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Insights to the internal sphere of influence of peasant family farms in using biogas plants as part of sustainable development in rural areas of Germany

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Abstract

Background: Within the last decade, the biogas branch has become an important economic sector in Germany. Many arguments are used to support a further and rapid expansion of local biogas plants in both quantity and capacity. They are centered on the potential of biogas plants for supporting rural sustainable development processes. On the other side, the national biogas praxis is accompanied by several unwelcome and partly severe side effects. This contrast has given rise to research on how to master the complex challenge of operating biogas plants as part of overall sustainable development processes in rural Germany.

Methods: The research presented in this article is mainly based on the extended case study method.

Results: It gives insight into the respective actions and significance of family farms that proactively use and develop their internal sphere of influence. These farms do so by embracing deciding factors of action such as unfolding synergies, mobilizing endogenous resources, as well as sustaining continuous innovativeness. Furthermore, they make use of a farm's capacity for self-regulation.

Conclusions: The strategies of the surveyed family farms reflect a regrounding in a peasant type of agriculture - a development which has currently been observed as a worldwide repeasantization. Given Germany's rapid decline of family farms over the past several decades, the future role of the farms in mastering the complex challenge of supporting overall sustainable development processes, e.g., with biogas plants as a technical link, is uncertain. Making use of current repeasantization processes for expanding the sustainable use of biogas plants is an approach which, to date, seems to be hardly noticed and considerably underestimated.

Keywords: biogas plant, family farm, peasant type of agriculture, sustainable development, self-regulation

Background

An ongoing expansion of biogas[a] plants can be observed in Germany, from 139 in 1992, 1,050 in 2000, to about 6,000 at the end of 2010 [1,2]. Between 2000 and 2010, the installed capacity increased from 65 to about 2,279 MWel, and the average electrical capacity of newly installed plants rose from 75 to 380 KWel [2]. Within the last 10 years, the German biogas branch has become an important economic sector which has achieved market leadership on a global scale [3]. It consists of several hundred companies, including manufacturers and providers of plant components and entire plants as well as service providers, operators, etc. Political documents on governance strategies, such as the National Biomass Action Plan, support a further expansion in order to realize the manifold-associated potential of biogas plants[b] [4]. A major potential of biogas plants is seen, for example, in their role for the transformation process from fossil fuel-based energy to renewable energy. Furthermore, they are intended to function as a major pillar of sustainable development strategies in rural areas. Biogas plants' ability to contribute to aims such as creating added value and closing resource cycles in their surroundings, as well as

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improving the efficiency of national energy supply structures, is a further argument in their favor [4]. Massive efforts are being made in development and research processes to realize this potential.

Analyzing the situation in Germany reveals the complex challenge of fulfilling the manifold potential of biogas plant operation. This is due, for example, to several side effects which are accompanying the fast and steady growth of biogas plants in both quantity and capacity.

One of the side effects is the continuing interwovenness of the sector's growth with a fossil fuel-intensive type of agriculture, demonstrated by the significance of corn cropped in monocultures for substrate supply [5]. Many production units are solely cultivating corn as an energy crop because of its excellent ratios of cost input to energy output. All in all, corn accounts for about 48%, measured in mass fraction, of all substrates that have been utilized in biogas plants since 2004 [6]. Between 2005 and 2010, the area for cultivating corn as an energy crop increased nearly eightfold from 70,000 to 525,000 ha [7].

Another side effect is the difficulty of achieving efficiency within the whole life cycle of the converted resources. The most notable aspect is the relatively low level of heat usage of biogas plants, with which heat-power cogeneration is coupled. On average, below 50% of the generated heat is used [6]. Only 10% of all biogas plant operators who have started after the 2004 amendment of the German Renewable Energy Law use more than 50% of the available heat energy [6].

