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Bachelor Thesis

Bio-Energy Villages in Germany

A Comparison of decentralized, rural Energy Systems

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AG	Aktiengesellschaft
BHKW	Blockheizkraftwerk
CO^2	Carbon dioxide
EEG	Erneuerbare Energien Gesetz
eG	Eingetragene Genossenschaft
EU	European Union
GbR	Gesellschaft bürgerlichen Rechts
GmbH	Gesellschaft mit beschränkter Haftung
GmbH & Co.KG	Gesellschaft mit beschränkter Haftung & Compagnie Kommanditgesellschaft
KfW	Kreditanstalt für Wiederaufbau
kWh	Kilowatts per hour
kWp	Kilowatt peak
L	Liter
m^3	Square metre
MW	Megawatt
OHG	Offene Handelsgesellschaft

1. Abstract

The liberalization of the energy market and the effort of the German government to trigger an "Energiewende" (energy transition) led to the development of modern decentralized energy systems in rural areas, called bio-energy villages. The following bachelor thesis was conducted to present differences and similarities of economic, institutional and technological characteristics between existing bio-energy villages in Germany and develop typologies for existing projects. Qualitative data was collected in a cross-sectional design through semi-structured interviews and complemented by pre-existing data from appropriate online sources. As the total number of 121 bio-energy villages in Germany exceeded the limit of examinable cases within the given time-frame, a step-wise case selection was conducted, ensuring a high variability between the cases.

During the assessment and analysis of these cases, a high variation between most aspects could be observed. As a fixed component the implementation of biogas plants, combined with a cogeneration plants and adhering heating networks was pointed out. Further, this thesis provides an institutionally and technology oriented classification of bio-energy villages, based on production technologies and organisational structures. According to these two dimensions five classifications were developed: the agriculture model, the cooperative model, the basic institutional hybrid model, the diverse institutional hybrid model and the capital company model.

2. Introduction

In recent years, various transformations in the energy sector could be observed due to technological and institutional changes, climate change and the limited capacity of fossil resources. As a response to the negative externalities caused by the use of fossil and nuclear energy, Germany introduced a key policy document in September 2010 outlining a framework for an energy transition (Energie Wende). This policy framework targets a greenhouse gas reduction of 80-95%, an increased share of 60% renewable energy supply as well as a 50% higher electricity efficiency for 2050 (Bundesregierung, 2010). The outline included an increased share of renewable energies for all energy sectors, heating, cooling, electricity and mobility, mainly due to the use of wind, solar and hydro energy.

The current transitions-process fosters a shift from the predominantly centralized energy infrastructure model to a decentralized community-based approach. As a conclusion, an increasing number of re-organized energy systems can be observed. In 2005, the village Jühnde in Lower Saxony, Germany, implemented a concept, developed by the interdisciplinary centrum for sustainable development of the university Gottingen, which enabled the community to cover its own energy demand through the use of local biomass technology and other renewable energy sources. Thus, Jühnde was the first community given the title, "Bioenergiedorf" (bio-energy village). Bio-energy villages represent a modern, rural, decentralized approach to re-organize the energy system and can be described as new growing phenomena in Germany and around the world. In scientific literature, no common definition for the term “Bioenergiedorf” can be found (Ruppert 2008). However, according to Ruppert (2008), such a community has to meet the following four conditions to be granted the status of a bio-energy village:

- The level produced electricity within the community has to cover its demand.
- At least 50% of the community’s heat consumption has to be covered, preferably through the use of combined heat and power (CHP).
- At least 50% of the production facilities have to be owned by farmers and consumers.
- Biomass used for energy production shall not be obtained from corn monocultures or genetically engineered plants

The deployment and integration of renewable energy is accomplished at the community level, involving scattered and small-scale production units located close to consumers (Bauwens, Gotchev et al. 2016). However, the broad outline of the term “bio-energy village” includes a wide range of different potential outcomes, concerning their institutional, technological and economic set-up. The concept and its tools for integrating renewable energies should be implemented in an economically optimal manner, meaning a cost-effective and efficient use of labor and resources. Further, a local energy infrastructure needs to be implemented that works in a self-sufficient way, or in harmony with the nationwide system. The community-scale integration of renewable energy technologies has to be established in a manner that guarantees a continuous energy supply. Existing bio-energy villages use different strategies and technologies to meet these challenges. At the moment only a few studies that compare these strategies. Present studies address first of all the rate of acceptance by stakeholders and in the public (Dobó et. al 2007, Domac et. al 2005, Lemmens & Kirkels 2007). These studies emphasize that the level of acceptance varies according to the region and is subject to a dynamic process. The leading share of the available literature that describes the set-up of bio-energy villages analyze the set-up of one or a few cases, focusing on the technological set-up or the organizational framework. Additionally, an emphasis is put on socio-economic and ecological effects, for example evaluating the degree of CO_2 reduction and the impact on the local economy. Furthermore, the potentials, costs and consequences of regional energy are discussed. Schmidt et al. (2012) gives a broad overview of their potential impact using the example of Austrian bio-energy-regions.

The available literature fails to properly address and visualize the high variability between communities conceptualized as, “bio-energy villages”. In order to fill this gap in scientific literature this study is examining similarities and differences between existing bio-energy villages in Germany. The objective is to learn about the structure of key issue-related features of existing communities. By pointing out existing patterns of bio-energy villages this study aims at creating useful typologies for bio-energy villages. As a conclusion, the following descriptive research question can be formulated:

What are differences and similarities between bio-energy villages in Germany regarding their economical, institutional and technological characteristics?

Underlying patterns may add up, representing a particular type of bio-energy village. As a conclusion a sub question of the study can be formulated as follows:

How can technological, institutional and economic similarities and differences give rise to theoretically grounded classifications?

3. Concept

In this section the concept “bio-energy village” in relation to the term “community energy system” will be further clarified. Scientific literature that refers to the general drivers of energy community as well as distinct literature about the set-up of bio energy villages will be presented. Moreover, relevant conceptualizations regarding institutional, economic and technical characteristics will be presented and explained how they will inform this study.

3.1 Energy communities and bio-energy villages

The concept “community energy system” or “energy community” cannot be clearly separated from the concept “bio-energy village”. Walker et al. (2012) define the term “community energy” as the following: “Community energy’ in broad terms refers to electricity and/or heat production on a small, local scale that may be governed by or for local people or otherwise capable of providing them with direct beneficial outcomes” (Walker et al., 2012, p.195). This rather vague concept of community energy encompasses the idea of the bio-energy village. However, the term bio-energy village represents a more specific approach: Only rural communities, with a focus on the use of biomass, qualify as bio-energy villages.

In general, energy communities share similar drives. Next to the environmental benefits gained by the usage of renewable energy, energy communities offer promising advantages if properly managed. Kiorala et al. (2016) points out that such community energy systems can create jobs and increase the economic prosperity of a community. Wildsporied, a village in Bavaria experienced a sudden increase of its income through its efforts to implement renewable energy sources. Further, Rupert (2008) emphasizes that the implementation of bio-energy villages represent an effective tool to reduce the dependency on foreign resource imports and avoid rising electricity prices caused by limited fossil resources. Additionally, the author mentions structural changes in rural areas in Germany, which result in a decrease of infrastructure and jobs in those areas. The establishment of bio-energy villages would effectively counter such developments and enhance the community cohesion.

3.2 Technological Characteristics

Technological assets and innovations represent an essential part of the concept, bio-energy village. New technologies enable the integration, coordination and storage of distributed renewable energy. Smart grids increase the efficiency of energy delivery through computer-based remote control and automation. As a conclusion of these changes, communities are able to take on energy-related matters by themselves (Kiorala et al. 2016). Such innovations are necessary to guarantee affordability, accessibility and storage opportunities of the produced energy. The choice for the technological composition is often bound to environmental compatibility, legal factors, regulations, costs and social as well as cultural preferences within the community (Kiorala et al. 2016). While many communities are connected to the regional grid, other communities aim for a total self-sufficiency and establish their own grid. As a conclusion of the different pre-conditions, needs and goals the technological composition and structures between bio-energy villages may differ. Based on the assessment of Kiorala et al. (2016) of technological issues within community energy systems, the following dimensions will be used in order to conceptualize the term "technological characteristics":

1. **Production technology:** Portrays the composition of renewable energy technologies.

2. **Storage**: Describes which and to what extent certain technologies are used for energy storage.

3. **Grid connection:** Gives information about the level of autarky (to what extent is the community dependent to the national grid?).

4. **Local balancing of supply and demand:** Describes how local demand and production of energy are matched.

5. **Energy efficiency:** Illustrates what methods are applied in order to increase the efficiency of energy supply (e.g. combined heat and power (CHP)).

3.2 Institutional Characteristics

In 1996, the EU introduced its first directive with the goal to liberate the energy market and triggered a transformation of the energy sector into privately owned and competitive industry. In accordance with this reform, major steps were undertaken to reorganize the electricity market. This restructuring of the energy sector included a horizontal splitting of supply and generation, providing third party access for electricity networks. Further, it enabled entry for new producers into electricity generation and the supply market, different forms of ownerships that include new private actors as well as a wave of privatization of state-owned businesses (Jasmasb et al., 2005). The liberalization of the energy market led to the development of alternative modes of organizations within the sector, which enabled the implementation of decentralized low-carbon energy systems. New roles for communities arose from this context, transforming them from passive consumers into prosumers (Kiorala et al. 2016). Different institutional set-ups within energy communities/bio-energy villages were implemented in order to enable the energy production and management on the community level. Based on the assessment of institutional characteristics by Kiorala et al. (2016), the term will be conceptualized using five different dimensions:

1. **Ownership:** Provides a portray of the ownership composition (communities, farmers, companies and other private actors).

2. **(Self-) governance:** Draws a picture of the coordination and administration of the cooperative.

3. **Energy democracy:** Describes to what extent consumers and/or the community are involved in the decision-making process.

4. **Regulation:** Illustrates regulations, policies and laws that influence the set-up of the bio-energy village.

3.3 Economic characteristics

Further, the study will assess economic similarities and differences based on the conceptualization of the term "business model" by Al-Debei (2008). The author defines a "business model" as an "…abstract representation of an organization, be it conceptual textual, and/or graphical, of all core interrelated architectural, co-operational, and financial arrangements designed and developed by an organization presently and in the future, as well as al core products and/or services the organization offers, or will offer, based on these arrangements that are needed to achieve its strategic goals and objectives". (Al-Debei, 2008, p. 5). Applying this concept to the bio-energy villages we will examine, economic aspects such as corporate structure, operating strategies, sales and pricing mechanisms, characterizing the cooperative business model on three different dimensions:

1. **Value Network:** Portrays the cross-company and inter-organization networks.

2. **Value Proposition:** Includes the portray of an organization's costs, benefits and value production.

3. **Value Finance:** Portrays information regarding an organization's method of pricing and costing.

4. Methodology

The following section will provide concise information about the methodological approach of this thesis.

4.1 Research Design

The overall purpose of this study is creating a picture of similarities and differences of existing bio-energy villages in the German context as they naturally occur. As a conclusion, this study follows a descriptive research design. Opposed to a causal research design this involves neither, testing a cause-effect relationship nor any form of manipulation. A descriptive research design can vary according to the time-frame of measurement that is whether the conducted study is a longitudinal, or a cross-sectional study (Bickman et. al., 2011). In longitudinal designs, data is collected during a significant period of time, while it is collected at the same point in time in the cross-sectional design. The benefit of a longitudinal study is the possibility to observe changes of the bio-energy village key characteristics. However, this design is more suitable for a small number of cases and cannot be applied due to the limited time-frame of this study. Furthermore, most variables that will be observed are likely to be stable. The advantage of a cross-sectional study design is the possibility to compare several variables at the same time (Bickman et al., 2011). Consequently, a wider range of characteristics of bio-energy villages can be compared in order to point out similarities and differences.

4.2 Case Selection

The German agency, "Fachagentur für Nachwachsende Rohstoffe" currently lists 121 bio-energy in Germany and further 56 communities that currently undergo a transition process towards a bio-energy village.[1] This study only includes the communities that already gained the full status of a bio-energy village, certified by the Ministry of Food and Agriculture.

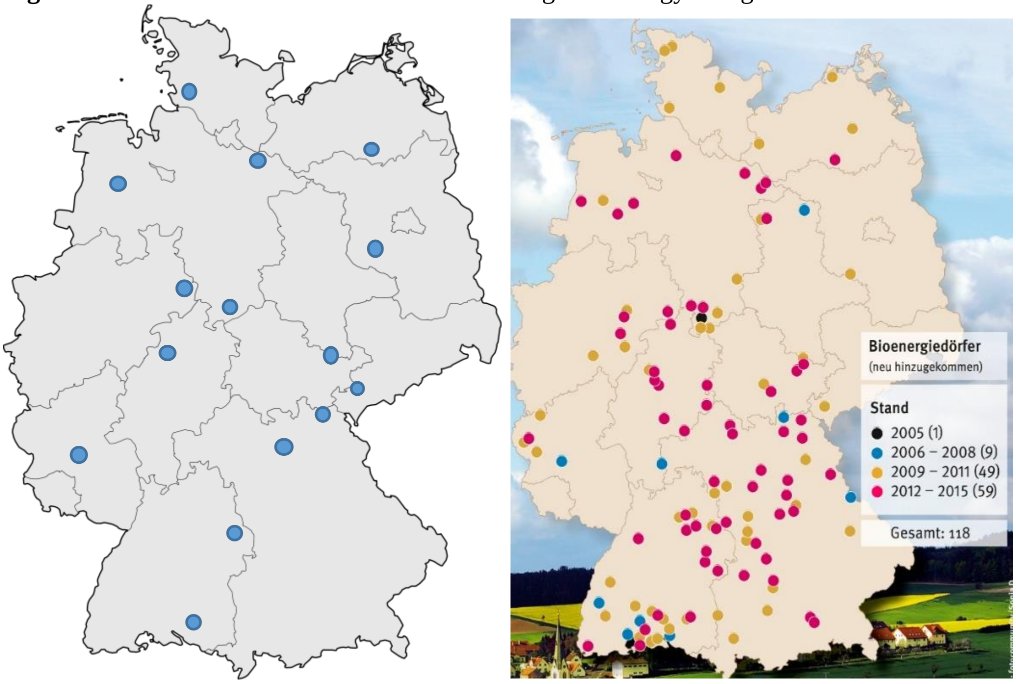
In order to discover existing patterns and to describe differences and similarities that occur between bio-energy villages in Germany, a wider range of cases should be selected. However, due to

[1] http://www.wege-zum-bioenergiedorf.de/bioenergiedoerfer/liste/

limited recourses and the given time-frame not all available cases could be assessed. Therefore, a step-wise case selection approach was applied. After carefully analyzing the existing literature and creating a sufficient knowledge base in this field of study, 15 cases were chosen according to three criteria that ensure a high level of variation between the cases (see **Table 1**). As a first step cases from different federal states were selected. The case density in the south far exceeds the one in the north. Cases that are bound to different jurisdictions and federal regularities differ in terms of their institutional characteristics. Further, communities were distinguished based on their size. Existing communities were grouped in small, medium and large communities according to their number of inhabitants. Small communities range from a size of 1-500 inhabitants, medium communities from 500-1000 residents and over 1000 citizens inhabit a large community. With an increased size of inhabitants an increased number of households has to be provided with heat and electricity. Such conditions require a different level of technological capacities and resources, altering the framework for the project and changing key-characteristics. As a third step the number of cases will be further reduced by selecting cases that differ in regard to their renewable energy sources. Next to the communities that only use biogas plants, villages with a different energy composition will be included. The technological set-up of a bio-energy village is closely related to its production technology. Therefore, a sample was selected that includes cases, using different renewable energy sources. The "Fachagentur für Nachwachsende Rohstoffe" provides a list with information about each village's production technologies and particularities according to which the cases were selected (see **Appendix E**).[2] **Figure 1** provides an overview of the location of selected cases in contrast to the overall number of cases.

