not entirely true: while intensive agricultural systems are required by our present development, intensive agriculturists do not really free themselves from constraints. On the contrary. Their intensive practice gives rise to new and more serious constraints than those posed by more simple technologies, complicating the problems for farmers. Yet, while this is an interesting question with regard to bounded rationality, it is not the subject of this research.

[74] *Best* in terms of the best input-output ratio of invested efforts in, and respectively obtained financial value from the product.

only permitted a more efficient exploitation of their basic resource (maize), but it would also broaden their *realised niche,* by including a second resource: fattened pigs (meat). According to one informant, during that period Totter, the initiator of the Mureck bio-Energy Cycle, specialised too in pig-breeding and became the leader of the association of pig-breeders in Eichfeld.

The diffusion of biomass district heating technologies and the establishment of the first biodiesel plants in rural areas were further attempts of farmers to either *broaden* their realised niche, and/or to *avoid competition* by shifting to new resources. According to ecological theory, these actions equalled an expansion of the traditional 'set of environments' utilised by farmers. This expansion was possible by including *additional* resources: the valorisation of wood that was not suitable for sawmills or for the board industry (Rakos, 1998), and the valorisation of rapeseed – a crop for which the government had created favourable conditions and for which little competition existed.

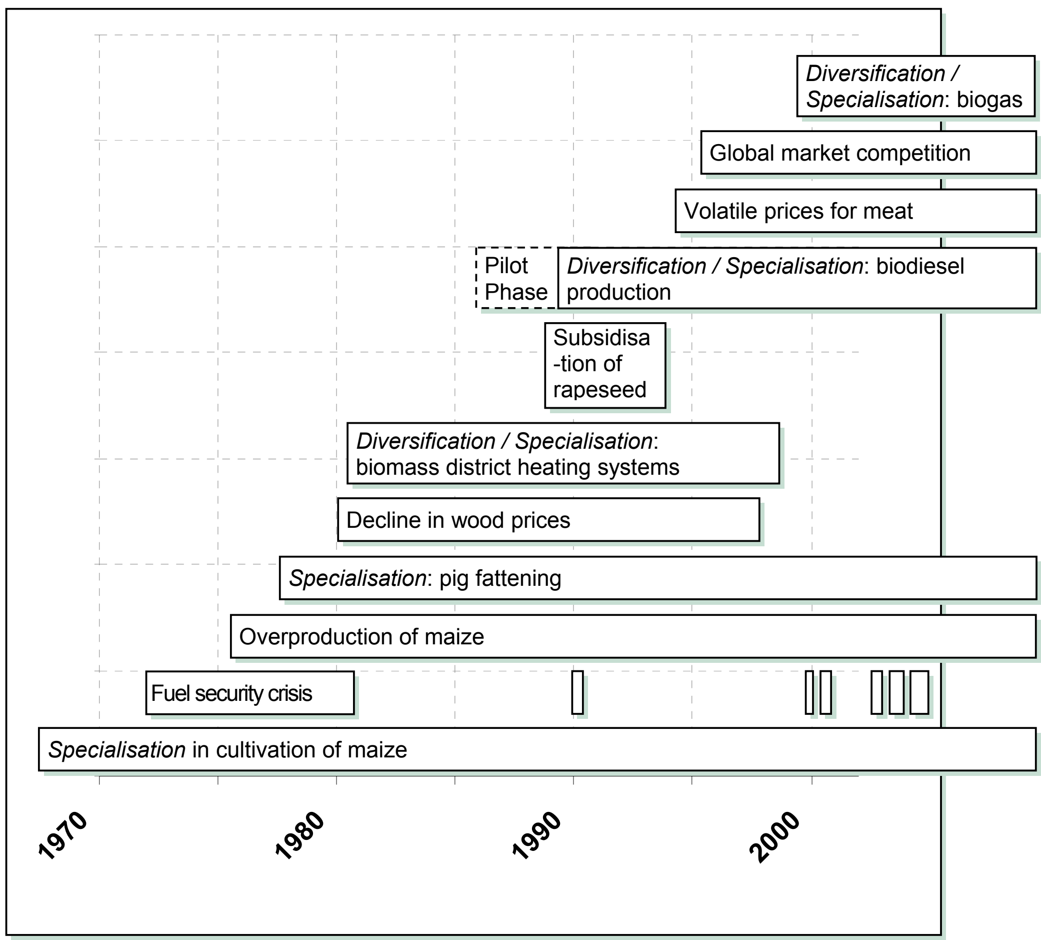

Figure 3-13 Approximate timeline of constraints on and responses of farmers since the 1970s

As Rakos (1998) shows, biomass district heating (BMDH) plants were developed in particular in regions with little alternative income opportunities (i.e. Radkersburg), whereas regions that provided more income opportunities showed a low interest in BMDH. It has been further shown that the oversupply of wood that triggered the decline in wood prices during the 1980s was a major driving force behind the diffusion of BMDH (Danielsen et al., 2001, 17; Rakos, 1998). Hence, as the income from selling wood became less and less attractive, the realised niche of farmers shrunk. In turn, this has put farmers under pressure to search for *new* income generating opportunities. This explains also the findings of Danielsen et al. (2001, 19), who argue that "the occurrence of biomass projects shows a striking coincidence with local cultural [bottom-up] initiatives: the probability to find a bioenergy project in a village with a cultural initiative is 8 times higher, than in a village without such an initiative". Hence, apart from the support of local authorities (see Section 3.3), the diffusion of BMDH was equally based on endogenous initiatives (Rakos, 1998; Roos, 1998, 78).

To return to pig fattening, gradually competition increased on this market segment too, driving prices down for meat, as neighbouring districts were squeezing in the same niche (Tischler Sen., 2005). Eventually, Austria's opening of the national agricultural markets in 1995 triggered the general plummeting of prices for agricultural products (Stradner, 2005; Pollak and Puntscher-Riekmann, 1999). While many small farmers were forced out of business by the tough competition, a few discovered new opportunities to survive, partially by adopting industrialisation to out-compete their competitors, partially by *expanding* their 'set of environments' through the valorisation of maize in biogas plants, or partially by shifting completely to the supply of energy services (i.e. changing their niches). Given the policy window that has existed for the establishment of biogas plants[75], this income opportunity was considered by many farmers to be more profitable and secure than pig fattening.

In short, fundamental changes – especially due to overproduction and increased competition – have shaped the environment for farmers in Radkersburg for the past 50 years and have created a turbulent setting. The base of competition was the provision of the same range of products (maize, meat and wood) to a market nearing saturation. Competition has lessened the financial revenues of farmers and has reduced the 'set of environments' in which they could sustain themselves. While specialisation has allowed farmers to raise their efficiency, it has also trapped them and their small communities in an unequal economic relationship with the outside. Specialisation has provided market-access to a larger number of competitors, initiating an ongoing devaluing process of agricultural labour and products. In turn, this process has forced farmers to specialise even more and to adopt 'industrialisation' to reach higher productivity rates, while their profit actually lessened. One representative of the Styrian Chamber for Agriculture and Forestry summarises this process: "As the profit per unit gets smaller and smaller, one has to raise the quantities. It is almost like within industrial workshops. Most sadly, but it is so!" (Moser, 2005).[76] Additionally, prices for agricultural products have become volatile, increasing the *generalised pressure on farmers*.

The result was a dramatic fall in the number of farms in the district (see *figure 3-14*). If several decades ago more than half of the working population in Radkersburg was still engaged in farming activities (Totter, 2005; Geissler, A., 2005; Stradner, 2005; Schwinger, 2005), currently, local farmers estimate that this quota ranges between 4 and 8%. Still, in individual communities agriculture and forestry continues to provide up to 35% of all jobs (Amt der Steiermärkischen Landesregierung, 2004, 36; Planungsregion Radkersburg, 2000).