Recently, the regional contribution of biogas plant operation to the growing pressures on cultivated land has become a source of an increasingly heated debate. Reasons for this are, on the one hand, studies which highlight the theoretical energy potential of all given livestock manure in Germany in comparison with studies which test the practical feasibility of such a theoretical energy potential within the boundaries of the requisite agricultural land. These comparisons show a wide gap.[c] On the other hand, more and more studies reveal regional developments of raising rents, notably due to the capital reserves of biogas plant operators who benefit considerably from some of the bonuses the German Renewable Energy Law is granting [8]. Financially influential investors from outside the farming sector with a vested interest in operating a variety of biogas plants in capacity ranges that are above average seem to gain influence rapidly [9].

The *frame* of the presented research project[d] is set by this national contrast between the manifold potential of biogas plants, on the one hand, and the range of unwelcome side effects which accompany the fast and steady growth of biogas plants, on the other. It focuses on how to master the complex challenge of operating biogas plants as part of overall sustainable development processes in rural Germany from a user's perspective. Keeping in mind that a variety of political and economical conditions as well as technical progress are the basis for the further development of Germany's biogas production and usage, the challenge for every operator is to use biogas plants in a very specific and complex way that supports overall sustainable development processes. The range of actions an operator takes in this regard delineates his or her internal sphere of influence. The individual experiences with the personal internal sphere of influence might differ widely. To investigate the capabilities of this sphere, a group was chosen for whom it is strategic to use their internal sphere of influence in order to construct and maintain a self-controlled resource base to a large extent. This group is of peasant family farms [*cf.* 10]. Several members of this group were part of Germany's biogas pioneers who had began operating biogas plants long before the German Renewable Energy Law began providing financial support.

The research *objective* is to describe the potential of peasant family farms in using biogas plants for supporting sustainable development processes in rural areas. In doing so, the presented empirical research process focused on the following question:

- How is the internal sphere of influence of family farms in Germany constituted with regard to implementing biogas plants in a sustainable manner?

This question is approached by starting with the two following definitions:

A *family farm* is defined as a living system in the format of a household, business, and ecosystem unit and is embedded in a network called a region (*cf.* Figure 1).

Following this understanding of the family farm as a living system [*cf.* 11-14], its main attributes are (1)

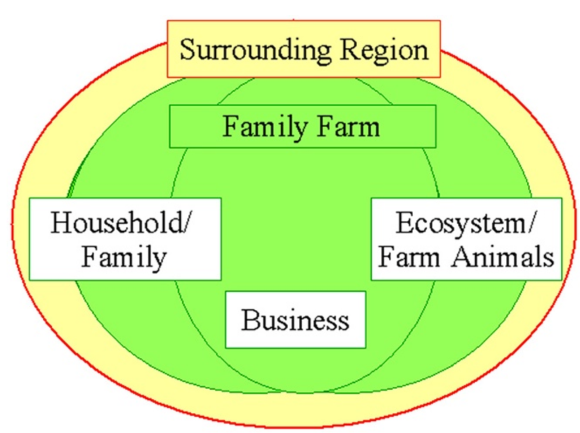

Figure 1 Family farm as a unit of household, business, and ecosystem, embedded in the surrounding region.

complexity as a result of multilayered interactions and relationships within the system as well as a high degree of variety in system behavior, which cannot be clearly predicted; (2) openness of the system, which is expressed in its manifold interactions with its surroundings through transfer of energy, mass flow, and information; (3) dynamic structures whose stability is dependent on continuous change; and (4) the ability to develop and transform the system's behavior internally.

Characteristics particular to a family farm [*cf.* 10,15] include (1) the primary provision of labor by the family members; (2) decision-making power over the considerable part of farm assets being held by the family; and (3) household and enterprise being interwoven, e.g., a shared use of resources between household and business.

A *sustainable manner of biogas plant application* is defined here as one that reflects the generation and usage of biogas in the context of sustainable development of the family farm that operates the plant with the potential of extending towards sustainable development processes of the surrounding region as well.

The following terms are used to delineate a family farm's sustainable development: (1) The target of viability in contrast to that of a continuous growth in scale [*cf.* 11-14,16,17]. (2) A basic degree of decentralized autonomy in function in contrast to that of primarily externalized supply and disposal structures [*cf.* 10,12,14,18,19]. (3) Multifunctionality in system roles and functions in contrast to that of a strong specialism [*cf.* 10,20].