[2] http://www.wege-zum-bioenergiedorf.de/bioenergiedoerfer/liste/

Figure 1. Selected Cases and Overview of existing Bio-Energy villages



Source: https://mediathek.fnr.de/grafiken/pressegrafiken/bioenergie/karte-bioenergiedorfer.html

One interviewee requested a confidential treatment of the collected data about heat prices and pricing mechanisms. Consequently, all selected villages were anonymized.

Table 1. Selected Cases

Bio-energy Village	Size[3]	Federal State
Village A	Medium	Mecklenburg-Vorpommern
Village B	Small	Brandenburg
Village C	Medium	Hessen
Village D	Medium	Baden-Württemberg
Village E	Small	Baden-Württemberg
Village F	Medium	Bayern
Village G	Small	Bayern
Village H	Large	Nordrhein-Westfalen
Village I	Medium	Niedersachsen
Village J	Small	Niedersachsen
Village K	Large	Niedersachsen
Village L	Large	Rheinland-Pfalz
Village M	Medium	Sachsen
Village N	Medium	Thüringen
Village O	Large	Schleswig-Holstein

[3] http://www.wege-zum-bioenergiedorf.de/bioenergiedoerfer/liste/

4.3 Operationalization and Data Collection Methods

As this study is the first one to develop a classification of bio-energy villages we acquired qualitative data to structure information in the field and generate hypothesis for subsequent quantitative analyses. Therefore, semi-structured interviews were conducted, as a method to collect the necessary amount of qualitative data. While a structured interview poses a rigorous set of questions, a semi-structured interview allows the interview to divert from the question and bring in new ideas (Bickman et al., 2009). Semi-structured interviews allow the researcher to investigate extensive aspects off an organization more clearly. “These include organizational processes, basic assumptions and beliefs, and critical organization-level phenomena - such as management control processes, relation to clients, and business strategies” (Bickman et al., 2009, p. 336). However, as specific characteristics need to be explored, a framework of themes was developed in the form of an interview guide. The following part presents the guide structure, based on the suggested conceptualization. The necessary data was collected, conducting available records and data, meaning existing literature, websites and semi-structured interviews with key actors involved in the project.

4.3.1 Development of an interview guide

The following interview guide was divided into three parts, each representing one sector of characteristics. This design ensures a comprehensible interview process and provides an outline for the later comparison of the results. This interview guide was modeled in accordance with the example of Bickman et al. (2009), containing a composition of several headings with main questions and further sub questions. Each of the main question and its associated sub questions represent indicators that were developed to operationalize the presented variables of the three sectors of characteristics. Each main question represents a variable and subheadings that can be derived from the mentioned concepts. Interviews were held in German. The following guide is translated to English and may slightly differ from the original, German version (see **Appendix D**). The first section of the guide focuses on technological aspects of the project:

1. **Production Technology: Which renewable energy sources do you use for the heat and electricity production?**
    - Do you use different energy sources next to biomass?
    - Which sorts of biomass do you use for the energy production?
    - How high is the production capacity?

2. **Storage: Do you use storage technology to save electricity and heat? If yes, explain what kind of technology.**

- How high is the capacity of storage installations?

3. **Grid Connection: Do you use technologies for the local distribution of heat or electricity?**
   - Does the community possess its own electricity grid or heating network?
   - Do you feed the produced electricity fully or partially into the regional grid?
   - Do you feed the electricity surplus (if such exist) into the regional grid?

4. **Local balancing of supply and demand: What Method or technology is used in order to balance the energy supply and demand?**
   - Does a heat surplus exist during summer? If yes, what happens to the heat surplus?

5. **Energy Efficiency: Do you undertake any measures to enhance the efficiency of energy supply and consumption?**

The second section focuses on institutional aspects of the project.

1. **Ownership: Can you clarify the ownership structures of the project?**
   - Who owns relevant assets?
   - How many owners exist?
   - What kind of legal structure regulates this ownership?

2. **Governance: Can you clarify the governance structure of the project?**
   - Who is operating relevant installations?
   - How is the project administered?
   - Who and how are internal processes coordinated?
   - What rules for the decision-making exist?

3. **Energy Democracy: How are relevant decisions for the project made?**
   - How and to what extent is the community and the consumer involved in relevant decision-making processes?

4. **Regulations**
   - Is the project affected by federal regulations?
   - What regulations on the community level affect the project?

The next section focuses on economic characteristics.

5. **Value Network: Who is involved in the project?**
   - Who are relevant stakeholders?
   - Which cooperations with public and private cooperations exist?
   - Do you cooperate with other bio-energy villages?
   - Did you receive subsidies for project installations? If yes, on which level? (EU, national, federal, community, KFW, etc.)

6. **Value Proposition**
   - What is your price for heat and electricity?
   - What additional cost does the consumer has to bear?
   - Are there different tariff structures and consumer categories?
   - What benefits exist in comparison to conventional energy suppliers?
   - What is special or better about your bio-energy village compared to other projects?

4.3.2 Interview process and choice of the interviewee

With all selected bio-energy villages interviews were arranged. In every case, the interview was structured according to the presented interview guide, whereby the order and exact wording of the questions could deviate according to the course of conversation. However, the full range of questions, mentioned in the interview guide was asked during the conversation. If a person was not able to give a satisfying response to one of the questions, the missing data was collected by contacting a second person that is familiar with the project, or via web pages and further textual information. Most online platforms provide information regarding the institutional setup of the bio-energy village and give an overview about the methods of energy production, assets, costs, benefits, and ownership as well as governance structure of the project. Further, key actors within the bio-energy village project provided additional information on request. All interviewees were persons, involved in the development and maintenance of the project. The interviews were held via a telephone call.

4.4 Data Analysis

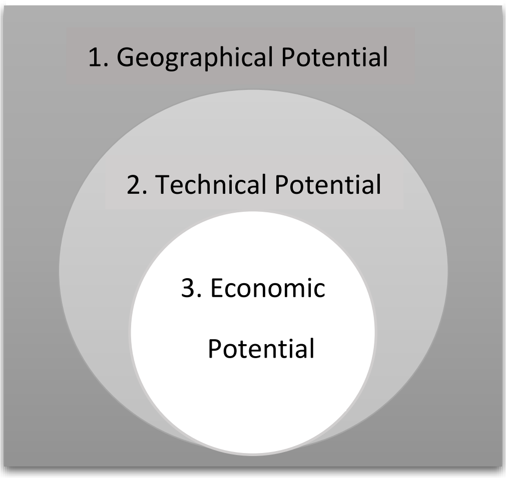
All interviews were recorded, evaluated according to Mayring (2010), and analyzed. During several steps the great amount of qualitative textual data, derived from interviews will be freed from redundancies and reduced to significant statements. This method allows an interpretation and comparison of the individual interviews with respect to the three core characteristics. In the following parts, the analyzed information will be presented. The sections **5.** to **7.** will present and structure the collected data with respect the three core areas, addressing the first research question. In the sections **8.** and **9.** classifications based on detected similarities and differences will be developed, addressing the second research question.

Two major problems occurred during the research. In three villages the interviewees were not able to make any statements about the heating prices as well as pricing schemes and no public data was available. Consequently, this data is missing in the study. Further, a noticeable problem posed the term "Energy Efficiency". Interviewees had different understandings of the concept and it had to be further clarified.

5. Comparison of Technological Characteristics

"Renewable energies are energy sources that are continually replenished by nature and derived directly from the sun (such as thermal, photo-chemical, and photo-electric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources" (Ellaban et al., 2015, p. 749). According to this definition, renewable energy sources can be separated into wind, hydro, solar, biomass, geothermal and tidal energy. The condition for a community to become a bio-energy village is to cover more than 50% of the local energy demand via such renewable energy sources. However, the term renewable energy covers a wide range of different energy sources and production technologies (see **Appendix A**) and the choice for a recourse is dependent to the pre-existing potential for its exploitation in a community. Vries et al. (2007) apply three different levels of potentials that determine the outcome of technological set-up in a bio-energy village:

Figure 2. Renewable Energy Potentials



1. The geographical potential describes the energy flux, which is theoretically extractable in locations that are considered suitable and available for this production, for example in areas that are not excluded by other incompatible land cover and/or through constraints set on local characteristics such as minimum average wind speed.

2. The technical potential is the remaining geographical potential after the losses of conversion from the extractable primary energy flux to secondary energy forms such as heat electricity and fuel are taken into account.

3. The economic potential describes the technical potential up to an estimated average production cost of the secondary energies, which are competitive with a locally relevant alternative.

As these potentials differ between the selected cases, the exploited energy sources and implemented technological set-up may differ. Therefore, the following part will present a comparison of the technological set-up.

5.1 Production Technology

In thirteen of the examined bioenergy villages the energy project mainly evolved around the use of biomass. Only in **Village B** and **Village O** the main share of energy is derived from wind and solar energy. In **Village B** the biomass installation serves as a back-up for the electricity production in a period without a sufficient amount of wind (Raschemann, 2016). Although, biomass does not always represent the central source of energy production all of the interviewed communities possess one or more biogas plants, making it an essential part of the bio-energy village concept. In these plants, biomass is used to produce biogas through anaerobic digestion (see **Appendix A**). In all villages, this biogas transferred to one or more “Blockheizkraftwerke” or “BHKWs” (Cogeneration Plants). These BHKWs simultaneously generate heat and electricity through a combined heat and power (CHP) system (see **Appendix A**). Further, in all projects the generated heat is made usable by implementing one or more heating networks. The transmission of useable heat between different buildings is described as local heat. Water is used as a medium for transport and heat accumulator. Through a heat exchanger the heat, produced by one or more heat generators, is used in order to heat the water in the pipeline system. The transported heat can be converted to power a radiator at the place of consumption using another heat exchanger. A return flow transports the water back to the heat generator (see **Appendix A**). The larger communities **Village H** and **Village L** possess several micro-heating networks. Grehl (2016) stated that a larger heating network would not be feasible in terms of the involved costs and effort. The combination of these three installations, bio-gas plan, BHKW and heating network represent a fundamental part of technological set-up of a bio-energy village. In nine cases the generated heat covers only the basic demand in the community. Therefore, wood chip burning plants were installed to cover the remaining heat demand and/or peak demands during the winter within the heating network system. In a wood chip burning plant, heat is generated through the combustion of wood chips.[4] **Table 2** provides an overview of the number of installed biomass plants in the interviewed bio-energy villages and their overall electric and heat production capacity. Four interviewees were not able to make a statement about the heat capacity of the existing cogeneration plants but emphasized that the degree of efficiency for heat production is always slightly higher than for electricity generation, resulting in a slightly higher heat production capacity for these installations.

[4]http://nef-feldheim.info/biomass/?lang=en

Table 2. Biomass Technologies

Bio-Energy Village	Biomass Technology	Heat Capacity (kWp)	Electricity Capacity (kWp)
Village A	2Biogas Plants/2BHKWs	n/a	1000
Village B	Biogas Plant/BHKW	560	526
	Wood Chip Burning Plant	299	
Village C	Biogas Plant/BHKW	480	400
	Wood Chip Burning Plant	850	
Village D	Biogas Plant/BHKW	200	180
	2 Wood Chip Burning Plants	600	
Village E	Biogas Plant/BHKW	620	593
	Wood Chip Burning Plant	408	
Village F	Biogas Plant/BHKW	780	745
	Wood Chip Burning Plant	200	
Village G	Biogas Plant/2BHKWs	n/a	420
	Wood Chip Burning Plant	500	
Village H	3 Biogas Plants/7 BHKWs	2300	1900
	3 Wood Chip Burning Plants	780	
Village I	Biogas Plant/BHKW	2200	1900
	Wood Chip Burning Plant	300	
Village J	Biogas Plant/3 BHKWs	1730	1550
Village K	2 Biogas Plants/10 BHKWs	n/a	2600
Village L	3 Biogas Plants/3 BHKWs	n/a	1050
	Wood Chip Burning Plant	400	
Village M	2 Biogas Plants/5 BHKWs	1400	1235
Village N	Biogas Plant/3 BHKWs	795	690
	Wood Chip Burning Plant	500	
Village O	Biogas Plant/BHKW	300	250

It can be observed, that the number of cogeneration plants, surpasses the number of biogas plants in several cases. The cases, **Village K**, **Village N**, **Village J, Village M** and **Village H** installed additional “Satelliten-BHKWs”. The term describes a BHKW that is spatially separated from the main installation. Those BHKWs are supplied with the necessary biogas via longer gas pipelines and enable an extension of the biogas catchment area.[5] As a conclusion a greater area can be provided with useable heat, guaranteeing a higher degree of energy efficiency.

The used biomass in all presented cases is of exclusively agricultural origin. According to the Renewable Energy Act of 2012 (EEG 2012) two categories of energy substrates have to be distinguished for installations built after 2012. The first category includes energy crops such as corn or beets; Category 2 includes ecologically-advantageous substrates like manure, biomass from landscape conservation or new energy crops, for example wild flowers (see **Appendix B**). Energy crops is a term used for plants that can be grown as a low-cost and low-maintenance harvest such as corn.[6] According to the collected data in **Table 3,** it can be observed that in all projects agriculture waste (manure) is used for the biogas production. As the most common mixture corn, manure and silage products are included.