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[75] Section 3.3 shows how policymakers have encouraged this alternative. Worth noticing is that only rural plants based on agricultural products receive the highest support.

[76] Weil der Gewinn pro Stück immer kleiner wird, dann muss die Menge erhöht werden. Es ist fast wie bei den industriellen Produktionsbetrieben – leider Gottes, aber es ist so!

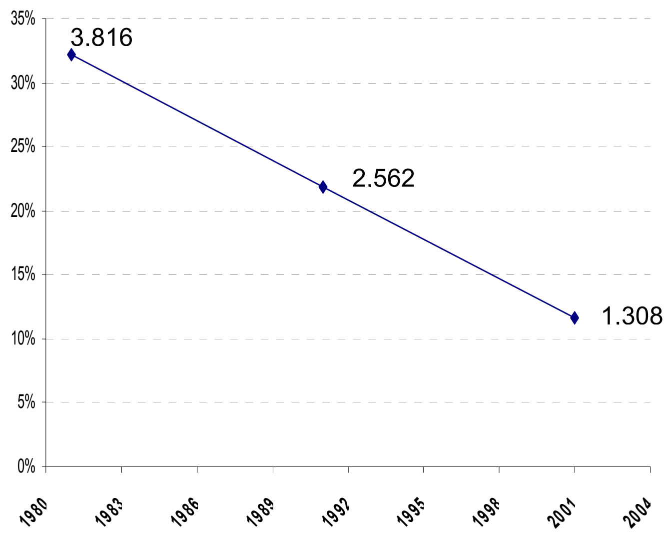

Figure 3-14 Employment in agriculture and forestry operations in Radkersburg (quota and absolute numbers) (source: Statistik Austria)

In Radkersburg, early adoption of industrial agriculture was hampered by the structural small size of the farms. The additional lack of regional income opportunities such as industry or tourism has convinced many farmers to pursue a *diversification strategy* based on their own farming resources. Having the potential to shelter them from the fierce competition on agricultural markets, bioenergy has gradually been understood by farmers as a new and legitimate source of income.[77]

2) **General socio-cultural traits in Radkersburg**

> *Organisms and species react to natural stimuli such as lack of food or the presence of a predator or to weather conditions, storms, fires and diseases. Human actors, firms and organisations react to prices, costs, tastes and preferences. Tastes and preferences are affected by their cultural context.*
>
> Korhonen (2004, 68)

The most distinctive feature of our species, *culture*, is a system of values, beliefs, customs and behaviours that members of a society share, use, learn from and transmit to each other to better adapt to their natural and social environment (Díez-Nicolas, 2003, 239; Townsend, 2000, 105; Bates, 1998, 7; Hawley, 1986). Discussed within this section, the existing socio-cultural traits in the district of Radkersburg and their influence on the developers of the Mureck bio-Energy Cycle are seen as additional means of interpreting the formation and evolution of the case in Mureck. The discussion is largely based on the interviews, survey and observations from the empirical study.

Social connectedness

In Radkersburg, the degree of social connectedness is very high, suggesting the existence of strong social networks, frequently based on kinship bonds. For instance, not only do people in various communities possess knowledge about their neighbours and fellow residents, but in general they are also aware about individuals from neighbouring communities. This is so

[77] Within the survey given to farmers, respondents stated first and foremost that *bioenergy projects in Styria aim principally to generate a new income driver for farmers.*

especially in the case of farmers, who know in detail about the activities of other farmers from Radkersburg and even from neighbouring districts. A partial explanation for this pattern is the strong interconnection of farmers, promoted by the Chamber of Agriculture through the organisation of regular meetings. The survey among farmers has found that most respondents are members of a political party.[78] As one informant summed up, "although there are few farmers nowadays, they have preserved their excellent lobby."[79]

Another explanation for the strong social connectedness concerns most individuals in Radkersburg and it refers to the large amount of time spent by people with socialising.[80] In spite of the rapid transformation process that started 50 years ago, this traditional behaviour pattern has been largely preserved in Radkersburg.

The high degree of networking offers an explanation to how collective activities are performed in the region. It also suggests how farmers became associated in the biodiesel cooperative SEEG and how the supply chains of the Mureck bio-Energy Cycle have been established. Moreover, this strong networking implies that in relative terms transaction costs for establishing the bioenergy system in Mureck were considerably lower as compared to the alternative of establishing this complex system in a region with less intensive networking.

Local trust and rural entrepreneurship

An interesting aspect especially for the formation of the MEC is the type and degree of social trust in the region. In the survey that was distributed after each interview, less than one half of all informants have agreed or strongly agreed with the statement that *most people can be trusted*. Besides, half of the respondents agreed or strongly agreed that *most people would try to take advantage of oneself if they got a chance to*. Hence, by implying that they need to be very careful in dealing with others, respondents indicated a rather ***low interpersonal trust***. An opposite claim is made by Padinger (2005), an expert in bioenergy projects who works for the Joanneum Research Institute in Graz, and who lives not far from Mureck. According to him, interpersonal trust is a *strong* asset in the region.

The field observations in this research actually support this latter view: Radkersburg is a small geographic territory where traditions work as a bond between people and where interpersonal trust occurs naturally, due to collective working and time spent together. Besides, the small-sized communities give proximity in space that facilitates ongoing personal contacts.

The responses in the survey might indicate yet another aspect of particular relevance to ***rural entrepreneurship***: proximity and neighbourliness place a series of *restrictions* on community members, especially if members are perceived as factors of change (Barth, 1943). In addition, new initiatives are regarded with suspicion not only because community members fear that *somebody else* is actually going to 'get rich'[81], but also because lack of trust in new technologies "is an anthropological constant, […] regardless of the type of innovation and the specific cultural context" (Rakos, 1998). Under such circumstances rural entrepreneurs must progressively build up community confidence by establishing interpersonal trust. They can

78 10 out of 13 responses to the survey distributed to farmers indicated this result.

79 Obwohl es wenige Bauer heute geblieben sind, haben sie ihr sehr gutes Lobby erhalten.

80 One part of the survey (Appendix IV) asked how often one meets friends, colleagues, members of the same congregation or co-members in clubs and voluntary associations. Most informants indicated for each category a *daily* interaction.

81 A series of anthropological case studies on Norwegian fishing communities have shown that community members try to place 'restrictions' on rural entrepreneurs whenever they fear that relations with these community members tend to develop in an asymmetrical way that would grant advantages in terms of income, status and ultimately power to the latter (Barth, 1963, 34).

only achieve community support if they fulfil *all* expectations that arise from *all* reciprocal relationships with their fellow-residents. Thus, while the previous section has argued that the alteration of the social environment of farmers in Radkersburg is likely to have pushed people towards entrepreneurial initiatives, only in combinations with human characteristics that favour entrepreneurship (such as self-confidence, need for achievement, leadership and strong internal control convictions) could this pressure lead to the actual implementation of bioenergy systems (Wiswede, 1995; Brockhaus, 1982).