The three represented terms have been empirically observed as intrinsic within self-sustaining living systems, both in ecosystems and socio-economic systems. They have been also observed as intrinsic to those farms which are following a peasant type of farming [10].

By using these two definitions, this is the first paper to bring together research of self-sustaining systems with new peasantry studies while also linking both fields to the practical side of biogas plant operation in Germany.

Methods

The first part of the research project was of an exploratory and preparatory character. Scientific literature from different disciplines was used to analyze and explore holistic approaches in theory and practice on coping with sustainable development processes in the countryside. Parallels have been identified between the general principles of sustainable development of complex living systems, on the one hand, and the peasant type of agriculture, on the other. To gain insight into the practical aspects of operating biogas plants by family farms in Germany, several families were visited, sometimes for a number of days, in order to be involved in the daily work flow and to apply participatory observation.

The second part of the research project consisted of extended case studies (following [21]), treating each farm within its surrounding region as an individual case. The main reason for choosing this method was to investigate the internal sphere of influence of family farms in its real-life context. Further reasons were to ensure an evolving and iterative research process through rotating phases of investigation and analysis. How the extended case study method, which has its origins in anthropology, is applied within the presented research project is described in the following section.

Case selection

Each case must satisfy criteria which are categorized into two groups: essential and variable. The essential criteria are further categorized into 'hard' and 'soft.' The hard criteria verify the status of a family farm as well as several aspects of the biogas plant itself, such as a minimum previous operational life of 5 years or a slurry/manure volume fraction of at least 30% of all renewable input substrates. The soft criteria are used to verify the case's interest in a course of action orientated on viability, decentralized circuits, and multifunctionality, described above as elementary terms of sustainable development processes. To ensure a sample of contrasting cases, several variable criteria are used (see Table 1).

To find the most appropriate cases, a two-step selection process was applied. In the first step, cases were preselected with the assistance of third parties who have direct contact to the selected family farms such as the German Society for Sustainable Biogas and Bioenergy Utilization and the German Biogas Association. In the next step, the analysis of the preselected family farms was intensified by a direct and selective standard interview based on the delineated hard and soft criteria.

All in all, the selected sample comprises eight cases. Alongside its compliance to the necessary criteria, the sample can be described by its specifications, some of

Table 1 Specifications of the sample concerning characteristics of the farms and biogas plants

Specifications	Sample
Geographical setting of the farms	Baden-Württemberg, Bavaria, Brandenburg, Niedersachsen
Farming types	Conventional and ecological
Initial plant operation	Beginning of 1990s to 2005
Plant capacity	20 to 600 KWel
Temperature range of fermentation microorganisms	Mesophilic and thermophilic
Substrates	Slurry, manure, and biomass
Operated cogeneration plants	Both gas and pilot injection engines
Location of biogas plant	Between 40 and 500 m to the residential building of the farms

which are delineated in Table 1. A main criterion for the decision on how many cases to include was empirical saturation.

Case studies

Following verification of each case's appropriateness, the case studies started with an initial investigation of the individual farmers' experience with realizing sustainable development in the context of his or her biogas plant operation, including practical impulses and constraints. To do so, at least one of the responsible family members was asked a few open questions in an interview. First, a shared understanding of the farm as a whole was assured by jointly visualizing the main interactions between production areas within the farm as well as the cooperation of the farm with stakeholders in the surrounding region, both in the context of the farm's biogas plant operation. A comparison between the empirical outcomes and the state of current research led to the definition of a rough concept concerning the internal sphere of influence of a farm when implementing a biogas plant in a sustainable manner.

The second phase of investigation was used to substantiate the extracted outcomes from the first phase for each farm with the help of a guided interview. To ensure a coherent starting point, the specific outcomes of the first investigation were presented before the interview. All of the second stage interviews have been transcribed. Each case is being analyzed based on the transcription and with reference to the common concept of a farms' internal sphere of influence that was extracted beforehand. Each family farm receives a copy of the resulting individual reports and is asked to review the accuracy of the results.

Results

The described results are divided into two sections which both elaborate a main aspect of a family farms' internal sphere of influence in using biogas plants in a sustainable manner: their way of acting as well as their way of self-regulation.