Table 3. Sources of Biomass used for Energy Production

	Category 1					**Category 2**			
Biomass / Bio-energy village	Grain Kernels	Corn	Beets	Silage	Whole Crop Silage	Silphium Perfolia-tum	Field Clover	Cattle Manure	Grass Clipp-ings
Village A	X	X	X	X			X	X	
Village B		X						X	
Village C	X			X				X	
Village D		X			X			X	X
Village E	X	X		X			X	X	
Village F		X						X	
Village G	X			X	X			X	
Village H		X	X		X			X	
Village I	X	X	X	X				X	
Village J	X	X	X					X	X
Village K	X	X		X				X	
Village L		X		X		X		X	
Village M	X			X	X			X	
Village N		X		X	X	X		X	
Village O	X	X						X	

Except for **Village O** and **Village B** other renewable energy sources fulfill a complementary function in the community. **Table 4** provides an overview of major renewable energy installations in the selected cases. Several interviews mentioned that additional private installations, including geothermal, wind and solar energy installations exist in the community, leading to an increased share of

[5] http://www.onmitan.de/landwirtschaft-und-anaerobe-fermentation/satelliten-bhkw.html
[6] http://biomassenergycentre.org.uk/portal/page?_pageid=75,17301&_dad=portal&_schema=PORTAL

renewable energy production in the community. To enable a scientific comparison only installation with a minimum capacity of ate least 150 kWp, which are not operated by private households, are included. Most noticeable here is that most villages additionally implemented photovoltaic installations. Another five villages possess a wind park in the community and only one village is in possession of larger solar thermic installations.

Table 4. Other Renewable Energy Technologies

Bio-Energy Village	Renewable Energy Technology	Capacity (kWp)
Village B[7]	Wind Turbines	81100
	Photovoltaics	2250
Village C	Photovoltaics	155
Village D	Photovoltaics	1000
Village F	Photovoltaics	1100
Village H	Wind Turbines	14000
	Photovoltaics	5000
Vrees	Wind Turbines	1800
	Photovoltaics	1200
Village L	Wind Turbines	28000
	Photovoltaics	10000
	Solarthermics[8]	(2400qm)
Village M	Photovoltaics	160
Village O	Wind Turbines	35000
	Photovoltaics	3000

5.2 Energy Storage

The term "Energy Storage" refers to the capture of produced energy at one point of time in order to use at a later point in time. Often this involves the conversion of inconvenient energy forms that are difficult to store into more storable forms. Most of the interviewed villages only possessed technologies for the storage of heat and gas, but not electricity. Only in one village, **Village B** larger quantities of electric energy are stored in a battery storage installation. It is the largest installation in Europe and was implemented in September 2015 by the Enercon GmbH and the Energiequelle GmbH. The installation is made up of a lithium-ion battery system that has a capacity of 10 MW and was built to ensure a

[7] http://nef-feldheim.info/windenergie/
[8] http://www.wege-zum-bioenergiedorf.de/index.php?id=2117&GID=0&KID=24&firma=16

constant grid frequency of the transmission system operator (Raschemann, 2016). The system was built to compensate fluctuating electricity infusions into the local grid by the local wind park. The battery bank consists of 3.360 storage modules produced by the Korean company LG Chem.

Further, in 2011 a “Power-To-Gas” pilot installation was tested for several weeks in **Village L**. Similar to the battery storage technology, this method was developed to counter the high fluctuation rate that occurs due to the use of solar and wind energy technologies. This pilot installation converts CO_2 and water, into methane gas using wind and solar energy. The necessary CO_2 for this process was derived from the local biogas plant. The generated gas can be used in a later process to generate heat, electricity or fuel. The pilot installation had a capacity of only 25 KW. An implementation of a bigger installation with a capacity of 6 MW was planned but the interviewee could not provide further information about details. Further, he emphasized that this technology was tested in 2011 and found unprofitable and too costly for an actual implementation. Also, a small battery storage plant on the rooftop of a kindergarten was installed to store solar energy (Grehl, 2016). All other villages do not possess means for electricity storage and two interviewees emphasized that the available technology necessary to store electricity would present a non-cost-effective measure for the community and can only be considered for lower price.

In contrast to electricity, heat can be stored more easily in a cost effective manner using a “Pufferspeicher” (hot water storage tank). Water can be utilized as cheap heat storage medium when stored in an efficiently insulated tank. Such a device can retain heat for several days. Therefore, the fluctuation between supply and demand can be compensated. **Table 5** shows that seven interviewees reported that a “Pufferspeicher” is used in their village to store heat. One interviewee reported that in **Village J** such an installation would be part of the future development of the bio-energy village (Koch, 2016). In all villages that possess a “Pufferspeicher”, the storage installations are part of a local heating network. Only in **Village F** the interviewee reported that an alternative method of storage technology is planned to be installed in near future as part of a cooperation project with the University of Bayreuth. The heat is supposed to be stored in transportable containers. Unfortunately, the interviewee could provide no further information about content of this project (Fischer, 2016).

Table 5. Overview of Heat Storage Technologies

Bio-energy village	Heat Storage Technology
Village A	Pufferspeicher 6m³ (6000L)
Village B	Pufferspeicher 2x45m³ (90000L)
Village C	Pufferspeicher 5m³ (5000L)
Village D	Pufferspeicher 12m³ (12.000 L)
Village E	Pufferspeicher 60m³ (60000L)
Village G	Pufferspeicher 16m³ (16000L)
Village H	Several Pufferspeicher (n/a)
Village I	Pufferspeicher 200m³ (200000L)

5.3 Grid Connection

All of the interviewed villages are connected to the regional grid. In fourteen villages the generated electricity is almost completely is fed into the regional grid. Only the electric energy necessary for the production installations is consumed directly and not fed into the regional grid. According to the "Erneuerbare Energien Gesetz" (EEG) all grid operators are obliged to connect plants that generate electricity from renewable energies to their grid on a priority basis and to purchase the produced electricity, at fixed rates of remunerate (see **Appendix A**). Therefore, in thirteen village's bio-energy villages no electricity is sold directly to the final consumer. In these villages, all resident is free to choose their own electricity supplier with its individual conditions and prices. In **Village O** a public utility company is located. The generated electricity is fed into the regional grid but sold by this public company (Vries, 2016).

Due to coordination difficulties, **Village B** implemented its own local electricity grid. Via this grid all connected local residents are supplied with electricity. The electricity necessary to cover the demand of the community is fed into the community owned grid. The generated surplus is completely fed into the regional grid (Raschemann, 2016).

Further, to enable a local distribution of usable heat generated in cogeneration plants heating networks were implemented in all cases. The number and capacity of these heating networks differs according the number BHKWs, their capacity and the number of consumers that requested a connection to the network

5.4 Local balancing of supply and demand

In general, as all generated electricity can be limitless fed into the regional grid, a compensation between supply and demand of electricity is unnecessary. All grid operators are obliged to fully accept electricity from renewable energy sources on a priority basis and operators are remunerated at a fixed rate (see **Appendix B**). Normally, BHKWs generate a constant amount of heat and electricity and therefore produce a base load. However, in order to guarantee a reliable energy supply the legislator desires a more demand driven supply system. As a conclusion, installation upgrades that enable a demand-driven energy production in biogas plants are subsidized (EEG2012 & EEG2014).[9] These upgrading process is called "Flexibilisierung". Installations, provided with additional technologies can compensate for regional fluctuations in supply and demand. The bio-energy villages **Village D**, **Village H**, **Village M** and **Village F** reported possessing such demand-oriented BHKWs and produce especially during summer lower rates of heat and electricity (Fischer, 2016).

Further, the bio-energy villages that cover the minimum demand of heat through the use of cogeneration in BHKWs and possess wood chip burning plants as complementary installations (see **Table 1**) can regulate the additional input into the system in accordance with the local demand. In addition to that, the storage technology mentioned in the latter part is applied to compensate for daily fluctuations between supply and demand (see **Table 5**). Still, a complete usage of the produced heat cannot be guaranteed, surpluses that cannot be efficiently consumed are simply released into the air.

5.5 Heat usage during summer

During the summer period, utilization of the heating network strongly decreases. Although, the heat production can be regulated through flexible production systems that involve a combination of BHKWs and wood chip burning plants and the "Flexibilisierung", the heat production in BHKWs is likely to exceed the local demand during the warmer period of the year. Nine bio-energy villages reported to use economic synergies to effectively sell off the produced heat for drying purposes (**Table 6**). Further, the communities **Village B** and **Village H** reported that currently plans are negotiated, to build such drying processes into the bio-energy concept of the community. Particularly, noticeable is that in all of these communities the produced heat is used to dry wood materials in form of chips, pellets etc., which are sold during colder periods in order to fuel wood chip burning plants and private local wood heating systems in the community. As a conclusion, an inclusive system is implemented that makes the heat surplus usable during summer and provides necessary resources for heating installations during colder periods.

[9] http://www.gesetze-im-internet.de/eeg_2014/BJNR106610014.html#BJNR106610014BJNG001100000

Table 6. Heat Usage during Summer

Heat usage /Bio-energy villages	Drying of Wood Materials	Drying of Grain	Drying of Digestate	Drying of concentrated feed
Village A	X	X		
Village B				
Village C				
Village D	X			
Village E	X			
Village F	X			
Village G	X	X		
Village H				
Village I	X	X		
Village J	X	X		
Village K	X		X	
Village L	X	X		
Village M	X			
Village N	X	X		X
Village O				

5.6 Energy Efficiency

The term "energy efficiency" is used for a process that delivers more services for similar energy input, or the same service for less energy input. Therefore, the concept covers a broad range of possible measures that could lead to a higher energy efficiency in a bio-energy village.[10] Therefore, the use of storage technologies, CHP-technology and "Sateliten BHKWs" to reduce the loss of generated energy can be described as a measure to increase the level of energy efficiency as well. In the following part, additional measures of efficiency insurance will be presented. However, it is unlikely that the data spans the whole spectrum of such measures and should be regarded as an overview of possible initiatives.

Naturally, an efficient energy production can be improved through the use of new technologies, like modern combustion engines that guarantee a higher degree of efficiency, certified by the manufacturer, as well as a proper maintenance of those machines. In the community **Village O** a test wind turbine to improve the practical application of this technology and test new parts (De Vries, 2016). Further, Hake (2016) emphasized that the biogas installation in **Village H** would constantly aim at improving the degree of energy efficiency by testing different mixtures of bio substrates. **Table 7** provides an overview of the most common responses. It shows that three interviewees pointed out to

[10] http://www.iea.org/topics/energyefficiency/

make use of “Prozessleittechnik” (process control technology). This technology is used to maintain the output of a specific process within an intended range (Litz, 2000).

On the consumption side, the most common response included the use of LED technology for public buildings and street lighting. Further, three villages emphasized to provide local energy consulting to improve the energy efficiency degree in local households.

Table 7. Energy Efficiency Initiatives

Bio-Energy Village	LED Lightning	Energy Consulting	Prozessleittechnick
Village A	X	X	X
Village B	X		
Village C			
Village D			X
Village E	X		
Village F			X
Village G			
Village H	X		
Village I			
Village J			
Village K	X		
Village L	X	X	
Village M	X		
Village N			
Village O			

6. Comparison of institutional Characteristics

The transformation of a rural community into a bio-energy village can be regarded as a complex and time-consuming process. The reconstruction takes approximately three years, depending on the individual set-up (Welz, 2011). Röpcke (2008) pointed out that there is not only a number of diverse actors involved in a bioenergy-village project, but also understanding of the concept varies greatly. The following part will provide an overview of the institutional variations that arise due to the different actors involved.

6.1 Ownership

By comparing the selected cases, it becomes evident that the great variation Röpcke (2008) mentioned, also exists between the selected bio-energy village projects. Not only the number of owners, investors and operators involved in a project differs but also their legal structure. Constraints, duties and rights result from these legal structures (see **Appendix C**). Thomsen (2013) indicates that the choice of the legal structure for a bio-energy project is based on the goals and resources of its initiator. This choice has an impact on taxation, administration, economic structure and consequences in regard to legal matters (see **Appendix C**). **Table 8** provides an overview about the ownership composition in each of the selected bio-energy villages.

Table 8. Ownership Structures

Village N & Village I	In two of the analysed bio-energy, villages all assets belong to a newfound local “Genossenschaft” (e.G.) (Fangmeier, 2016 & Perschke, 2016).
Village M	In **Village M** all assets belong to an agricultural cooperative (e.G.) (Weymann, 2016).
Village B	In **Village B**, the citizens founded a “Gesellschaft mit beschränkter Haftung & Compagnie Kommanditgesellschaft” (GmbH & Co. KG.). The biogas plant, wood chip burning plant, the local electricity grid and the local heating network are owned by this company. The wind park, solar park and battery storage belong to supra-regional private companies in the form of a “Gemeinschaft mit beschränkter Haftung” (GmbH) such as Energiequelle GmbH. Additionally, one wind turbine (Bürgerwindrad) is owned by the Energiequelle GmbH and a local agricultural cooperative (Raschemann, 2016).
Village G	In **Village G** a GmbH & Co. KG was founded and is the owner of the local heating network and the wood chip burning plant. Further, the biogas plant is in possession of a GbR, whereas the two co-generation plants belong to a single entrepreunership (Appel, 2016).
Village J	The biogas plant in **Village J** belongs to four entrepreneurs that founded a GmbH & Co. KG. The two additional satellite BHKWs are owned by two of these entrepreneurs in the form of an “Offene Handelsgesellschaft” (OHG). Each of these companies owns an adhering heating network as well (Koch, 2016).
Village E, Village F & Village C	In Village E a local cooperative is in possession of the heating network and all related facilities (Mezger, 2016). The biogas plant and a wood chip burning plant are operated and owned by a local farmer who founded a GmbH for that purpose. In **Village C** and **Village F** a similar ownership structure can be observed. However, in **Village C** the wood chip burning plant and photovoltaics are owned by the cooperative (Henkel, 2016). In **Village F** the biogas-farmer operates in the form of

	a GmbH & Co. KG and the photovoltaic installations are in possession of single entrepreneurs and agricultural companies. (Fischer, 2016).
Village A	In **Village A** the two biogas plants are owned by agricultural companies, whereas the heating network is partially owned by the local government and partially by a “Gesellschaft bürgelichen Rechts” (GbR) (Schätzchen, 2016).
Village K	In **Village K** the two existing biogas plants and two separate heating networks are owned by two different GmbHs, which entrepreneurs are mainly farmers. The photovoltaics and wind turbines are in private hands in the form of single entrepreneurship (Rieken, 2016).
Village O	In this case, the biogas plant is owned by an agricultural company that at the same time owns a small heating network, supplying a close range of buildings. In the community the subsidiary company, “Gemeindewerke GmbH” was founded, to sell gas and electricity in the community. The local government is the only entrepreneur in this company. Further, the company owns three wind turbines and several photovoltaic installations. The remaining installations are owned by supra-regional capital companies (De Vries, 2016).
Village L	**Village L** is one of the communities with the largest size and a more diverse set-up, therefore posing a somewhat more complex picture. Different private investors and firms like the Juwi Ag hold shares of the local wind park. Further, one wind turbine is owned by the community (Bürgerwindrad). One of the biogas plants is owned by the stock company as well. The other two biogas plants are owned by agricultural companies in the form of a GmbH. The photovoltaic installations belong to different private firms and the community. As a future project a community owned wind park is planned (Grehl, 2016).
Village H	A similar picture can be observed in the case of **Village H**. The three biogas plants are owned by different private investors in the form of GmbHs. The heating networks are partially in possession of the biogas plant operators and partially owned by the community. The main share of the wind park and the photovoltaic installations is owned by supra-regional companies and a few of them are owned by private investors in the form of single entrepreneurships (Hake, 2016).
Village D	In **Village D** the local heating network and the two wood chip burning plants are in possession of regional utility company in the legal structure of a stock company. The company operates solely in the renewable energy sector, specialized in bio-energy village projects and not stock-market-oriented. The biogas plant belongs to an agricultural company in the form of a GmbH & Co. KG (Gebele, 2016).