As an endogenous initiative, the Mureck bio-Energy Cycle had to undergo the same laborious trust-building process: "my father […] has spent a long time with convincing [people] – be it private households, the township; [he has remained] many nights outdoors and has made calculations […] and practically this is how he has convinced all [residents] one by one"[82], says Totter Junior (2005). Totter's success to develop a sense of community coherence in Mureck supports the interpretation that the region has a traditional culture for open communication, which is based on high interpersonal trust. Yet, it further implies that Totter, the main developer of the Mureck system, had the necessary *social* and *entrepreneurial skills* to form a trust-base relationship with the Mureck community, from which he ultimately gained direct support for the bioenergy projects. Totter emerges as a ***project champion*** and a *catalyst* for the development of the Mureck bio-Energy Cycle. This interpretation is also supported by the survey and the interviews: almost all respondents who were asked to name key drivers of the MEC have begun by mentioning Totter and his incredible energy.[83] The important role played by indigenous champions as both drivers and upholders of sustained development of local bioenergy initiatives is also highlighted by Domac et al. (2005), Tomescu (2005a), Rösch and Kaltschmitt (1999) and Roos (1998).

As project developer, Totter was able to convince residents, farmers and local authorities that he will *not* behave opportunistically in the absence of real guarantees or enforceable promises. In doing so, he largely benefited from a second type of trust: ***systemic trust.*** Scholars have shown that the German-speaking part of Europe has developed a *high* systemic trust, as a result of coherent institutions and cultural traditions of collective decision-making (Bachmann and Lane, 1997; Lane and Bachmann, 1997; Lane and Bachmann, 1996; Lane, 1995; Stewart et al. 1994). Bachmann (2003, 77) posits that "the flexibility between individual economic actors in Germany and Austria does indeed constitutively draw on strong collective guarantees and institutional control." He further argues that these features are strong enough as to *discourage* opportunistic business behaviour driven by individual interests. This finding has explanatory power for the case in Mureck, in particular with regard to the gradual development of the basis for cooperation between the three co-located bioenergy projects. The finding may also suggest that, once the local authorities became supportive of the bioenergy initiatives, it became easier to develop community solidarity for these projects. A preference for collective decision-making may also explain one finding from the interviews. Namely, the fact that residents in Mureck endorse the farmers' cooperative SEEG with higher trust than the more recent Nahwärme and Ökostrom, which were established as limited companies.

To summarise, trust in the region of Mureck is based on traditional mutual commitment within a culturally homogenous area. Given the high transaction and coordination-costs required by innovative systems (DeBresson and Amesse, 1991; Scott, 1991), trust has

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[82] Mein Vater hat [...]sehr viel Zeit aufgewendent um Ueberzeugungsarbeit zu leisten, sei es bei den Privathaushalten, in der Gemeinde, draussen wo er Naechte gesessen ist und es vorgerechnet hat [...] und praktisch einen nach den anderen so ueberzeugt hat.

[83] 16 out of 21 respondents considered that the existance of the MEC ows in particular to the vision of a few people in Mureck.

represented a valuable social capital for the Mureck bio-Energy Cycle, by lowering the transaction costs related to the development of the project.

Traditional agricultural values, self-sufficiency and natural system vision
The industrial ecosystem in Mureck is in essence a rural agricultural initiative. The gradual evolution of the system in the direction of industrial symbiosis was assisted by the roundput philosophy of Totter, one of the main developers:

> *I have been a farmer myself […] and I remember very well when […] I collected hay for the draught animals with my father. When the mechanisation began, we abandoned this cycle […] And this has distracted us […] from the circular flow economy and the closed-loop thinking and the closed-loop acting.*

Like the majority of his generation in the district, Totter has grown up on a farm. The relatively homogenous socio-cultural background in Radkersburg, the high socio-cultural connectedness and the geographical proximity in the district have lead to the formation of a locally shared *cognitive representation* (Fornahl, 2003, 44). Cognitive representations have an impact on peoples' worldview and philosophy of life (Fornahl, 2003, 40) and affect the decisions made by individuals. That is, they influence the information that is memorised, the set of alternatives that are taken into consideration, their evaluation and finally the behaviour of a person (Anderson, 1980). For that reason, it is argued that traditional agricultural values, but also the profound transformation process that began in the 1950s in Radkersburg, have shaped the shared cognitive representation in the district and have ultimately imprinted on Totter's philosophy.

Totter's philosophy rests on two distinct bedrock principles:

1. the closing of *material loops*, which stems from a *biological analogy* (nature as a cycle), and

2. the closing of *production loops* for local farmers[84], which represents a wish for increased *self-sufficiency*.

First, as regards the closing of material loops, there is much historical evidence that material recovery has been a traditional practice in farming and agriculture. According to van der Ploeg (1994, 7), "A particular feature of farming is that the required resources entail 'nature' and that the subsequent conversion entails, in part, the management of biological processes, that is, *'natural cycles'*."[85] The same point is made by Desrochers, who analyses the historical recovery of animal by-products (Desrochers, 2000), and who shows the widespread collection of manure and its closed-loop use as fertilizer during the nineteenth century (Desrochers, 2002).

Besides, one century ago the 'turning of waste products into resources' was widely acknowledged as a feature of the German speaking part of Europe (Talbot, 1920; Spooner, 1918). Although slightly stereotypic, Talbot (1920, 19) for instance writes that "the German, when he encounters a waste, does not throw it away or allow it to remain an incubus. Saturated with the principle that the residue from one process merely represents so much raw material for another line of endeavour, he at once sets to work to attempt to discover some use for refuse."

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[84] According to Totter, cyclical farming should help farmers to "become independent from the world market and all its risks by meeting [their] personal requirements with raw materials from the local region" (Bio-energy Cycle Mureck, 2005, 4).

[85] The emphasis in italics was added by the author of this thesis.

If in Radkersburg too material recovery and loop-closing represent an important agricultural practice, then these elements have shaped the shared cognitive representation of residents in the district. This means that a new representation (i.e. the *loop-closing philosophy* of Totter), could have been introduced at individual level by processes like copying of representations or elements from one context to another (Fornahl, 2003, 41), hence, from farming to management of bioenergy technologies.

Second, Rakos (2005) considers that self-sufficiency is too a traditional agricultural value that is not necessarily limited to a regional phenomenon (e.g. Radkersburg). An example might be the concept of 'food self-sufficiency' that was predominant at community level before mechanisation began. In the survey that was distributed to farmers, most respondents agreed or strongly agreed that *if possible, a farmer should strive for self-sufficiency*.[86] However, during the interviews most farmers would say that 'these days traditional self-sufficiency is not feasible anymore'.

An interesting point is that more than half of the respondents to the survey considered that *in Austria the Länder (provinces) should have more power than at present*. Their response might suggest a local wish for more *self-reliance*. In addition, a web-browse for the German word 'Autarkie'[87] indicated that in Styria the concept of 'energy *self-sufficiency*' is very popular, being adopted as a goal by many rural communities. This is also the case in Mureck, where the community wishes to become 100% self-sufficient in terms of energy generation, within the next few years. Besides, in a general survey that inquired about top motivations of customers for connecting to biomass district heating plants, 75% of the responding residents have indicated that self-sufficiency played an important role (Rakos, 1997).

While *self-reliance* is related to the control over decision-making, *self-sufficiency* is linked to resource use by a particular individual or community (Vergunst, 2002, 149). Moreover, both self-reliance and self-sufficiency form the 'bedrock philosophy' of the 'Localisation school', which argues that local economies, as opposed to international economy, should become the centre of economic activity (Buckman, 2004, 150; Vergunst, 2002, 152; Simms, 2000, 17). In turn, localisation is seen as a *reaction* to the process of globalisation (Vergunst, 2002, 149) and as a solution to disembeddedness – the alienation of persons, objects or concepts from the *context* from which they previously derived their meaning (Hornborg, 1999, 149).