Factors of action

Three deciding factors proved to be particularly relevant in delineating how the family farms act to use and operate their biogas plants as part of sustainable development processes. These factors are unfolding synergies, mobilizing endogenous resources, and sustaining continuous innovativeness.

Unfolding synergies

Synergies are understood here as concurrences between different areas of production and between stakeholders that hold a high and/or multilayered benefit such as reinforcing, stabilizing, and complementing each other (following e.g. [10,11,22]).

Synergies were observed between the operation of the biogas plant and many production areas. Those which could be found most often[e] are shown in Figure 2 and are described below.

A strong synergy is demonstrated between dairy farming and the biogas plant, for example, due to the use of slurry as a substrate. Slurry is a substrate of value and almost free of charge. The value[f] of this substrate is due to its stabilizing effect on the whole fermentation process as a result of the bacteria the animal excrement contains. At the same time, the transport is managed with a minimum of energetic or financial effort by using short distances, on average less than 60 m, and often through pipelines using gravity. Through fermentation, the usefulness of the slurry as an organic fertilizer is preserved - multiple usages therefore are possible. On the other hand, having examined the supply chain of the biogas plants and the cows, a number of similarities arose which are used by the peasants in a well-directed manner, for example, the similarities between both processes of methane production. By building upon prior knowledge and experience gained from years of dairy farming, similar conclusions are drawn and applied, especially with regard to the feeding procedures with silage. Furthermore, working steps are easily combined, e.g., within the feeding procedures of cows and biogas plants, such as a combined use of the telehoist load lugger. An example of a synergy that reflects a rather particular situation is when a peasant uses self-generated heat in order to maintain a frost-free milking parlor which, in turn, improves the comfort in the cowshed for both the cows and the working people.

The interaction of biogas plant operation, on the one hand, and crop production and grassland usage, on the other, is another area in which several different synergies

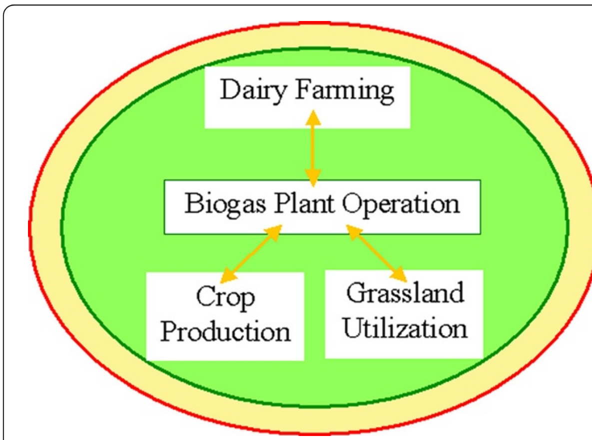

Figure 2 **Correlated areas of production with energy and mass flow in both directions within the family farm.**

can unfold. The starting position in all cases is that the family farms produce at least half of the silage needed as substrates themselves from energy crops such as grass, clover grass, and corn grown on their own cultivated land in the near surroundings. Thus, they minimize the logistic and transaction costs which are thereby incurred. At the same time, they benefit from the space for experimenting with new crops or cultivating methods for substrate production. All farmers experience benefits in the process of fertilizing their fields with the fermented product of digestate. A better handling of the digestate due to its improved consistency is just one example. The production of substrates and the application of digestate on the fields can easily be achieved by drawing upon already available farm machinery and established working steps.

Some general synergies are concerned with an increased significance of the repair shop and being able to use much of the existing equipment. One farmer who is operating a 300-KW biogas plant reported that he only spent around €100 for extra equipment in total even though he is using his workshop for all kinds of frequent maintenance. To maintain his oldest co-generator from 2006, the most important purchase was buying a new inch wrench set because the metric wrenches did not fit.

Almost all of the surveyed family farms used their step towards operation of a biogas plant as a step towards regional cooperation, whether starting, expanding, or strengthening such involvement. Figure 3 delineates some of the cooperation that gives an impression of synergies which are often experienced.