6.2 Governance

In general, the assets are owned and managed by the same company. Within the selected cases the community **Village N** poses an exception. All assets belong to the local cooperative, but the biogas plants and BHKWs are operated via a service contract by a local agriculture cooperative (Perschke, 2016). The local cooperative is responsible for the coordination and administrative tasks of the plants. In **Village A** the local government is investor and shareholder of the local heating network but the installation is operated by the GbR. A cooperation agreement regulates the relationship between these two parties. The municipal supervisory authority is constantly informed about the current status of the project and the municipal council can further influence decision-making processes through the budget plan. Also. Further, in some cases like **Village H** the local government hold shares of the heating network but leaves the management to the private shareholders.

Selected cases, in which assets are operated and managed in the form of a local cooperative, the inhabitants joined together to collaboratively produce energy or operate a grid. Members of the local cooperative are owners and consumers at the same time or relevant suppliers. Relevant bodies of a cooperative are the executive board, the supervisory board and the general assembly. Critical strategies and decisions are made by the general assembly, the daily business is run by the executive board and the supervisory board is responsible for the supervision of the executive board. The decision-making process within the general assembly follows a one vote for each member rule. In general, this legal structure does not serve the purpose of generating profits (see **Appendix C**). In five cases the interviewees reported that the executive board is working on a voluntary basis. **Village C** represents an even more interesting case in terms of voluntary administration. The project is almost completely based on voluntary engagement of cooperative members. A system called "Rentnermanagement" was implemented, constantly assigning members to different changing tasks. Tasks that require a professional background such as some maintenance operations may be excluded from this system.

Another type of operators are agricultural cooperatives. They are successor organizations of the former "Produktionsgenossenschaften" (production cooperatives) in the "Deutsche Demokratische Republik" (DDR) and therefore only exist in the eastern federal states.[11] These cooperative produce agricultural products and operate, in contrast to local the cooperatives, in a profit-oriented manner but possess the same legal and administrative structure.

In the case of **Village B** the local heating network and electricity grid is administered via a "Bürgergesellschaft" every consumer is at the same time a limited partner of the operating company (Kommanditist). All limited partners elected an advisory board, which is responsible for the daily business of the company. Once a year the company is holding a general meeting, where all local citizens are informed about the current situation of the project. Also, in **Village G** consumers are at the same time limited partners in the GmbH & Co. KG. However in this case, the consumer has no obligation to

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[11] http://wirtschaftslexikon.gabler.de/Definition/agrargenossenschaften.html

become part of the company, which results in a different pricing scheme for such consumers. Decisions concerning the daily business are made by an executive board and relevant questions for the company are brought up in a general assembly. The coordination with the heat supplier is based on a supply contract.

In capital companies (see **Appendix C**) the administrative structure is based on a partnership agreement between the entrepreneurs. Usually, an executive board is responsible for the daily business and all critical decisions. Within this sample no higher institution or company is responsible for the coordination of private operators in bio-energy villages. Generally, the coordination between owners and operators is based on individual agreements and supply contracts. Of course, the local government, if not operator or investor itself, has a severe interest in the success of a bio-energy village project and therefore can function as a mediator between companies.

6.3 Energy Democracy

The concept, "Energy Democracy" is originally based on the basic understanding that decisions that influence people's lives should be jointly established and be non-profit driven (Kunze et. al, 2014). "Many people see democracy as something to aspire to and not as something that we have already achieved. Practices that aim to broaden the scope of democracy abound, and almost always include the demand for a democratization of the economy" (Kunze et. al, 2014, p. 9). Therefore, the selected cases were compared according to structures conducive to increased participation in energy policy (see **Table 9).** These structures can be distinguished into representative democratic structures through the involvement of the local government and direct democratic structures through the direct involvement of the consumer and the local citizen. **Table 9** shows that three different forms of direct participation could be observed. Five interviewees reported that the public support for the project has been guaranteed via a community meeting, presenting the initiative. Further, in eight villages the consumer is directly involved in decision-making processes through the membership in a local cooperative, or a limited partnership (see **Appendix B**). Critical decisions like an investment into a large installation are made in a general assembly, where each member has a voting right. In five cases the local government is member of the cooperative as well. Therefore, the local government and the individual consumer participate in critical decision-making processes. In another two cases the local government held an ownership of relevant assets or functions as an operator through the establishment of a subsidiary company. In **Village A** the local government is a main investor for the heating network a cooperation agreement with the GbR was established.

Table 9. Forms of local Participation

	Involvement of the local Government			**Direct democratic Involvement**	
Local Government involvement/ Bio-Energy Villages	Ownership or subsidiary company	Membership in a Cooperative/ Partnership	Cooperation Agreement	TownMeeting or Voting Process	Consumer Administration
Village A			X		
Village B				X	X
Village C				X	X
Village D					
Village E		X			X
Village F					X
Village G		X			X
Village H	X				X
Village I		X		X	X
Village J					
Village K		X		X	
Village L					
Village M					
Village N		X		X	X
Village O	X				

6.4 Regulations

Bio-energy village projects in Germany are bound to a diverse set of rules and regulations. Policies that set rules for the renewable energy sector and environmental protection are implemented on a national level. Therefore, all selected cases are bound to a national legal framework (see **Appendix B**) including the Renewable Energy Sources Act (EEG) as central key stone.

The federal legislation impacts the potential legislation in two ways. First, construction laws are federal state specific, meaning that the federal states set different standards and requirements for necessary buildings and installations needed for bio-energy projects (Grehl, 2016). Further, the authorization for wind turbines with a height lower than 50 meters is not based on the federal Emission Control Act (see **Appendix B**), but based on federal legislation.[12] Secondly, a range of federal states in Germany implemented several funding pools in order to boost renewable energy projects. In ten cases

[12] http://www.klein-windkraftanlagen.com/basisinfo/genehmigung-rechtliche-grundlagen/

interviewees reported that subsidies were received from the federal state level for the installation of renewable energy technologies or heating networks (see **Table 6**). These funding pools are bound to certain time-windows. As a conclusion, opportunities for subsidies differ among bio-energy according to the dates of application. Also on the community level, funding pools were implemented in two villages. Additionally, regulations on the community level for the use of public properties can have a severe impact on the project. Therefore, a communal approval and affordable charging scheme is necessary. In **Village L** the communal regulations used to demand a monthly concession. In order to enable an affordable construction of a local heating network, the regulation was changed in favor of the operators, requiring a one-off payment (Grehl, 2016). None of the interviewees mentioned any policies or regulations that relate to the bio-energy village concept as whole.

7. Comparison of Economic Characteristics

In the following part economic characteristics of the project will be compared, including stakeholders, customer advantages and obligations of the consumer.

7.1 Stakeholder and Cooperation Overview

A constant set of stakeholders involved in bio-energy projects exists (see **Table 10**). Suppliers for necessary assets, engineers and construction companies need to be contracted in order to transform a community. The acquired assets have to be maintained by maintenance companies. Further, regional grid operators are involved in the project through the infusion of decentralized electricity into their grid. Also, agricultural companies and farmers have a severe interest in the success of bio-energy projects. Especially, for landowners controlling smaller territories, the cultivation of energy crops can represent a profitable business (Rieken, 2016). Agricultural companies and agricultural cooperatives (see **Table 8**) supply their own installations, whereas plants owned by non-agricultural companies and local cooperatives receive the necessary biomass through supply contracts with local farmers. Particularly noticeable here is that several interviewees reported that the procumbent is kept local in order to further strengthen the regional economy. Additionally, the bio-energy villages **Village A, Village I** and **Village L** reported to cooperate with local universities and educational institutions to further develop renewable energy technologies

Table 10. Overview of Stakeholders

Farmers/Agricultural Companies
Operating Companies
Engineers
Construction Companies
Suppliers (Technology & Raw Materials)
Grid Operators
Local Governments
Maintenance Companies
Consumers

Throughout the interview process, the existence of networks between bio-energy villages was assessed. Seven villages reported to hold informal relationships with other bio-energy villages to exchange information about project-developments, current technologies, etc. (see **Table 10**). Three of these cases (**Village O, Village I** and **Village B**) entered relationships and formed a network through the "Bundeswettbewerb Bioenergie-Kommunen", a nationwide competition that awards three particularly innovative bio-energy communities, which use local resources for energy generation in a very efficient manner, with 10000 €.[13]

Another four communities reported that they engage in formal cooperation with other bioenergy village projects. The community, **Village C** is a member of a purchasing cooperative (BioEnergieservice Marburger Land eG) together with seven other bio-energy villages in the region (Henkel, 2016). Through this cooperative relevant resources such as wood chips and technological equipment are shared. As a member of BürgerEnergie Thüringen e.V., **Village N** is linked with other bio-energy villages and other renewable energy cooperatives (Perschke, 2016). This umbrella association functions as pool for information regarding local renewable energy projects and lobby organisation.[14] Further, the community, **Village A** is initiator and member of several regional networks such as the consortium "Dorfkern"[15], which fosters renewable energy projects and rural development (Schätzchen, 2016). In cooperation with the Environmental Campus Birkenfeld[16], **Village L** engaged for four years in a European cooperation program (ZECOS) for a systematic acquisition of data about renewable energy potentials and energy efficiency potentials, with universities and renewable energy communities from England, Ireland and Belgium (Grehl, 2016).

[13] http://www.bioenergie-kommunen.de/informationen-zum-wettbewerb/
[14] http://buergerenergie-thueringen.de/
[15] http://www.dorfkern.eu/
[16] http://www.umwelt-campus.de/ucb/index.php?id=home&L=1

Table 11. Cooperation with other Bio-Energy Villages

Funding Bio-Energy Village	Formal Cooperation with other Bio-Energy Villages	Informal Cooperation & Information Exchange
Village A	X	
Village B		X
Village C	X	
Village D		X
Village E		X
Village F		X
Village G		X
Village H		
Village I		X
Village J		
Village K		
Village L	X	
Village M		
Village N	X	
Village O		X

7.2 Financing

The acceleration of renewable energy extension in Germany influences the decision for or against a transformation into bio-energy village through the creation of economic incentives and support programs (Welz, 2011). The amount of the necessary capital for the implementation and operation of energy plants as well as the combination of financial instruments vary between the projects. Particularly, because they depend on the choice of the legal structure of operating companies (Welz, 2011). In general, five different financial sources are used for the conversion of the community: private funds, outside funds, fund financing, contractual models and subsidies.

As a result of the political attempt to foster the development of renewable energy supply the EU, the Bund (e.g. Marktanreizprogramm), the federal states and the communities (Städte, Landkreise, Gemeinden) offer targeted subsidies for the utilization of renewable energy sources, to increase investments. In Germany local heating networks can be funded by the "Bundesamt für Wirtschaft und Ausfuhrkontrolle", under the condition that the used heat is a product of cogeneration.[17] Is the heat generated, using renewable energy sources, the operator can apply for public funding via the

[17] http://www.bafa.de/bafa/de/energie/kraft_waerme_kopplung/stromverguetung/index.html

"Kreditanstalt für Wiederaufbau" (KfW) is possible.[18] The KfW is a development bank owned by the German government, which also provides low-interest loans for renewable energy projects.[19]

All cases received subsidies from such public institutions (see **Table 6**). Seven cases received funding from the EU-level, for example through the LEADER-program. Another seven communities made use of national support programs. A low-interest loan with repayment bonus for local heating networks from the KfW was claimed by another nine communities. Ten projects reported to made use of federal subsidies and two bio-energy projects were supported through community-based programs. Several interviewees emphasized that without these subsidies a successful implementation of a bio-energy village would not have been possible.

Table 12. Received Funding

Level/ Bio-Energy Village	EU	National	Federal	Community	KFW
Village A		X	X		
Village B	X		X		
Village C	X		X		X
Village D			X		X
Village E	X	X	X		X
Village F		X			X
Village G					X
Village H	X	X	X		
Village I	X	X	X	X	X
Village J		X			X
Village K			X		
Village L	X		X	X	X
Village M					X
Village N	X		X		
Village O		X			

[18] https://www.kfw.de/inlandsfoerderung/%C3%96ffentliche-Einrichtungen/Wohnwirtschaft/Finanzierungsangebote/Erneuerbare-Energien-Premium-(271-281)/index.html
[19] https://www.kfw.de/kfw.de.html

7.3 Customer Advantages

In all cases, heat is generated through cogeneration or biogas plants and sold on a community basis. However, in two of these cases (**Village O** & **Village L**) only micro-heating networks were installed that supply only a few buildings in a closer range. The interviewees contacted in these cases were not able to name advantages and prices for heat sales, as they represent only a minor aspect of the project. In **Village H** three different biogas plants are owned and operated by the different private companies, each using different pricing schemes and tariff. With no further public data available and unable to reach responsible actors the information from these cases is missing in the data collection.

The remaining cases gave similar responses regarding the advantages of local heat consumers. First of all, interviewees emphasized that the produced heat can be purchased for a relatively low price (see **Table 5**) in comparison to oil and gas based systems. Although, the oil price is in Germany is on a historically low level (Ca. 43.2 cent/L)[20] all cases claimed to offer a cheaper or at least competitive price. Through the connection to such a system, no own heater and boiler are necessary resulting in an increase of useable space within the building. Additionally, no costs incur due to the work of chimney sweepers and none of the interviewees reported that consumers are responsible for occurring maintenance costs. However, the **Village M** represents an interesting outlier in this regard. The agricultural cooperative guarantees no constant heat supply, therefore it is necessary for the consumer to possess an alternative heating system (Weymann, 2016).

In two more cases (**Village B** & **Village O)** also electricity is sold by regional operators. In both cases, interviewees mentioned the regional consultancy and customer proximity as advantages for the electricity consumer.