Disembeddedness has been shown to characterise Austrian rural settlements too. It has been referred to as the 'syndrome of acquired depression' that results from the "general cultural and social disintegration in rural areas" (Danielsen et al., 2001, 18; Rakos, 1998). In Radkersburg, farming communities are also affected by disembeddedness. The problem has emerged from the profound transformation process of the past 50 years that has altered the *traditional socio-cultural context* of these people.[88] As this transformation process went on, the deteriorating situation of farmers gradually raised individual awareness over personal income security. Therefore, self-sufficiency probably emerged as a community theme and as an element of the shared cognitive representation in Radkersburg, playing a role in the formation of Totter's loop-closing philosophy:

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[86] 8 out of 13 farmers agreed or strongly agreed with the statement, while only 4 farmers rather disagreed with it. One did not respond to the question.

[87] Autarky is a Greek word for self-sufficiency. In Hellenistic thought it referred to the state of being isolated and free from the demands of society. Currently it stands for economic independence as a (national) policy (McGraw-Hill Higher Education, 2005; Princeton University, 2005).

[88] Nowadays, farming communities in Radkersburg are so dependent on the external market, that farmers have to buy food for themselves at the marketplace. A general withdrawal from the market is not feasible anymore.

And if the people in charge for the world don't sleep well or if they get up on the wrong side of the bed, then we farmers might start getting in trouble. And we would like to avoid that, by becoming more self-reliant, more independent, by farming according to natural cycles and for the well-being of everybody within the region.[89]

Totter (2005)

[89] Und wenn die Verantwortlichen in der Welt einmal schlecht schlafen oder nicht so froehlich aufstehen, dann kann's Probleme geben mit uns Bauern. Und dem wollten wir entgehen, dass wir selbststaendiger werden, unabhaengiger werden, im KsLf der Natur bewirtschaften und zum Wohle aller in der jeweiligen Region. Nicht nur fuer die 4% Bauer die in At noch sind.

4 Conclusions

The examination of the Mureck bio-Energy Cycle from a systemic viewpoint that distinguished between four relevant dimensions of the case – (1) a techno-economic, (2) a socio-economic, (3) a political and (4) a socio-cultural – has provided meaningful insights and has generated pertinent responses to the research questions of this thesis. This chapter synthesises these insights in order to provide a better understanding of the case and to underpin the answering of the research questions. It further presents some general reflections upon the study and indicates areas that are perceived as meaningful for further research.

4.1 Integrative view

The Mureck bio-Energy Cycle, based on the integrated deployment of three different and innovative conversion technologies – a biodiesel plant (SEEG), a biomass district heating plant (Nahwärme) and a biogas plant that produces 'green' electricity (Ökostrom) – is in essence an endogenous agricultural initiative.

As shown in Section 3.4, on the socio-cultural subsystem of the case, since the 1970s a major driver for local initiatives towards bioenergy was the *niche overlap* of small farmers in Radkersburg (the district to which Mureck belongs) and their more efficient outside competitors. This overlap has forced farmers in the region of Mureck to search for alternative sources of income. One such alternative was bioenergy. Through the pressure exerted by the perception of the respective problem of farmers at the social level, a support policy for farmers was initiated by authorities in the 1980s. The initial promotion of rural bioenergy projects represented an effort of policy-makers to establish an 'artificial sub-environment' within which unprepared Austrian agriculturists would be sheltered from the tough competition on the global market.

Progressively, bioenergy has come to be regarded both at the political and at the socio-cultural level as an income generating alternative for farmers. While the degree and the purpose of the governmental promotion have varied over time, each of the three bioenergy projects in Mureck has received considerable financial support. An explanation is that these projects were established at times when *opportunities for support* for certain bioenergy initiatives were present at the political level.

Since the establishment in 1991 of the biodiesel plant SEEG in Mureck, the plant's deployers were confronted with the necessity to find a suitable application for glycerine, a considerable by-product that results from the production of biodiesel. The permanent striving of SEEG's deployers to make the best economic use of their by-product has driven the cooperation process with Nahwärme and later on with Ökostrom. As the cooperation harnessed reciprocal benefits for each participant, the actors gradually extended their cooperation basis, which came to include not only the use of glycerine, but also the joint use of machines and premises, the sharing of expertise, the integration of certain functions or departments for all three bioenergy projects and the cyclical deployment of Ökostrom and Nahwärme, as heat suppliers of the city of Mureck. By this, the projects in Mureck have gradually formed an *industrial ecosystem* that includes higher operational and energy efficiency, the valorisation of by-products and the novel, integrated deployment of the three different bioenergy technologies.

The emergence of this symbiotic pattern was facilitated through the *natural ecosystem vision* and *loop-closing philosophy* of Totter, the influential developer of the farmers' biodiesel cooperative SEEG. As shown by the analysis of the socio-cultural subsystem, Totter's philosophy has been shaped by both traditional agricultural values of closed-loop farming in the region, and by the generalised economic pressure on farmers in Radkersburg over the past 40 years, which generated a strive for more self-sufficiency.

All three bioenergy projects in Mureck have adopted a participatory approach, not least because their owners and developers are farmers from the region. As their proprietary rights were accompanied by the performance of services, they stood in a direct relation to the local community. On one hand, this has made side-stepping of obligations impossible. On the other hand, it has permitted a continuous stakeholder dialogue that facilitated information exchange among local actors and that fostered new local and regional initiatives.

Some of the most important regional benefits of the Mureck bio-Energy Cycle are job creation, increased convenience (especially for customers of Nahwärme), additional income opportunities for local farmers, and increased prestige and added value for the Mureck community. As a negative effect, the system contributes indirectly to increasing the local land use competition. However, this is rather a cumulative consequence of the high number of biogas plants in the region. In particular small pig breeders have complained about this effect, but it is likely that the situation will evolve towards a balance.

A further finding is that the Mureck bio-Energy Cycle uses to a large extent renewable resources, such as rapeseed, maize or wood, which are harvested from within the immediate agricultural setting in which the system operates, and which therefore increases the local self-sufficiency. However, SEEG's reliance on external resources (i.e. used frying oil that is collected within a radius of 200 km) indicates that the system is neither local, nor self-sufficient.

A general explanation to the innovative character of the case is the existence of a thorough cooperation triangle in the region, which includes the developers in Mureck, centres of knowledge excellence and technology suppliers. Cooperation has either taken the form of joint R&D activities, or that of joint planning, construction and optimisation of processes and installations based on a 'trial and error' process. Worth mentioning is that the biodiesel plant SEEG is a *university spin-off* that has evolved from a pilot project of the University of Graz. Not only has SEEG preserved its excellent ties to this knowledge centre, but it has also built new partnerships with the Technical University Graz and with the University of Natural Resources and Applied Life Sciences in Vienna. Through action research, these institutions have facilitated the development of the industrial ecosystem in Mureck and have constituted an ongoing trouble-shooting service for problems which have occurred over time. The direct and continuous flow of information between design, construction and practical operation of the plants has contributed significantly to the development and early adoption of innovations in Mureck, stressing the crucial role of networking for the promotion of innovation.

4.2 General reflections upon the study

This study showed that two major drivers have initiated the establishment of the bioenergy projects in Mureck:

1. the generalised economic pressure on farmers that triggered local bottom-up initiatives, and

2. the willingness of authorities to support (rural) bioenergy projects that spurred top-down support.

However, it is important to note that Austria has gathered a considerable experience with bioenergy, and that the country has established a reliable technology support system.

In the region of Mureck, four obvious, yet often overlooked preconditions for the implementation of bioenergy systems were available:

- abundant biomass resources, and their traditional use,
- R&D centres and technology suppliers, which provided the basis for innovation,
- local trust, which was essential for establishing the system, and ultimately
- local entrepreneurs, who were willing to take up the challenge.