7.4 Basic Fee and Price per kWh

Table 13 clarifies the composition of the local heating costs. In four villages the heating price consists of a basic fee and a price for the consumption of kilowatt per hour. In two of these cases the basic fee is bound to the connection capacity (price/kW ordered capacity). In another six villages the price per kWh is charged but no basic fee. Further, in **Village M** and **Village K** the heat price is bound the price of regional gas suppliers. In one village the heat price amounts always 70% of the local gas price and in the other case the amount always 60% of the local supplier's classic tariff is charged, therefore guaranteeing a constantly cheaper price in comparison to heat based on fossil resources. Also, **Village D** guarantees a heat price that at least 10% cheaper than the standard price of the regional oil supplier.

[20] http://de.statista.com/statistik/daten/studie/2633/umfrage/entwicklung-des-verbraucherpreises-fuer-leichtes-heizoel-seit-1960/

In **Village C** and **Village J** the consumer can choose between two different tariffs. In the first case the consumer can choose between a consumption-dependent tariff for 8.3 Cents per kWh and a flat rate with a monthly price of 29.95 €. In the second case the first tariff is also consumption-dependent with a price of 4.95 Cents per kWh. Choosing the second tariff the consumer has to pay a fixed price for ten years. This prices is calculated according to the consumption of the previous year before the contract term starts. The heat price for the kWh is one Cent cheaper in this case. Furthermore, in **Village I** the interviewee reported that associations can purchase heat for a cheaper price. In **Village J** the interviewee mentioned that a pigsty will be built in the community, which distributes manure directly via a pipeline to the biogas installation. This installation will receive heat for a cheaper price

In two cases electricity is directly sold directly in at the community-level. In **Village B** electricity can be purchase for a fixed rate of 16.5 cent/KWh. In **Village O** the consumer has to pay a basic price of 69.36 € per year and 26.90 cents per kWh. This village offers cheaper conditions to consumers that operate heat pumps, electric heaters and storage heaters. A high price gap between the community that distributes electricity via its own grid and the community that feeds electricity into the regional grid can be observed here.

7.5 Connection Fees and Capital Contribution

As a member of a local cooperative or limited partner the consumers in nine of the selected cases are obliged to invest a capital contribution (see **Appendix C**). This capital can be contributed in the form of cash investments, assets, services, transfer of use and hidden contributions. However, all interviewees reported that the necessary contributions are made in the form of cash investments. The amount of the contributions is defined in the partnership agreement. **Table 9** shows that in six cases the consumers were obliged to submit a membership contribution. In all cases these were cash contribution ranging from 300- 7000 € for each member. In **Village B** the consumer is obligated to invest 1500 € per grid connection, meaning that any consumer who is connected to both, heating network and electricity grid has to make a total contribution of 3000€.

In three villages the consumer is obliged to pay a connection fee to access the local heating network. The fees range from 300 – 5000 €. Additionally, in **Village N** the founding members of the cooperative were charged no connection fee. New consumers are obliged to pay 65% of the effective price of the connection to the heating network.

Table 13. Overview of Heating Prices, Connection Fees and Capital Contributions

Bio-Energy Village	Basic Price per Year in Euro	Price in Cent/kWh	Connection Fee in Euro	Capital Contribution in Euro
Village A	58,80€/kW	3,3	1500	
Village B		7,5		1500
Village C		8,3		7000
Village D	250	7,6		
Village E		6,9	5000	300
Village F	Price/kW Connection	4		
Village G	300	7,5		7000
Village H	No Heating Price available			
Village I		6	1000	1500
Village J		3,95		
Village K	60 % of the EWE classic Tariff			
Village L	No Heating Price available			
Village M	70 % of the local Gas Price			
Village N	300	6,68	65% of the effective connection price	2000
Village O	No Heating Price available			

7.6 Additional Costs

In addition to, the costs presented in **Table 8,** the consumers of those villages that guarantee a constant heat supply are responsible for the dismantling of former heating installations such as boilers and tanks. These costs cannot be quantified, as they differ between individual consumers.

7.7 Special Features

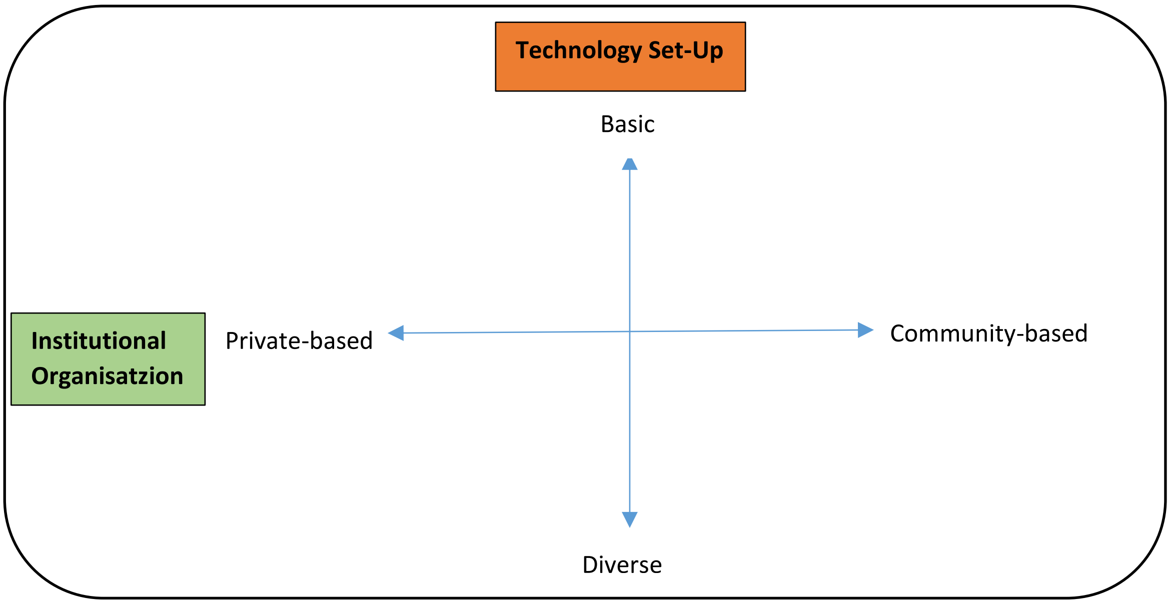
In two of the selected cases (**Village J** & **Village N**) the construction of the pipeline system, necessary for the local heating network, was used to install a fibre-optic network in the community. In these cases, available synergies were used to further increase the attractiveness of the community and value of connected properties.

8. Development of a Classification Scheme

Based on the previous comparison it can be stated that cases differ in various aspects. In terms of the technological set-up we find cases, in which energy production is solely based on biomass and is composed of only a few installations and cases that exploit several renewable energy sources at the same time and have installed a complex set of technologies. The comparison of the institutional set-ups provides a similar picture. In some cases a multi-level set of private, community-based and public institutions are involved in bio-energy village projects whereas other projects are managed by a single cooperative.

According to Finger et al. (2005), a mutual relationship between the technical and institutional coordination of infrastructure can be expected. Applying this theory to the community level a two-dimensional classification scheme was developed (see **Figure 3**). Using this typology scheme it is possible to position different bio-energy village models vis–à–vis each other and group similar cases together. The first dimension representing the institutional organisation of a bio-energy village was developed to show the extent to which the project is based on community-based organizations that were found by citizens or private investors and pre-existing companies. The second dimension provides a picture of the technological diversity of the project and whether it is based purely on biomass installations or different renewable energy production systems. With respect to the letter introduced three dimensions of key characteristics the reader might notice that this scheme includes no economic dimension. As no economic patterns were detected that could be directly linked to the other two dimension, the economic dimension was excluded and findings with respect to economic characteristics will be clarified in the part **9.1 Further Results.**

Figure 3. Classification Scheme



9. Systematization and Classification

It can be stated that one of the major similarities between the selected cases is the existence of at least one biogas installations and a cogeneration plant with an adhering heating network, producing heat and electricity at the same time. Therefore, this composition will be describe as **basic** technological set-up. Three models were developed that describe the relationship of villages, which technological set-up is mainly based on biomass installations and their institutional organization of the project. Another two models were developed that classify villages with a more diverse technological set-up including solar and wind parks (see **Figure 4)**.

1. **Agriculture Model**: In two bio-energy villages (**Village M** & **Village J**) a basic technological set-up was implemented including one biogas plant in **Village M** and two in **Village J.** In **Village M** the farmers additionally installed a small number of photovoltaics (160 kWp). None of these villages possesses an additional wood chip burning plant that serves as back up for heat production but both the installations have relatively high total capacities (see **Table 2**). Also, none of them uses any storage technologies. The project was initiated and primarily developed by local farmers or agricultural companies/cooperatives. Thus, they were initiated to strengthen the local agriculture industry and to create long-term alternatives for this sector. As Rieken (2016) pointed out, a biogas installation represents a profitable business not only for the operating companies but also for small land owners. In some cases, the cultivation of such small areas is only profitable due to the presence of a biomass energy installation (Rieken, 2016). Additionally, if harvested products are not competitive due to the current market price, energy production represents a reliable alternative for its use. In this model farmers and agricultural companies/cooperatives are in possession and responsible for the management of all relevant assets. Information events and conversations with inhabitants were conducted to guarantee for a high connection to the heating network among heat consumers. However, neither the consumer nor the local government have a direct influence on the daily business and relevant decision-making processes (see **Table 13**). As in this bio-energy village model, the production is almost exclusively based on the use of biomass and the institutional organization dependent on the agricultural sector it was named Agriculture Model.

2. **Cooperative Model:** Also, in **Village I** and **Village N** the heat and electricity production is based on the one biogas plant in each village. Further, a wood chip burning plants were installed and also a “Pufferspeicher” in **Village I**. In these villages people of the community joined together and founded a local cooperative all technological assets. In **Village I** the University of Göttingen initiated the project, while in **Village N** the impulse for the project came from within the community. In both villages the plan for the project and its implementation were based on the broad support of the community and the active participation of villagers. The interviewee in

Village I strongly emphasized that this project is purely based on the community without the involvement of non-local entrepreneurs (Fangmeier, 2016).

In this model the technological set-up is based on the use of biogas and the combustion of wood. The institutional organization of the project, is based solely on cooperatives that were founded by villagers/consumers. Also, in both cases the community is a member of the cooperative resulting in a high degree of democratic participation in the overall project. With respect to the two-dimensional scheme this bio-energy village can be described as basic regarding the technological set-up and purely community-based.

3. **Basic institutional hybrid Model:** Similar to the villages in the previous model in **Village A, Village E, Village F, Village C and Village G** the energy production is based one or more biogas plants with a wood chip burning plant as complementary installation. Further, three of these villages implemented a "Pufferspeicher". Additionally, in **Village C** farmers installed smaller photovoltaics (155 kWp) on the roof of their barns. In these cases, local heating networks are owned and operated by entities that were newly found by community members whereas the biogas installations are in the hand of private actors from the local agricultural sector. As limited partners of a GmbH & Co. KG or member of a local cooperative the consumers the consumer is actively involved in decision-making processes and is regularly briefed about the project status. In **Village C** even the management of installations is based on the voluntary engagement of community members. In two cases the community is a member as well. The cooperation with the agricultural entities, operating the biogas plants, is based on a supply contract. Here the project was initiated by actors from the agricultural sector and community members or consumers. With regard to the distinguished institutional organization based on the agricultural sector and the community involvement, this model can describe as hybrid of the former two models. It has to be stated that to some extent **Village A** represents an outlier in this model. In this case the heating network is partially owned by the local government and a GbR founded by community members to administrate the heating network. In contrast to the previous cases, the consumer has no direct influence on decision-making process in a GbR.

In these models the ownership structure and operation is purely based on local actors. Further, only small and middle size communities, with a size of 271-1000 inhabitants are represented here. It is likely that in smaller villages, community-based organizations can be established and managed more easily. In contrast, lager communities require a broader more complex technological set-up. More biomass installations and heating networks, as well as large-scale renewable energy installations are necessary to meet the requirements for the bio-energy village status. This results in a more diverse model, which includes local and supra-regional private actors and institutions.

4. **Capital Company Model:** In three large-size communities (**Village O**, **Village H**, **Village L** and **Village K**) and one middle-sized community (**Village D**) biomass installations, large-scale solar parks and wind parks with capacities higher than 1000 kWh were built. In these communities a more complex set of actors including supra-regional stock companies (AGs) and GmbHs or GmbH & Co. KGs is involved, as these installations pose a major investment. For larger capital companies operating in the renewable energy sector can efficiently install and manage the necessary assets as they have sound experience and a larger capital basis, reducing the risk of such an investment. Different projects were initiated by various private actors and agricultural companies resulting in a bio-energy village. However, the involvement of supra-regional capital companies reduces the direct influence of the community and consumers on the overall project as their institutional organization of projects includes no participation mechanisms. Although, these companies are dependent to the local governments in regard to approvals for the use of public space, the installations are privately operated and managed in a purely profit-oriented manner. With reference to the classification scheme this model can be described as diverse and based on private institutional organization. In this classification **Village O** represents an outlier. The biomass installation is only a minor part of the project and the major share of electricity supply is based on the wind and solar park. Further, it is the only community in which the local government founded a public utility company to sell electricity. Still, the consumer has no direct influence on decision-making processes.

In the small-sized **Village B** three dimensions of actors are involved and a very diverse technological set-up can be found. By looking at the combination of different technological and institutional aspects it becomes obvious that this model takes on a unique position within the sample:

5. **Diverse institutional Hybrid Model:** Similar to the case **Village G,** the villagers in **Village B** joined together and founded a GmbH & CO. KG in order to operate a heating and electricity grid and a wood chip burning plant, whereas the biogas plant is in possession of the local agriculture cooperative. The wind and solar park, as well as the battery storage, belong to supra-regional capital companies. Several community and non-community based initiatives came together in this case and this project reached a different proportion compared to other small sized and middle sized projects with a wind park that has by far the highest capacity in this sample (91100 kWp). The agricultural sector, private investors and firms are involved in the project, while the grids institutional organization of the grids is based on the support of consumers and their support for the project (see **Table 9**). In theory, this bio-energy village can function completely independent from the regional grid and other energy suppliers and therefore. The connection to the regional grid is only necessary due to the generated electricity

surplus. In this small-sized village we can observe a very unique institutional organization as well as a diverse technological set-up, including Europe's large battery-storage facility. With respect to the classification model this bio-energy village can be described as diverse, partially community oriented and partially private oriented.

Figure 4 provides an overview of the five models according to the previously developed classification scheme. **Figure 5** provides an overview of core aspects of each model.

Figure 4. Bio-Energy Village Models

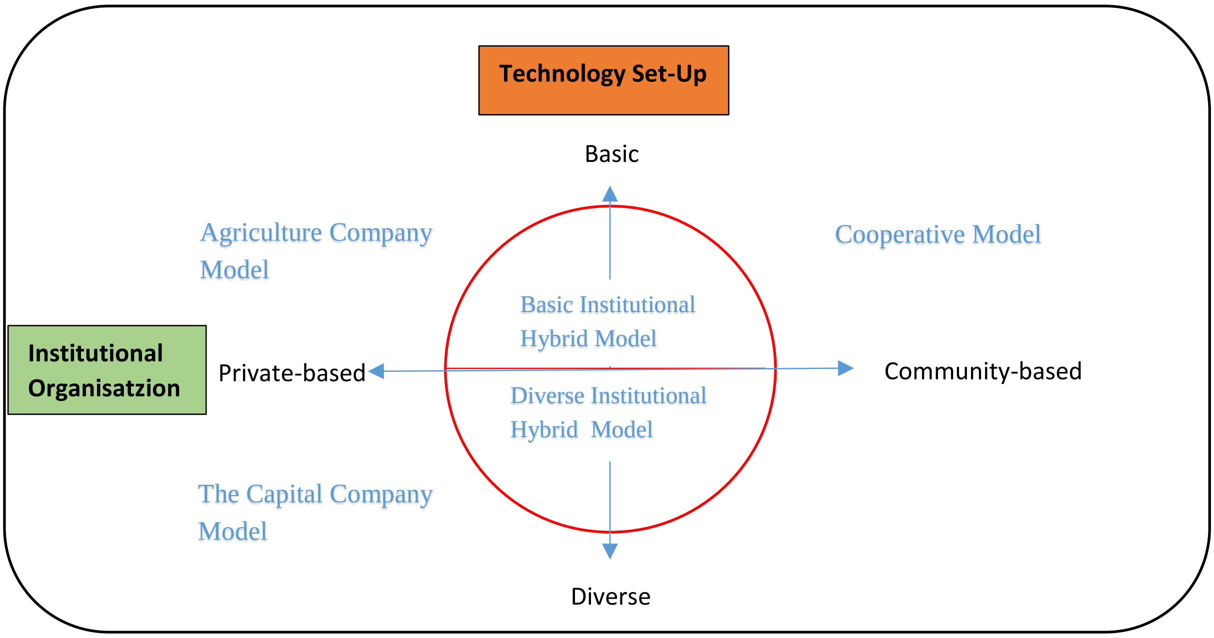
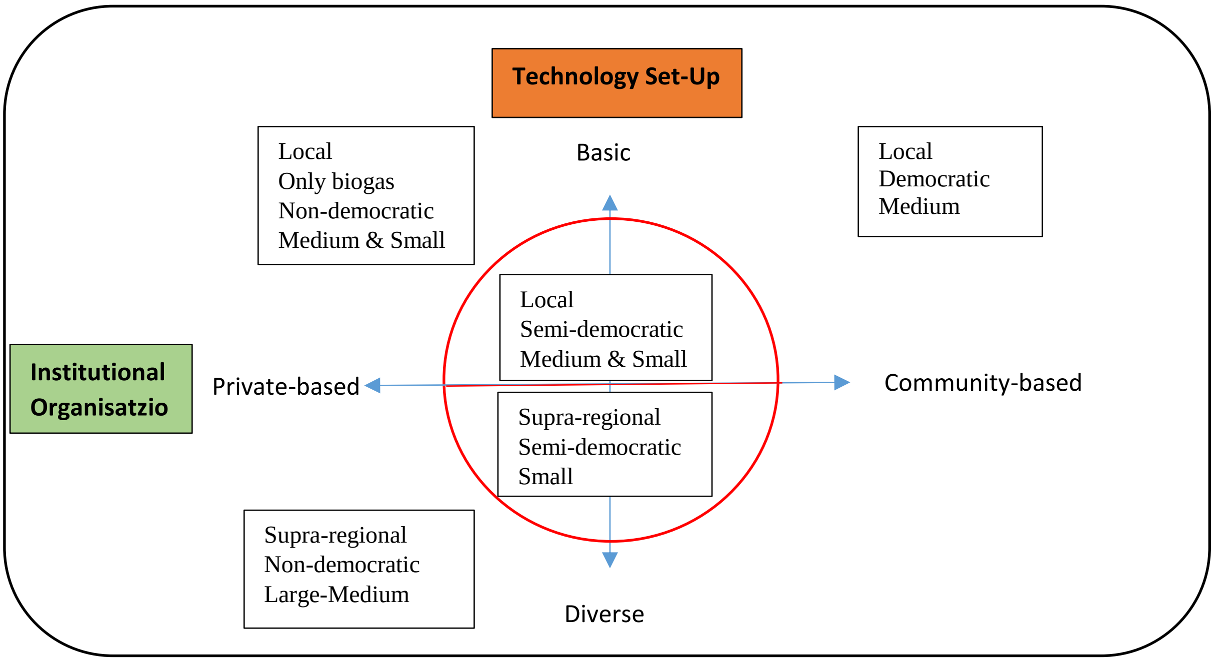


Figure 5. Characteristics of Bio-Energy Village Models



9.1 Further Results

Some aspects, assessed in the interview cannot be clearly linked to the suggested classifications and will be further clarified in the following part.

In fourteen interviewed villages interviewees reported that a constant heat supply represents an elemental part of their concept, emphasizing that a reliable energy supply based on renewable energies is possible. As **Village M** represents the only exception, it is likely that such a supply guarantee is part of most bio-energy village systems. The implementation of wood burning chip plants represents the common method to ensure a sufficient heat supply, if the capacities of cogenerations plants cannot guarantee a constant heat supply. Further, the implementation of a hot water storage tank can be described as another energy efficiency measure. Such measures are undertaken by private and community oriented institutions alike, as long as they represent a cost effective improvement. Energy efficiency measures are dependent on a range of factors such as necessity, profitability, available capital and support within the community or organization.

Additionally, it can be observed that in private and community-oriented systems possible agricultural synergies are exploited. Operators of biogas plants have severe interest to create additional revenue through heat sales in summer and are connected to heating installations. At the same time such agricultural synergies improve the attractiveness and prosperity of the community. The only model in the classification that does not include such a cooperation is the diverse institutional hybrid model. But as **Village B** stated that plans are being made in order to exploit such synergies in the future, no specific link to one of the models can be made.

An important factor that influences that can influence the technological set-up of existing bio-energy villages is the date of the project implementation. As regulations for the renewable energy sector and particularly the EEG were changed and revised several times (EEG 2004, EEG 2009, EEG 2012, EEG 2014) the legal framework for bio-energy projects can differ. For example, the composition of biogas-substrates is not only dependent on market prices for crops and the farmer’s individual possibilities for cultivation. Installations that went into business after 2012 receive different remunerations for two distinguished categories of substrates and a bonus is paid for operators that use a certain share of manure in the process. Also, the promotion of “Flexibilisierungs” upgrades differ between the amendments. Consequently, incentives for different substrate mixtures are strongly linked to the relevant legal framework.

Furthermore, while analysing the collected data on economic aspects, no stringent link between the first two dimensions and an economic dimension could be developed. In fourteen villages heat is sold, while only in two villages electricity. The energy is sold by the grid operators, or agricultural entities and in one case a public utility company. The presented classifications visualize the link between the institutional organization and the technological set-up of the project. However, the parts **7.3**, **7.4**, **7.5** and **7.6** asses’ only economic aspects of operators, which sell energy directly to the villagers in the community. These institutions do not necessarily differ between the presented classifications. Therefore, these parts can only partially be linked to the institutional dimension. Still it has to be stated that part of the financial assets of community-based organizations are based on the contribution of consumers or members. Consequently, in model two, three and five the community members are prosumers and investors alike. The heat price modalities however, were designed individually to specifically match each project. A common feature in that regard represents the emphasis to provide a cheaper supply compared to fossil-based suppliers.

Furthermore, the availability of subsidies is dependent on a range of factors. Subsidy programs have different time-spans. Hake (2016) reported that their bio-energy village received funding for its heating network from a national pool and the KFW. For six weeks both pools were overlapping and after that projects could only apply for one of them. Based on these information, it can be concluded that application date and the age of a community represent important factors. Further, no funding pool for a bio-energy village as an entity exists. The support certain types of technologies such as heating networks or wind energy. Therefore, available funding pools can differ according to the technological set-up.

10. Conclusion

The term "bio-energy village" does not provide a clear concept for decentralized energy communities but rather represents a status or title that these communities can achieve if they fulfill the four criteria stated in the introduction. As a variety of different decentralized energy production systems exist, this study was conducted to provide a stringent conceptualization for different bio-energy villages, based on key characteristics. Therefore, two research questions were assessed. In a first phase of this study similarities and differences of technological, institutional and economic characteristics were presented. In a second phase, a classification scheme was created to develop theoretically grounded classifications of different projects. This assessment was based on qualitative data, gathered through the conduction of semi-structured interviews and complemented with information from various project websites. Based on a case selection approach, ensuring a high variety, fifteen bio-energy villages were selected and analyzed with regard to different project implementations, energy plant configuration, participating stakeholders, regulations, efficiency measures, and heat pricing systems. As expected a great diversity across different bio-energy villages was found, given this strategy of case selection. However, as a major similarity it can be observed that the technological set-up used for the exploitation of biomass energy in every village is composed of biogas installations, cogeneration plants and adhering heating networks. Using CHP technologies systems were implemented that provide a high degree of energy efficiency compared to conventional energy systems.

In order to answer the second research question a two-dimensional classification scheme was developed including, and technological and institutional dimension. With the help of this classification scheme five bio-energy village were developed and common characteristics pointed out. Larger villages with a more diverse technological set-up, including solar -and wind parks tend involve supra-regional actors, private investors, farmers and capital companies. Their structure is not primarily based on the support of the community and its residents and therefore provides no mechanisms for a democratic participation of villagers in the project. In contrast smaller and middle-sized communities that mainly generate energy using biomass, systems were created that are based on the involvement of the local agriculture industry and newfound community-based organizations. These organizations are bound to the support and involvement of villagers and at the same time offer mechanisms for an active democratic participation in the projects.

As a result of the study it can be stated that bio-energy villages represent a phenomenon that covers a complex range of possible systems. The qualitative assessment enabled a detailed and in depth examination of the selected cases and a cross-case comparison. Complexities and important factors that are relevant for the research topic could be discovered and implemented into the research, that were likely missed by more positivistic enquiries. Consequently, a rich amount of scientific data about decentralized rural energy communities with a “bio-energy village” status could be contributed to the scientific community. Stringent conceptualizations based on key characteristics are not only helpful but necessary to ensure reliability, internal validity and reproducibility of future studies investigating these rural energy systems. Furthermore, by developing five different bio-energy village classifications, a basis was created for the scientific investigation of key characteristics and environmental circumstances that lead to a bio-energy village’s success. Additionally, the classification of the selected bio-energy villages provides a knowledgebase, upon which existing communities can gain new insights for further improvement (yard-stick approach). Communities that plan on transforming their energy system can access this knowledge about different types of bio-energy villages and can design a blueprint according to pre-existing patterns and presented aspects. Moreover, this study might raise awareness about the existence of bio-energy villages and their potentials in the scientific community and beyond.

With regard to the limitations of this study it has to be mentioned that the qualitative data was collected from only a small number of existing cases in Germany. Furthermore, a case-selection was used to increase the variability. As a conclusion, the findings are not representative and cannot be generalized. Additionally, due to the use of semi-structured interviews as method of data collection, data can be influenced by the researcher's personal biases and idiosyncrasies, which could have had an affect the subject’s responses. Concepts such as “Cooperation” or “Energy Efficiency” can lead to different implications if not sufficiently explained. Future research is necessary to properly assess the extent of different decentralized, rural energy systems that the term, bio-energy village can cover. I would recommend a more extensive approach that covers a larger sample, using interviews combined with a quantitative survey, questioning all operating companies involved in a project.

Concluding this study, it can be stated that bio-energy villages are an interesting example for the increased share of renewable energy communities in Germany. The liberalization of the energy market, constant rates of remuneration for renewable energy sources as well as a broad spectrum of available funding pools and investment incentives, have led not only to an increased share of renewable energies, but also to a more decentralized production. The implementation of a bio-energy villages provides an effective option to properly asses' local needs, strengthen local economies, support local farmers, cut down costs, reduce CO^2 and reduce dependency to national oil, gas and/or electricity suppliers. Additionally, the community level approach offers structures that can increase and secure consent and participation of the local citizens.

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Appendix A

Overview of Renewable Energy Sources and Technologies

Wind Energy: "Wind energy" describes a process in which wind is used to produce electricity or mechanical power. Wind turbines can convert the kinetic energy of the wind into mechanical power. This mechanical power in turn can be converted into electricity by a generator. Wind turbines turn in the moving air masses and fuel a generator that supplies an electric current.

Because the energy content of the wind increases by the factor eight if the speed of the wind doubles, most of the wind turbines are located in areas that guarantee an optimal rate of energy generation. As a conclusion most of the wind parks are built along the coast line, on higher terrain and in offshore areas that guarantee a stable wind rate with a high speed (Welz, 2011).

Hydro Energy: As well as wind, flowing water can generate a great amount of kinetic energy by using water wheels or turbines. For example a dam can guarantee the necessary pressure in order to power a generator. Hydro Energy Plants can be distinguished into three types (Welz, 2011):

1. Run-of-river power station, that use the natural flow of a river.
2. Storage power plants that pile up flowing water and generate electricity through the fall of the water through a turbine.
3. Pumped storage plants, that use two reservoirs, which are connected by a pipe system. Water can be pumped up into the upper reservoir and released again through a turbine in order to generate electricity.

Solar Energy: Systems that are used in order to convert solar energy into heat and electricity can be distinguished into three types (Welz, 2011):

1. Thermal collectors absorb solar radiation in order to heat up a medium like water and make it useable for heating.
2. Solar power plants reflect the solar radiation and concentrate it on a certain point in order to boil liquids like oil or water and use the steam to power turbines.
3. Photovoltaics are devices that use semiconductor technology to perform a conversion of electromagnetic radiation, such as sunlight, into electricity.

Geothermal Energy: The term describes thermal energy that is stored and generated in the earth. Thermal energy is defined as the energy that determines the temperature of matter. It can be distinguished between close-to-the-surface geothermal energy extractions and the extraction of energy from deeper geological formations. By using a pump hot steam can be extracted to heat a building or power turbines and generate electricity (Welz, 2011).

Biomass Energy*:* Biomass represents the central renewable source of the bio-energy village concept. According to Ruppert et al, (2008) the term "biomass" describes into plant form converted solar energy. It can be regarded as CO_2 neutral energy source as in the long-run nearly as much CO_2 is emitted during the combustion as bound during the plant growth.

Biomass sources can be used to generate fuel, heat and electricity through different methods of conversion (Table 2). The scope of the term biomass in regard to the energy production includes wood, straw, grasses, cereal plants, plants that contain sugars and oils, manure, industrial and household organic waste, sewage sludge, biogas, sewage gas and landfill gas.