The location-related positive externalities of the projects in Mureck, but also the nature of their technologies, highlight that *industrial ecosystems* can bring gains in all three dimensions of sustainable development: economic, social and environmental.

The gradual evolution of cooperation points out that the present structure of the system has neither been foreseen from the beginning, nor has it been designed from scratch. Instead, the system has evolved *gradually*, as new opportunities arose and as cooperation unfolded. For this reason it is argued that the industrial ecosystem in Mureck is not a pilot project to be literally replicated within other regions which cannot bring together the basic conditions that were present in Mureck. Perhaps one should acknowledge instead the role of cooperation with research institutions and with technology suppliers. This networking has made possible the diffusion of innovations and of novel solutions for the recovery of by-products in the system.

Further, the importance of the guiding *natural ecosystem vision* and *loop-closing philosophy* needs to be stressed. In Mureck, the vision and philosophy have influenced the goal-setting at the mission level, acting as a leverage point that facilitated the development of the industrial ecosystem.

Last but not least, the analysis of the innovative Mureck bio-Energy Cycle has contributed to the understanding of factors that influence bioenergy diffusion in general. As regards the successful penetration of bioenergy systems, the study stresses that it is rather the cumulative effect of a wide range of interlinked factors, than the result of few overwhelmingly significant aspects. Additionally, the system in Mureck offers '*best-practice' information* especially by showing the important role of industrial ecology, as a management philosophy. The case may also offer a new vision for rural development, based on development options which naturally complement the traditional agriculture and forestry sectors in Europe.

4.3 Suggestions for further research

The present study has found that in Styria cultivation of rapeseed and maize for energy purposes is mainly done on set-aside land, and that the trend for rapeseed cultivation is falling. Given (1) the structural small size of the farms in the region that determines the size of the set-aside land, and (2) the boom of biogas plants in the region, an interesting area to explore is whether rapeseed cultivation for biodiesel competes for land use (on set-aside land) with maize cultivation for biogas plants, and if so, what are the likely consequences of this competition.

A further interesting area for research concerns the degree of self-sufficiency of the system in Mureck. As it was shown, this system relies to a large extent on resources collected from within the immediate regional boundaries. However, the lack of data on the collection of used frying oil has prohibited the analysis on the degree of localisation of the Mureck bio-Energy Cycle.

More generally, this paper researched the evolution, functioning and implications of an industrial ecosystem consisting of three bioenergy projects in the region of Mureck. It found that local culture has contributed significantly to the evolution of the system, by decreasing overall transaction costs and by influencing the regional cognitive perception of entrepreneurs (i.e. through analogies to natural cycles). Schwarz and Steininger (1997), who conducted a survey of waste recycling linkages in the larger province of Styria, have concluded that there are more complex and dynamic inter-industry recycling structures in this (traditionally agricultural) province, than in the Danish Kalundborg. Although the authors do not emphasise, it seems that the majority of these recycling linkages were formed around materials derived from farm and forestry activities, such as sawdust, residual wood, wood chips, bark, slaughter house and meat waste, spent malt, fodder, rapeseed cake and others (Schwarz and Steininger, 1995, quoted by Chertow, 2000, 318). Therefore, it would be interesting to research whether the tradition of closed-loop farming has any implications upon the emergence of industrial ecosystems.

Finally, this thesis has found that the system in Mureck was supported by a local champion, who has acted as both a driver and upholder of the initiative. Although some authors (Domac, 2005; Tomescu, 2005a; Rösch and Kaltschmitt, 1999) have stressed the important role of local leaders as prime catalysts for the implementation of bioenergy systems, perhaps the relevance of project leadership was underestimated and should be looked into more carefully.

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Abbreviations

BD	Biodiesel
BMDH	Biomass District Heating
BoKu Vienna	University of Natural Resources and Applied Life Sciences in Vienna
CHP	Combined heat-and-power (plant)
IE	Industrial Ecology
IEA	International Energy Agency
IIIEE	International Institute for Industrial Environmental Economics
IS	Industrial Symbiosis
EU	European Union
MEC	Mureck bio-Energy Cycle
RES	Renewable Energy Sources
RME	Rapeseed Methyl Ester
SEEG	South Styrian Cooperative for Energy and Protein Production
UFO	Used frying oil
UFO-ME	Used frying oil Methyl Ester
WAF	Waste animal fat

Appendix I: Overview of technologies at the MEC

SEEG Mureck (biodiesel)

Technology:

BDI/Junek/Mittelbach

2 screw extrusion presses with a procession capacity of 400 kg rapeseed crops/h

Reservoir for crude vegetable oil: 600 m^3

Cleaning devices, laboratory, 2 transesterification units

Storage tank for final product: 500 m^3

Storage tank for glycerine: 100 m^3

Nahwärme Mureck (BMDH)

Technology:

Kohlbachkessel 2 x 2 MW

Tissue filter/flue gas cleaning

District heating network: 12.5 km; Supplied objects: 200

Heat-exchange installations Nopro

Ökostrom Mureck (biogas)

Technology:

LIPP/Nahtec/Tvp/Deuz/ARGE Mandelbauer-Röck

Temporary silo: 600 m^3; Driving silo: 6 000 m^3;

Mixing pit: 100 m^3; Hydrolisis tank: 200 m^3

Anaerobic Methane Fermentation Reactors 4 x 1 000 m^3, each equipped with a 300 m^3 gas-reservoir

Storage tank for separation of solids

Substratum repository (biogas manure storage tanks):

- 2 x 3600 m^3 in Mureck
- 1 x 1300 m^3 in Wittmansdorf
- 1 x 700 m^3 in Gosdorf
- 1 x 5300 m^3 in Weitersfeld

Gas engine of Deutz company:

- Electrical power 999 kW
- Thermal output 1165 kW

Appendix II: Description of the biogas fermentation process

(Adapted from Wang, Y. et al., 2001, Nov. 15 - Dec. 20)

Biogas fermentation is a complex process, based on the interaction of a variety of bacteria under different conditions in a complicated relationship. The biogas fermentation process was thought to consist of two stages: first the dissolving of complex organic compounds into basic structure, leading to accumulating organic acids that decrease the total pH value. Second, simple organic matters ferment to make methane.

More recent research highlights that the biogas fermentation process might consist of three stages: since only a few compounds (such as acetic acid, formic acid, H2 or CO2) are accepted as substrate for microbes to produce the final methane gas, the anaerobic digestion process consists of (1) liquefaction, (2) production of hydrogen and acetic acid, and (3) production of methane gas.

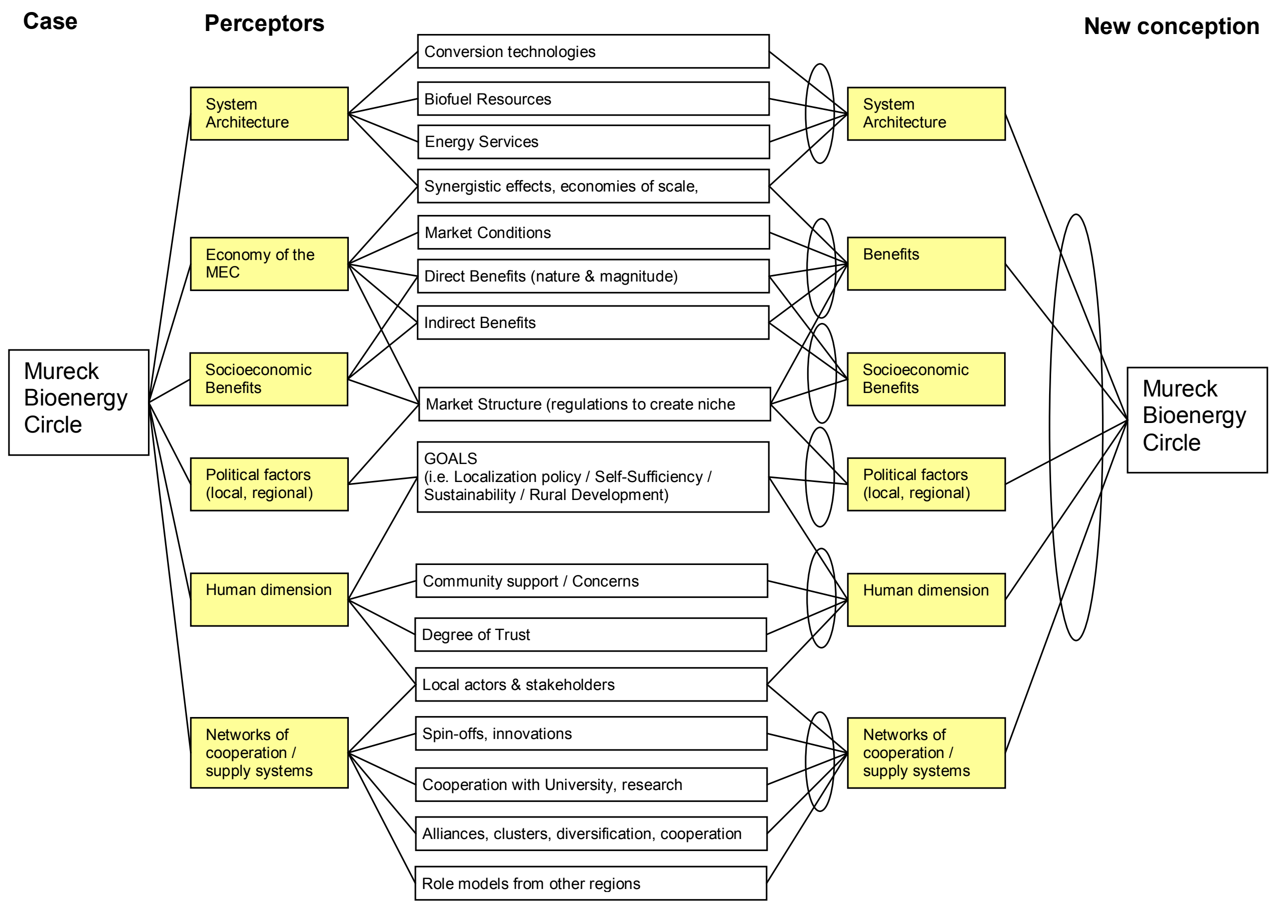
(1) Liquefaction
During the liquefaction process complex organic matters, such as fibre, protein and fat, are degraded to simple organic matter by hydrolysing bacteria. Protein is made into polypeptide and amino acid, fat into glycerine and strand fatty acid, amylose into monosacride and polysacride. These hydrolysing bacteria are heterotrophic, meaning that they are facultative microbes and a few anaerobic bacteria that widely exist in the surroundings.

(2) Production of hydrogen and acetic acid
Simple organic matters produced by or contained in materials are converted into H2 and CO2 by microbes. The acting bacteria (i.e. bacillocin, microglobal bacterium, or pseudominas) are called bacteria for production of hydrogen and acetic acid.

(3) Methane producing
Methane-producing bacteria transform acetic acid, H2 and CO2 into methane. Methane is produced in two ways: either it is directly transformed from the CH3 existing in the molecule of acetic acid, or it is produced by redox of CO2 and H2. Some 70% of all methane is generated from acetic acid, the rest being produced from CO2 and H2. Methane-producing bacteria (i.e. Methanomicrobium, Methanosarcina, Methanococcus, and Methanothrix, etc.) are strict anaerobic bacteria. Usually they require strict pH-values and have low adaptability to temperature changes. The bacteria that were cultivated at a certain temperature can destroy digestion when the temperature is lowered by 1-2oC. However, they can reproduce fast, a new generation needing only 4-6 days.

In general, biogas fermentation results from the interaction of non-methane bacteria and methane-producing bacteria, where the interaction process is based on the transfer of hydrogen between the types of bacteria: hydrogen produced by the former is provided to the latter to produce methane from carbon dioxide.

Appendix III: Analysis framework of the case



Appendix IV: Survey Adjacent to the Interview

Zusätzlicher Fragebogen zum Interview
Survey Adjacent to the Interview

Für die nächsten drei Fragen, bitte kreisen Sie jeweils eine Antwort ein, die am besten Ihren Einstellungen entspricht.
For the next three questions, please mark one answer, which corresponds best to your personal views.

1. **LINKS, MITTE und RECHTS sind drei Begriffe, die häufig gebraucht werden, um politische Ansichten zu charakterisieren. Können sie mir sagen, wo sie selber auf einer Skala stehen, bei der 0 ganz links bedeutet, 5 die Mitte ist und 10 für ganz rechts steht.**
In political matters, people talk of "the Left", "the Center" and "the Right". How would you place your views on a scale, where 0 means far Left, 5 means Center and 10 means far Right.

(0	1	2	3	4	5	6	7	8	9	10)
Links				Mitte				Rechts		
Left				*Center*				*Right*		

11 Weiss nicht — 11
Don't know
12 Keine Antwort — 12
No answer

2. Bitte sagen Sie mir, ob Sie Mitglied einer politischen Partei und/oder Organisation sind.
Can you please tell me if you are member of a political party or organisation?

1 Ja — 1
Yes
2 Nein — 2
No
3 Keine Antwort — 3
No answer

3. Bitte sagen Sie mir, in wie vielen ehrenamtlichen Verbänden, wie z.B. gemeinnützige Organisationen oder Interessengemeinschaften, Sie Mitglied sind?
Can you please tell me in how many voluntary associations, such as non-profit institutions, social movements or communities of interest you are a memeber?

0 1 2 3 4 5 6 7 8 9 10 mehr als zehn (wie viel? __)
more than ten (how many? __)

Wir möchten Ihnen jetzt einige Aussagen zu verschiedenen Aspekten der österreichischen Gesellschaft präsentieren. Bitte kreisen Sie jeweils eine Antwort ein, die am besten Ihren Wünschen für Österreich entspricht.
We are now going to present some statements about the Austrian Society. For each statement, can you please mark one answer, which corresponds best to your wishes and expectations for Austria?

4. Österreich sollte sich vermehrt nach außen öffnen.
Austria should open up more towards the outside (world).

1 Einverstanden — 1
1 Agree
2 Nicht einverstanden — 2
2 Disagree
3 Weiß nicht — 3
3 Don't know
4 Keine Antwort — 4
4 No answer

5. Die BürgerInnen Österreichs sollen sich mehr an den wichtigen Entscheidungen der Regierung beteiligen.
The Austrian citizens must participate more in important government decisions.

1 Einverstanden — 1
1 Agree

2 Nicht einverstanden *2 Disagree*	2
3 Weiß nicht *3 Don't know*	3
4 Keine Antwort *4 No answer*	4

6. Die Regierung sollte Österreichischen BürgerInnen bessere Chancen als Ausländern zur Verfügung stellen.
The government should provide better chances to Austrian citizen than to immigrants.

1 Einverstanden *1 Agree*	1
2 Nicht einverstanden *2 Disagree*	2
3 Weiß nicht *3 Don't know*	3
4 Keine Antwort *4 No answer*	4

7. In Österreich sollte Zentralplanung mehr wiegen, als Wettbewerb auf dem Markt.
In Austria, central planning should weigh more than market competition.