Table 14. Methods for Conversion of Biomass

Methods for the conversion of biomass	**Energy sources based on biomass**
Carbonization	Coal
Gasification	Purified Producer Gas
Alcoholic Fermentation	Ethanol
Compression/Extraction	Plant-based Oil
Compression/Extraction and Subsequent Transterification	Vegetable Oil Esters, "Biodiesel"
Anaerobic Digestion	Biogas
Aerobic Digestion	Compost
Pyrolysis	Pyrolysis Oil

Source: Welz, J. (2011). Geschäftsmodelle und Erfolgsfaktoren von deutschen Bioenergiedörfern. Eine empirische Untersuchung. Lüneburg: CSM, Centre for Sustainability Management. P. 20

Biomass can be stored easily in a liquid, gaseous and solid form. Therefore it can be converted for energy generation in accordance to the current demand. In contrast to hydro-, water- and geothermal energy the availability of solar and wind energy is characterized by high fluctuations.

Table 15. Biomass Installations

Biogasanlage (biogas plant)
Blockheizkraftwerke (cogeneration plant)
Biomassekraftwerk (biomass plant)
Holzheizung (wood heater)
Holzhackschnitzelanlage (wood chip burning plant)
Pelletheizung (pellet boiler)

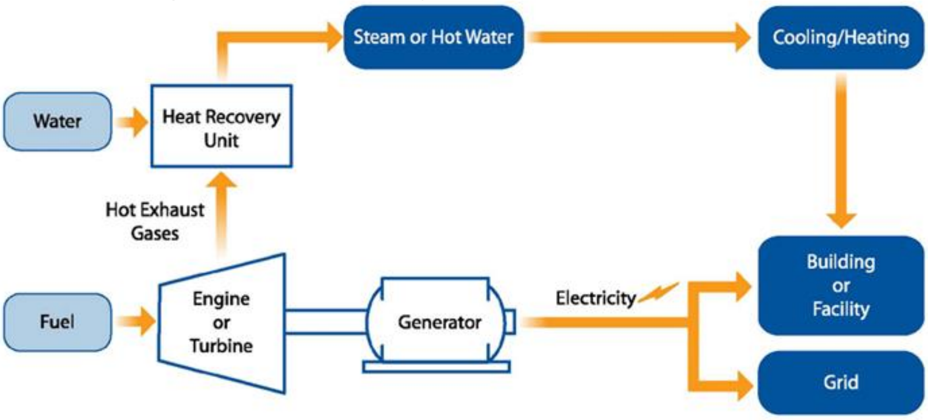
Source: Welz, J. (2011). *Geschäftsmodelle und Erfolgsfaktoren von deutschen Bioenergiedörfern. Eine empirische Untersuchung*. Lüneburg: CSM, Centre for Sustainability Management. P. 24

Biomass Plants/Biogas Plants: In a biomass plant electricity is generated through the combustion of biomass. Further, in a biomass heating plant the resulting heat is made commercially usable. Different biogenic fuels such as wood and energy crops are used.

Biogas plants produce biogas using anaerobic digestion. The term describes a collection of processes in which microorganisms are used to break down biomass in the absence of oxygen.[21] Commonly plants that are operated by agricultural holdings that use manure and energy crops to power the plant. Energy Crops are plants that can be grown as a low-cost and low-maintenance harvest such as corn.[22] Most bio-energy plants are connected to a cogeneration plant to convert the produced gas into heat and electricity.

Cogeneration Plants: Cogeneration through combined heat and power (CHP) refers to a group of technologies that simultaneously produce electricity and utilize heat. Both are produced from the same fuel input. The heat derived from the electricity production can also be used for non-heating purposes such as cooling. Cogeneration can be part of a decentralized energy distribution model whereas energy production takes place close to the point of consumption. Cogeneration is regarded as more energy efficient as for the same fuel input the output of useful energy exceeds far exceeds the level of conventional separate heat and electricity production.[23] **Figure 5** and **Figure 6** provide an overview of the two most common versions of cogeneration plants.

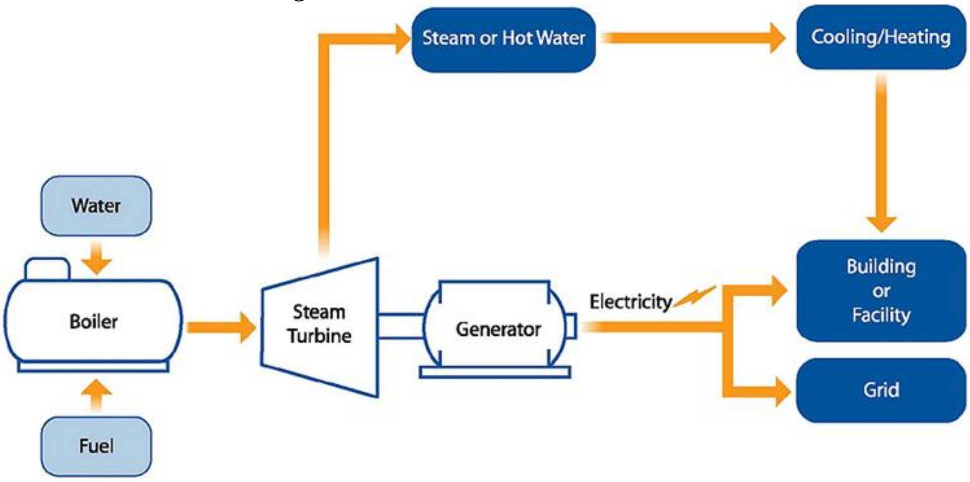
Figure 6. Gas Turbine or Engine with Heat Recovery Unit



Source: Cogeneration / Combined Heat and Power (CHP). (n.d.). Retrieved May 28, 2016, from http://www.c2es.org/technology/factsheet/CogenerationCHP

[21] http://www.fnr.de/nachwachsende-rohstoffe/bioenergie/biogas/
[22] http://www.fnr.de/nachwachsende-rohstoffe/bioenergie/energiepflanzen/
[23] http://www.c2es.org/technology/factsheet/CogenerationCHP

Figure 7. Steam Boiler with Steam Engine



Source: Cogeneration / Combined Heat and Power (CHP). (n.d.). Retrieved May 28, 2016, from http://www.c2es.org/technology/factsheet/CogenerationCHP

Wood Heating Systems: In a Wood Heating System the biomass, wood is burned in order to heat rooms and buildings. Wood is a biogenic fuel. Different forms of wood such as chips, wood pellets, firewood, piece wood and wood briquettes can be used for the combustion. In general, pellets and wood chips are used in heating systems that contain an automatic loading. They produce less ash and most of them have higher degree of energy efficiency.[24]

Local Heating Network: The transmission of useable heat between different buildings is described as local heat. In comparison to district heat, local heat is transferred only via relatively short distances. However, the transition to district heating that include a pipeline network with a wider range is fluent. Water is used as a medium for transport and heat accumulator. Through a heat exchanger the heat, produced by one or more heat generators, is used in order to heat the water in the pipeline system. The transported heat can be converted to power a radiator at the place of consumption using another heat exchanger. A return flow transports the water back to the heat generator.

In contrast to district heat system a local heating system can be implemented on a decentralized small scale level. The typical thermal capacity of a local heating network lies between 50 kilowatts and a few megawatts. Additionally, the necessary heat can be transferred using relatively low temperatures in the system. As a conclusion, not only the generated heat in cogeneration and heating plants but also the lower heat generated from geothermal and solar plants can be used

A local heating network usually supplies several buildings, an industrial park or a smaller community. Generally, the size of the coverage are matches the level of available heat that is generated by decentralized energy plants, such as biogas and cogeneration plant.[25]

[24] http://www.meineheizung.de/holzheizung
[25] http://www.geothermie.de/wissenswelt/glossar-lexikon/n/nahwaerme-netz.html

Appendix B

Legal Framework

Table 16. Legal Framework

EEG	The Renewable Energy Sources Act (EEG) was implemented in 2000 to encourage the generation of electricity from renewable energy sources, with later amendments in 2004, 2009, 2012 and 2014. According to the Act all grid operators are obliged to connect plants generating electricity from renewable energies to their grid on a priority basis and to purchase the generated electricity, at fixed rates of remuneration. Further, the act provides a regulatory framework for the generation of electricity from renewable energies. Depending on the installation type and its capacity level the level of remuneration differs. The remuneration period amounts 20 years plus the year in which the installation is put into operation. The standard remuneration as well as the bonuses are subject to an annual degression, which is 1% for installations put into operation until 31.12.2011 (EEG 2009)[26], and 2% for installations put into operation from 2012 onwards (EEG 2012).[27] Biogas and Biomass Plants put into service after 2012 are bound to an additional input substrate tariff; this tariff is separated from the graduated basic remuneration. Here two categories are distinguished: Category 1 includes energy crops such as corn and beets; Category 2 includes ecologically-advantageous materials like manure, biomass from landscape conservation or new energy crops, for example wild flowers. The input substrates in category 2 receive a higher remuneration compared to those in class 1. The remunerations for both categories do not come within the scope of the annual degression. Bonuses can be granted for bio waste fermentation plants as well as biogas upgrading. Further, as special remuneration for small slurry plants, with a maximum electrical capacity of 75 kW can be granted. As a new element the EEG 2012 introduced a binding minimum use of the produced heat and a limit for the input of corn and grain kernels. Plant operators are obliged to present documentary proof that installations meet the standards of the EEG framework, including documentation on the input substrates used.
KWKG	According to the combined heat and power act (KWKG) the CHP electricity that is fed into grids of all voltage levels for the regular supply is subsidized. The system operator has to take in the electricity and pays an extra charge dependent on the installation type. Also, CHP electricity that is not fed into the public grid is

[26] https://www.clearingstelle-eeg.de/eeg2009
[27] ttps://www.clearingstelle-eeg.de/eeg2012

	subsidized. Further, the act regulates the expansion and construction support for cooling and heating grids as well as storages.[28]
BIMSchG	The federal Emission Control Act or BIMSCHG contains legal provisions for the protection of harmful external environmental influences such as contamination of the air, noises, etc. and is complemented by a large number of regulations.[29]
EnWG	In 2005 the second energy industry (EnWG) law was implemented. The act contains a set of rules that aim at unbundling and regulating the electricity grids according to the EU directives for the energy market liberalization. All grid operators are required to guarantee non-discriminatory access to their electricity and gas grids for all customers. The customer only has to pay network charges that are approved by the German Federal Grid Agency.[30]
Biomasse Verordnung	The biomass regulation defines the term biomass in accordance to the EEG and defines the scope of application of the EEG. The Regulation defines, substances that can be categorized as biomass, it define technical processes for electricity generations for which the EEG can be applied as well as environmental provisions for the use of this biomass.[31]

[28] https://www.gesetze-im-internet.de/kwkg_2016/
[29] http://www.gesetze-im-internet.de/bimschg/
[30] https://www.gesetze-im-internet.de/enwg_2005/
[31] http://www.gesetze-im-internet.de/biomassev/

Appendix C

Legal Structures

T**able 17**. Legal Structures in Germany

Einzelunternehmen	**Gesellschaften**	
	Personengesellschaften	*Kapitalgesellschaft*
	Gesellschaft bürgerlichen Rechts (GbR)	Aktiengesellschaft (AG)
	Offene Handelsgesellschaft (OHG) Kommanditgesellschaft (KG)	Gesellschaft mit beschränkter Haftung (GmbH)
	Special Form	
	Gesellschaft mit beschränkter Haftung & Compagnie Kommanditgesellschaft (GmbH & Co.KG)	
	Eingetragene Genossenschaft (eG)	

Einzelunternehmen: An entrepreneur who produces or distributes energy in the legal form of an "Einzelunternehmen" or sole proprietorship is solely reliable for the project. The entrepreneur is liable towards all third parties and this liability extends from the company's assets towards his personal assets. In order to start a sole proprietorship no minimum capital is necessary (Thomson, 2013).

An alternative for the sole proprietorship represents the "Personengesellschaft" or partnership structure. In this scenario several entrepreneurs with a common business purpose affiliate based on a partnership agreement. A partnership represents no legal entity in Germany.

Gesellschaft bürgerlichen Rechts: The primary legal form of a partnership is the GbR. A GbR can be established by at least two persons or legal entities that are mutually bound to a common business purpose. No minimum capital is necessary to create a GbR. The entrepreneurs can be held liable towards their creditors with their corporate assets and their private assets if the latter is not sufficient. Entrepreneurs can be held liable with their corporate and private assets. In case part of the common business is a commercial trading business an alternative legal structure needs to be applied. This includes the commercial distribution of heat and electricity. Depending on the external liability a KG or OHG can be applied (Thomsen, 2013). According to German law all entrepreneurs of a GbR are entitled to manage the company. Based on the partnership agreement deviating regulations can be introduced.[32]

Offene Handelsgesellschaft: An OHG is another partnership in which two or more persons or legal entities join together to start a trading business. Further, the OHG can be distinguished from the

[32] https://www.gesetze-im-internet.de/bgb/__709.html

GbR by the fact the generally all entrepreneurs are entitle to a sole management. A deviating regulation can be implemented through the partnership agreement. No minimum capital is necessary in this case and every entrepreneur can be held directly liable towards creditors with their personal assets. Further, an OHG has to be signed into the national trade register (Thomsen, 2013).

Kommanditgesellschaft: In order to found a KG at least one entrepreneur is necessary who can be held liable with his private assets. In contrast to an OHG limited partners can join a KG, whose risk of liability is reduced to the amount of their capital contribution. This fact represents the crucial difference between an OHG and a KG. The limited partner is obliged to contribute the in the national trade register defined sum (Thomsen, 2013). In general the personal liable partners are entitled to a sole management of the company whereas limited partners are excluded from the management. A deviating regulation can be implemented through the partnership agreement.