1 Einverstanden *1 Agree*	1
2 Nicht einverstanden *2 Disagree*	2
3 Weiß nicht *3 Don't know*	3
4 Keine Antwort *4 No answer*	4

8. Heutzutage und in der Zukunft sollen Leute ihren wirtschaftlichen Wohlstand einschränken, wenn dadurch dem Umweltschutz beigetragen werden kann.
Currently and in the future people should limit their economic wealth if this can prevent environmental pollution

1 Einverstanden *1 Agree*	1
2 Nicht einverstanden *2 Disagree*	2
3 Weiß nicht *3 Don't know*	3
4 Keine Antwort *4 No answer*	4

9. In Österreich sollten die Länder mehr Macht haben als bis jetzt.
In Austria the Länder should have more power than at present.

1 Einverstanden *1 Agree*	1
2 Nicht einverstanden *2 Disagree*	2
3 Weiß nicht *3 Don't know*	3
4 Keine Antwort *4 No answer*	4

10. In Österreich sollen Traditionen höher als moderne Werte gestellt werden.
Traditions in Austria must be ranked higher than modern values.

1 Einverstanden *1 Agree*	1
2 Nicht einverstanden *2 Disagree*	2
3 Weiß nicht *3 Don't know*	3
4 Keine Antwort *4 No answer*	4

Wir haben einige Argumente zu unterschiedlichen Aussagen zusammengestellt. Geben Sie bitte jeweils an, was Sie von diesen Ansichten halten.
We have prepared some arguments to various statements. Would you please say with which of these statements you yourself agree?

11. Sind Sie voll einverstanden, eher einverstanden, eher nicht einverstanden oder überhaupt nicht einverstanden?
Do you agree strongly, rather agree, rather disagree or strongly disagree?

Traditionale landwirtschaftliche Tätigkeiten stehen unter zunehmenden Druck
Traditional agricultural activities are subjected to increased pressure

1 Voll einverstanden *1 Strongly agree*	1
2 Eher einverstanden *2 Rather agree*	2
3 Eher nicht einverstanden *3 Rather disagree*	3
4 Überhaupt nicht einverstanden *4 Strongly disagree*	4
5 Weiß nicht *5 Don't know*	5
6 Keine Antwort *6 No answer*	6

12. Sind Sie voll einverstanden, eher einverstanden, eher nicht einverstanden oder überhaupt nicht einverstanden?
Do you agree strongly, rather agree, rather disagree or strongly disagree?

Man kann den meisten Leuten vertrauen.
Most people can be trusted.

1 Voll einverstanden *1 Strongly agree*	1
2 Eher einverstanden *2 Rather agree*	2
3 Eher nicht einverstanden *3 Rather disagree*	3
4 überhaupt nicht einverstanden *4 Strongly disagree*	4
5 Weiß nicht *5 Don't know*	5
6 Keine Antwort *6 No answer*	6

13. Sind Sie voll einverstanden, eher einverstanden, eher nicht einverstanden oder überhaupt nicht einverstanden?
Do you agree strongly, rather agree, rather disagree or strongly disagree?

Falls es möglich wäre, würden die meisten Leute versuchen, jemanden auszunutzen.
If they got a chance, most people would try to take advantage of oneself.

1 Voll einverstanden *1 Strongly agree*	1
2 Eher einverstanden *2 Rather agree*	2
3 Eher nicht einverstanden *3 Rather disagree*	3
4 Überhaupt nicht einverstanden *4 Strongly disagree*	4
5 Weiß nicht *5 Don't know*	5
6 Keine Antwort *6 No answer*	6

14. Sind Sie voll einverstanden, eher einverstanden, eher nicht einverstanden oder überhaupt nicht einverstanden?
Do you agree strongly, rather agree, rather disagree or strongly disagree?

Soweit möglich, sollte ein Landwirt Autarkie anstreben.
If possible, a farmer should strive for self-sufficiency.

1 Voll einverstanden 1
1 Strongly agree
2 Eher einverstanden 2
2 Rather agree
3 Eher nicht einverstanden 3
3 Rather disagree
4 Überhaupt nicht einverstanden 4
4 Strongly disagree
5 Weiß nicht 5
5 Don't know
6 Keine Antwort 6
6 No answer

Wir möchten Ihnen einige allgemeine Fragen zu der Gemeinde Mureck und seinem Bio-Energiekreislauf stellen. Geben Sie bitte jeweils an, welche der folgenden Aussagen Ihrer Ansicht entspricht.
We would like to ask you some general questions about the Mureck community and its Bioenergy Cycle. Please indicate which of the following statements corresponds to your personal view.

---

15. Sind Sie voll einverstanden, eher einverstanden, eher nicht einverstanden oder überhaupt nicht einverstanden?
Do you agree strongly, rather agree, rather disagree or strongly disagree?

Der Murecker Energiekreislauf (MEK) ist der Stolz der Gemeinde.
The Mureck Energy Cycle (MEC) is the pride of the community.

1 Voll einverstanden 1
1 Strongly agree
2 Eher einverstanden 2
2 Rather agree
3 Eher nicht einverstanden 3
3 Rather disagree
4 Überhaupt nicht einverstanden 4
4 Strongly disagree
5 Weiß nicht 5
5 Don't know
6 Keine Antwort 6
6 No answer

---

16. Sind Sie voll einverstanden, eher einverstanden, eher nicht einverstanden oder überhaupt nicht einverstanden?
Do you agree strongly, rather agree, rather disagree or strongly disagree?

Der MEK erhöht den Druck auf die Umwelt.
The MEC increases the pressure upon the natural environment.

1 Voll einverstanden 1
1 Strongly agree
2 Eher einverstanden 2
2 Rather agree
3 Eher nicht einverstanden 3
3 Rather disagree
4 überhaupt nicht einverstanden 4
4 Strongly disagree
5 Weiß nicht 5
5 Don't know
6 Keine Antwort 6

6 No answer

17. Für die nächsten drei Fragen, kreisen Sie bitte alle Antworten ein, die Sie als zutreffend betrachten.
For the next three questions, please mark all answers which you believe are appropriate.

Der MEK verdankt sich hauptsächlich:
The MEC ows in particular to:

1 den Rohstoffen die vorhanden sind *1 the availability of resources*	1
2 den erwarteten Gewinnmöglichkeiten *2 the profit opportunities that were expected*	2
3 der Vision einiger Leute aus Mureck *3 the vision of a few people from Mureck*	3
4 den örtlichen Kooperationsbeziehungen die das Projekt ermöglichten *4 the local cooperation that made the implementation of the project possible*	4
5 der Förderung durch die Behörden *6 the promotion/aid from authorities*	5
6 anderes, was? *6 something else, what?*	6
7 weiß nicht *7 don't know*	7
8 keine Antwort *8 no answer*	8

18. Das Einsammeln von Altspeiseöl ...
The collection of used cooking oil ...

1 ist umweltfreundlich *1 is environmentally friendly*	1
2 ist wirtschaftlich nützlich *2 is economically advantageous*	2
3 sollte erweitert werden *3 should be expanded*	3
4 ist zu kompliziert *4 is too complicated*	4
5 anderes, was? *5 something else, what?*	5
6 weiß nicht *6 don't know*	6
7 keine Antwort *7 no answer*	7

19. Bioenergieprojekte in der Steiermark bezwecken hauptsächlich ...
Bioenergy projects in Styria aim principally to ...

1 den Umweltschutz zu erhöhen *1 increase the environmental protection*	1
2 ein neues Standbein für die Landwirte zu erschaffen *2 generate a new income driver / a second string to the bow of farmers*	2
3 Österreichische Innovationen umzusetzen *3 implement Austrian innovation*	3
4 die Österreichische Importabhängigkeit an fossilen Brennstoffen zu vermindern *4 reduce the Austrian fossil fuel import dependency*	4
5 weiß nicht *5 don't know*	5
6 keine Antwort *6 no answer*	6

Zum Abschluss noch einige Statistik-Fragen.
Finally a few statistical questions.

20. Welcher Konfession gehören sie an?
To which religious denomination do you belong?

römisch-katholisch *Roman Catholic*	1
christkatholisch *Christian Catholic*	2
protestantisch *Protestant*	3
keine Konfession *no denomination*	4
5 weiß nicht *5 I don't know*	5
6 keine Antwort *6 no answer*	6

21. Wie oft, wenn überhaupt, treffen Sie Ihre Freunde?
How often, if at all, do you meet your friends?

1 einmal die Woche oder öfters *1 once a week or more often*	1
2 mindestens einmal im Monat *2 at least once a month*	2
3 mehrmals jährlich *3 several times a year*	3
4 nur bei speziellen Anlässen (Taufen, Hochzeiten, Begräbnisse) *4 only on special occasions (christenings, weddings, funerals)*	4
5 nie *5 never*	5
6 keine Antwort *6 no answer*	6

22. Wie oft, wenn überhaupt, treffen Sie Ihre KollegInen außerhalb des Arbeitsplatzes?
How often, if at all, do you meet your colleagues outside of the workplace?

1 einmal die Woche oder öfters *1 once a week or more often*	1
2 mindestens einmal im Monat *2 at least once a month*	2
3 mehrmals jährlich *3 several times a year*	3
4 nur bei speziellen Anlässen (Taufen, Hochzeiten, Begräbnisse) *4 only on special occasions (christenings, weddings, funerals)*	4
5 nie *5 never*	5
6 keine Antwort *6 no answer*	6

23. Wie oft, wenn überhaupt, treffen Sie Personen, die zu Ihrer Kirchengemeinde gehören?
How often, if at all, do you meet persons who belong to your congregation?

1 einmal die Woche oder öfters *1 once a week or more often*	1
2 mindestens einmal im Monat *2 at least once a month*	2
3 mehrmals jährlich *3 several times a year*	3
4 nur bei speziellen Anlässen (Taufen, Hochzeiten, Begräbnisse) *4 only on special occasions (christenings, weddings, funerals)*	4
5 nie *5 never*	5
6 keine Antwort *6 no answer*	6

24. Wie oft, wenn überhaupt, treffen Sie Mitglieder von Klubs und Interessengemeinschaften zu denen Sie gehören?
How often, if at all, do you meet co-members in clubs and voluntary associations?

1 einmal die Woche oder öfters *1 once a week or more often*	1
2 mindestens einmal im Monat *2 at least once a month*	2
3 mehrmals jährlich *3 several times a year*	3
4 nur bei speziellen Anlässen (Taufen, Hochzeiten, Begräbnisse) *4 only on special occasions (christenings, weddings, funerals)*	4
5 nie *5 never*	5
6 keine Antwort *6 no answer*	6

25. Bitte deuten Sie mit einem Kreuz (X) die höchste Ausbildungstufe die Sie vervollständigt haben, an:
Please indicate with a cross (X) the highest education level that you have completed:

a. Obligatorische Schule (Primar-, Sekundar-, Real-, Bezirksschule, Pro-, Untergymnasium) ☐
Obligatory school (primary school, secondary school, secondary modern school, district school, etc.)
b. Berufslehre oder Vollzeit-Berufsschule ☐
Vocational school, full-time vocational school
c. Maturitätsschule, Primarlehrerausbildung, Berufsmaturität ☐
Elementary school teacher training
d. Höhere Fach- und Berufsausbildung (Bsp: Kunstgewerbeschule) ☐
Higher special training and technical education
e. Höhere Fachschule (z. B. HTL, HWV) ☐
Higher technical school
f. Technische Hochschule (z. B. ETH), Fachhochschule (FHS) ☐
Technical college
g. Universität ☐
University

26. Bitte sagen Sie mir, welches Ihre gegenwärtige *Berufstätigkeit* ist
Please indicate your current occupation

27. Bitte sagen Sie mir, welches Ihre frühere Berufstätigkeit gewesen ist
Please indicate your previous occupation

28. Bitte sagen Sie mir, in welchem Jahre Sie geboren wurden
Please indicate your date of birth

Jahr _______________
Year _______________

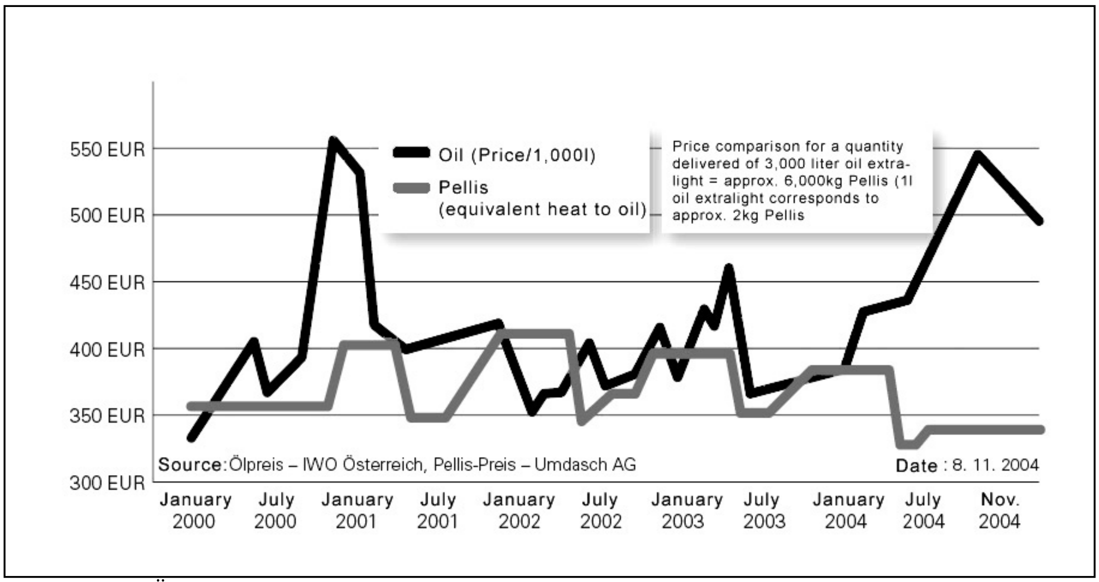
Sind Sie in Mureck/Bad Radkersburg geboren? Ja ☐ Nein ☐
Were you born in Mureck/Bad Radkersburg? *Yes* *No*

Das wäre es.
That would be all.
Sind Sie mit der Befragung zufrieden? **Ja** ☐ **Nein** ☐
Are you satisfied with the interview? ***Yes*** ***No***

Ich danke Ihnen und wünsche Ihnen einen schönen Tag! / ***Thank you and wish you a nice day!***

Appendix V: Price development for light fuel oil – pellets

According to the Biomasseverband Österreich, the price of pellets is with 30 to 40% higher than the price of wood chips. Since 1996 the prices of wood chips have increased with only 5% in Styria, while the prices for pellets have decreased with 9% starting with the year 2000. The same source states that in October 2004 the production of one kilowatt hour from oil would cost approximately 5 Cents in Styria, being twice as high as the costs of producing the same amount of energy from wood chips, and with 40% higher than if pellets were used (Styrian Chamber for Employees in Agriculture and Forestry, 2004, 2)



Source: IWO Österreich, Pellis-Preis – Umdasch AG