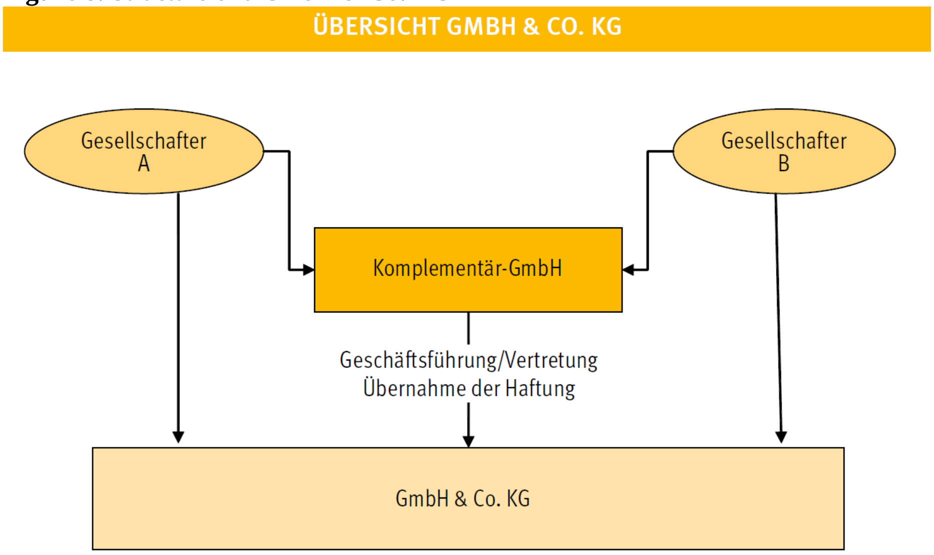
In Germany a capital company is a body under private law based on a partnership agreement. The members of a capital company follow a common, in most cases economic purpose. They can be distinguished from “Personengesellschaften”. These companies have comply with statutory capital contribution and conversation rules. Further, a capital company represents a legal entity and the weighting of individual votes in decision-making processes are in general dependent to the amount of capital contributions.

Gemeinschaft mit beschränkter Haftung: A GmBH can be founded by one or more members and represents a common legal form among smaller and middle-sized operators in bio-energy villages. In order to found a GmbH a minimum capital of 25.000 Euros is necessary. Additionally, all shareholders have to invest an initial contribution in form of money or comparable assets. The company can be held liable towards creditors only with the company’s assets. New entrepreneurs can join the GmbH by providing additional capital. In a shareholder meeting all enterprises have the right to decide about relevant questions through a voting process (Thomsen, 2013).

Aktiengesellschaft: The AG is a capital company, which capital is divided into shares. The share capital has to amount to at least 50.000 euros. The AG represents a legal entity and the shareholders can be held liable only to the amount of their investment. The choice to found a stock company in order to run a single bio-energy village is rather unlikely due to the strict legal requirements for such companies. The shareholders can participate in relevant decisions through voting on shareholder meetings. (Thomsen, 2013).

Gesellschaft mit beschränkter Haftung & Compagnie Kommanditgesellschaft*:* The GmbH & Co. KG is a special form of a KG and focused on trading business. The GmbH represents a complementary part of the company and can be held liable towards the creditors. Therefore this form can be described as a partnership without a liability for the participating natural shareholders. The GmbH & Co. KG is represented through the complementary GmbH which also manages the common business (Thomsen, 2013). **Figure 7** provides an overview to clarify the structure of a GmbH & CO. KG.

Figure 8. Structure of a GmbH & Co. KG



Source: Thomsen, J. (2013). *Geschäftsmodelle für Bioenergieprojekte: Rechtsformen, Vertrags- und Steuerfragen ;*. Gülzow: Fachagentur Nachwachsende Rohstoffe.

Eingetragene Genossenschaft*:* Another, suitable legal structure fort the commercial distribution of energy represents the cooperative form or eG. In bio-energy villages people join together in form of an eG to collaboratively produce energy or to operate a grid. Members of the eG are owners and consumers at the same time or suppliers of the eG. In general this legal structure does not serve the purpose of generating profits. In order to found an eG a minimum number of three members is necessary. Relevant bodies of an eG are the executive board, the supervisory board and the general assembly. The general assembly has the right to elect the supervisory board and the executive board who runs the regular business of the eG and is supervised by the supervisory board. However, the general assembly is considered to be the most important body where critique decisions are made, usually through a one person one vote system. In contrast to the GmbH and AG no minimum capital is necessary. The amount each member has to contribute is determined by a statute. Further, the eG can be held liable only through its common assets (Thomsen, 2013).

Appendix D

German Interview Guide

1. **Production Technology: Welche Arten von erneuerbaren Energien werden verwendet?**
   - Warum werden neben der Biomasse noch andere Energiequellen verwendet?
   - Welche Arten von Biomasse werden verwendet?
   - Welche Kapazitäten haben die Produktionsanlagen?

2. **Sotorage: Verwendet der Betreiber Technologien zur Speicherung von Energie (Strom und Wärme) und wenn ja, welche?**
   - Welche Kapazitäten haben die verwendeten Speicheranlagen?

3. **Grid Connection: Werden Technologien zur lokalen Verteilung von Strom und Wärme verwendet?**
   - Existiert ein gemeindeinternes Strom- oder Wärmenetz?
   - Wird überschüssiger Strom in das überregionale Netz eingespeist um Gewinne zu generieren?

4. **Local balancing of supply and demand: Wird auf der Gemeindeebene die Produktion und der Verbrauch ausbalanciert, bzw. wie wird ein Ausgleich zwischen Angebot und Nachfrage geschaffen?**
   - Wenn ja, welche Technologien, Methoden werden verwendet?
   - Was passiert mit der produzierten Wärme im Sommer?

5. **Energy Efficiency: Werden Maßnahmen getroffen um die Energieeffizienz in der Produktion und im Verbrauch von Energie zu erhöhen?**

Institutionelle Aspekte

6. **Ownership: Wie setzen sich die Eigentumsverhältnisse zusammen**
   - Wer ist in Besitz von relevanten Produktionsmitteln?
   - Wie viele Betreiber gibt es?
   - Welche Rechtsformen haben die Betreiber

7. **Governance: Wie setzt sich die Organisationsstruktur des Bioenergiedorfes zusammen?**
   - Wie wird das Unternehmen verwaltet?
   - Wer und wie werden die Abläufe koordiniert?
   - Welche Regularien zur Entscheidungsfindung gibt es?

8. **Energy Democracy: Wie werden wichtige Entscheidungen getroffen?**
   - Welche Art von Entscheidungsfindungsprozessen gibt es?
   - Inwiefern ist die Gemeinde bzw. der Verbraucher in relevante Entscheidungsfindungsprozesse involviert?

9. **Regualtions: Gibt es spezielle gesetzliche Vorschriften und Regularien für das Bioenergiedorf?**
   - Gibt es Landesspezifische Vorschriften?
   - Gibt es kommunalspezifische Vorschriften

Ökonomische Aspekte

10. **Value Network: beschreibt die interne und externe Netzwerke des Betreibers**

- Wer sind relevante Stakeholder und auf welche Art und Weise sind diese in das Projekt involviert?
- Gibt es Kooperationen mit öffentlichen Unternehmen?
- Gibt es Kooperationen mit privaten Unternehmen?
- Gibt es Kooperationen mit anderen Bioenergiedörfern?
- Wurden Fördermittel in Anspruch genommen (Eu, Bund, Länder, Gemeinde, KFW etc.)

11. **Value Proposition:**

- Welche Vorteile hat der Kunde
- Wie hoch ist der Preis für Wärme und Strom?
- Welche weiteren Kosten und Lasten trägt der Kunde?
- Gibt es verschiedene Tarife und Konsumentengruppen?
- Welche Besonderheiten/Vorteile gegenüber anderen Bioenergiedörfen gibt es?

Appendix E

Case Overview

Table 18. Data for Case Selection

Bio-energy villages	Renewable energy sources, (other than Biomass)	Inhabitants/ Households	Federal State
Erlacher Höhe	Solar Energy	150	Baden-Württemberg
Heubach-Buch		336	Baden-Württemberg
Raibach		207/90	Baden-Württemberg
Unterspeltach	Solar Energy	97/30	Baden-Württemberg
Hellmannshofen		52/20	Baden-Württemberg
Untermaßholderbach	Solar Energy	100/40	Baden-Württemberg
Siebeneich	Solar Energy	208/81	Baden-Württemberg
Füßbach		100/40	Baden-Württemberg
Ersingen		500/190	Baden-Württemberg
Hintertal		1901	Baden-Württemberg
Mauenheim	Solar Energy	430/100	Baden-Württemberg
Randegg	Solar Energy	1300/300	Baden-Württemberg
Weiterdingen	Solar Energy	854/213	Baden-Württemberg
Schlatt am Randen	Solar Energy	450/100	Baden-Württemberg
Büsingen	Solar Energy	1390/400	Baden-Württemberg
Bioenergiedorf Möggingen	Solar Energy	860/186	Baden-Württemberg
Renquishausen	Solar Energy, Wind Energy	750	Baden-Württemberg
Rottweil-Hausen		1995/586	Baden-Württemberg
St. Peter	Solar Energy, Wind Energy	2530/1100	Baden-Württemberg
Freiamt	Solar Energy, Wind Energy hydro energy	4200/1780	Baden-Württemberg
Hägelberg		738/218	Baden-Württemberg
Lausheim	Solar Energy	280/90	Baden-Württemberg
Lampertsweiler	Geothermal Energy, Solar Energy	300/109	Baden-Württemberg
Völlkofen		403/125	Baden-Württemberg
Reichenbach	Solar Energy	600/150	Baden-Württemberg
Oberopfingen		700/228	Baden-Württemberg
Meßkirch		175/59	Baden-Württemberg
Lautenbach	Solar Energy	300	Baden-Württemberg
Leibertingen	Solar Energy, (Wind Energy)	679/180	Baden-Württemberg
Lippertsreute	Solar Energy	650/120	Baden-Württemberg
Hausen ob Lontal		110/42	Baden-Württemberg
Schnittlingen	Solar Energy, Wind Energy	113	Baden-Württemberg
Erdbach	Solar Energy	40/14	Baden-Württemberg
Reinstorf-Steinhausen	Solar Energy	175/71	Bayern
Schlacht	Solar Energy	194/75	Bayern
Sielenbach		1648/600	Bayern
Tödtenried		360/85	Bayern
Villenbach	Hydro energy, Solar Energy	1250/490	Bayern
Rehau		250/75	Bayern
Ortlfing		217/67	Bayern
St. Ottilien		120	Bayern
Wildpoldsried	Wind Energy, Solar Energy, Hydro energy, Geothermal energy	2579/900	Bayern
Münzinghof	Solar Energy	145	Bayern

Breitenbrunn		140/63	Bayern
Willersdorf	Solar Energy, Geothermal Energy, Hydro Energy	600/160	Bayern
Mausdorf	Wind Energy	200/50	Bayern
Ulsenheim	Solar Energy	380/85	Bayern
Larrieden	Wind Energy, Solar Energy	218/56	Bayern
Merkendorf	Solar Energy, Hydro Energy,	2900/1100	Bayern
Ostheim	Solar Energy	385/148	Bayern
Hüssingen	Solar Energy	259/75	Bayern
Engelsberg	Solar Energy	114/27	Bayern
Rohr	Solar Energy	272/151	Bayern
Niederhofen	Solar Energy, Wind Energy	65/19	Bayern
Albersrieth		210/41	Bayern
Schäferei		127/43	Bayern
Ascha	Solar Energy	1532/520	Bayern
Selbitz-Wildenberg	Solar Energy, Wind Energy		Bayern
Guttenthau		85/32	Bayern
Wundenbach	Solar Energy	49/18	Bayern
Großensterz	Solar Energy, Wind Energy	/16	Bayern
Oberleiterbach		273	Bayern
Effelter	Solar Energy, Hydro Energy	271/75	Bayern
Gössersdorf	Solar Energy, Wind Energy	130/30	Bayern
Hopferstadt		670/162	Bayern
Wettringen eG		220/67	Bayern
Großbardorf		946/234	Bayern
Feldheim	Wind Energy	145/37	Brandenburg
Breuna OT Wettesingen	Solar Energy	1240	Hessen
Oberrosphe	Solar Energy	850/240	Hessen
Schönstadt		1600	Hessen
Erfurtshausen		615/175	Hessen
Gontershausen		270/60	Hessen
Haarhausen		150/21	Hessen
Poppenhausen-Sieblos		114/57	Hessen
Grüsselbach		210/60	Hessen
Bioenergiedorf Burgjoß im Spessart eG	Solar Energy	700/180	Hessen
Bergheim	Solar Energy	668/280	Hessen
Breuberg	Solar Energy	900/150	Hessen
Ivenack	Solar Energy	480/160	Mecklenburg-Vorpommern
Bioenergiedorf Bollewick im Garten der Metropolen	Solar Energy	647	Mecklenburg-Vorpommern
Hermannshof		70/25	Mecklenburg-Vorpommern
Neuhof		300/80	Mecklenburg-Vorpommern
Neuenkirchen		200/50	Mecklenburg-Vorpommern
Bantin		300/80	Mecklenburg-Vorpommern
Ellringen		174/57	Niedersachsen
Malstedt		240/68	Niedersachsen
Düngstrup		203/70	Niedersachsen
Breese in der Marsch		220/90	Niedersachsen

Volkfien	Solar Energy	72/24	Niedersachsen
Barlissen		330/68	Niedersachsen
Jühnde		750/200	Niedersachsen
Reiffenhausen		750/200	Niedersachsen
Sohlingen	Solar Energy, Wind Energy	600/120	Niedersachsen
Asche		350/100	Niedersachsen
Krebeck		765/230	Niedersachsen
Wollbrandshausen		639/210	Niedersachsen
Beuchte	Solar Energy	380/160	Niedersachsen
Lüsche		912/230	Niedersachsen
Vrees		1700/480	Niedersachsen
Lathen		2605	Niedersachsen
Peckelsheim	Solar Energy, Wind Energy	11833/671	Nordrhein-Westfalen
Lieberhausen	Solar Energy	330/103	Nordrhein-Westfalen
Ebbinghof		28/7	Nordrhein-Westfalen
Robringhausen	Solar Energy	177/55	Nordrhein-Westfalen
Altenmellrich		340/110	Nordrhein-Westfalen
Wallen		509/117	Nordrhein-Westfalen
Morbach	Solar Energy	11000/4400	Rheinland-Pfalz
Niederbettingen		300/100	Rheinland-Pfalz
Wiesbaum		631/250	Rheinland-Pfalz
Niederweiler		100/35	Rheinland-Pfalz
Altscheid		91/35	Rheinland-Pfalz
Preist	Solar Energy	744/315	Rheinland-Pfalz
Theuma	Solar Energy	1078/440	Sachsen
Sieben Linden	Solar Energy	142/22	Sachsen-Anhalt
Tangeln	Solar Energy	480/110	Sachsen-Anhalt
Iden		1000/300	Sachsen-Anhalt
Honigsee		475/245	Schleswig-Holstein
Linnau		288/96	Schleswig-Holstein
St. Michaelisdonn	Solar Energy, Wind Energy	3650/1660	Schleswig-Holstein
Dörpum		n/a	Schleswig-Holstein
Bechstedt		165/50	Thüringen
Döllschütz / Pretschwitz	Solar Energy, Wind Energy	49/20	Thüringen
Schkölen		1200/500	Thüringen
Schlöben		Ca. 1000	Thüringen
Ilmtal	Solar Energy, Hydro Energy	4000/1770	Thüringen

Source: http://www.wege-zum-bioenergiedorf.de/bioenergiedoerfer/liste/