All surveyed family farms which use energy crops as substrates initiated cooperation in the field of substrate supply with farms nearby. Synergies that could be observed in several cases include, for example, an activation of regional value chains, a relationship of trust among the cooperating family farms, a contribution to their mutual income, maintenance relief in periods of work peaks - during harvest for example, and a stabilization of regional rents for farmland. The surveyed family farms started the cooperation by implementing cornerstones such as systematically purchasing substrates instead of leasing or buying new arable land in the area, using a minimum contractual bond and maximizing fair pricing - for example, by paying higher than average prices in years of slumped prices within the international market of agricultural commodities or via a fee-free release of digestate on a pick-up basis.

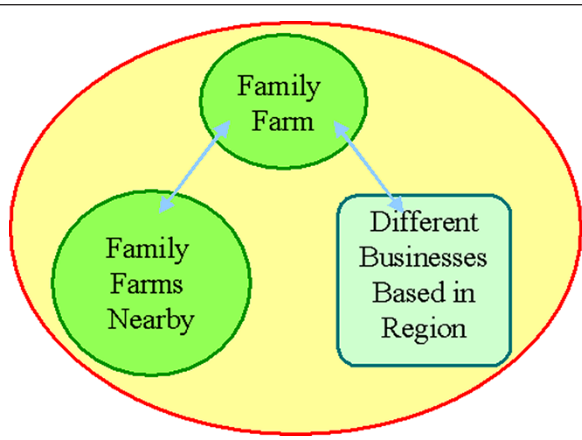

Figure 3 **Cooperation initialized by surveyed family farms with mutually high or multilayer use within the region.**

Another area of observed synergies is the cooperation between family farms and businesses based in the same region. This covers a diverse range, e.g., energy providers, renewable energy providers, providers of equipment, assemblers, contractors, etc. Some of the very common synergies are improvements in regional value chains with benefits for both parties involved. Many further synergies found in this field are quite specific depending on the particular regional situation.

Mobilizing endogenous resources

Endogenous resources are understood here as those which are internally available and hold a high potential of being internally improved and reused (following e.g. [10,23]). Those which were most frequently found can be differentiated in ecological and human capital.

Ecological capital is defined here as the peculiar functions and assets of nature which the farming families knowingly draw upon. Those which were referred to most in the context of operating their biogas plant comprise substrates, soil fertility, organic fertilizer, and energy carriers.

Substrates. Part of it is an increased differentiation of resources providing basic forage and substrates, both produced within the farm. A very common example is the differentiation of grassland or clover-grass cuts according to different needs and demands in quality for either the dairy cows or the biogas plant. Since silage with a low standard of quality is neither adequate for feeding the cows nor the biogas plant, the family farms ensure that an overall high quality is maintained. At the same time, the biogas plant can use silage of reduced quality easier. So whenever fodder silage of reduced quality is accidentally produced, the biogas plant can function as a buffer. Another example is the effective use of manure, which includes, *inter alia*, the conversion of volatile carbon. The use of given residual matters as substrates, such as residual feed in the mangers, is mostly minimal but still an important part in the farmers' efforts to reduce waste to zero. Experimenting with crops and cropping methods that improve the ratio of effort to reward in producing substrates is of strategic value for all farms.

Soil fertility. Within all surveyed family farms, an intense and multilayered examination of experimentation and engagement in sustaining soil fertility could be observed in the context of operating the biogas plant. Examples given include a systematic increase of the humus content in cultivated soils with the help of digestate separation. While the solid fraction is then used for cropland, the fluid fraction is applied to grassland. Concerning the implemented or strengthened cropping systems which actively protect or build up soil fertility, the examples found ranged from intercropping, undersown cropping, no tillage farming, and cultivation of legumes for nitrogen fixation. The cultivation of corn as the central energy crop was mostly seen as critical from a soil fertility point of view and combined with an active experimentation with alternatives.[g] Several surveyed farms are simultaneously in the process of actively reducing corn in cultivation and as substrates.

Organic fertilizer. By using digestate as a fertilizer, all the family farms experienced an increase in value compared to the former use of slurry. Alongside an increased effectiveness of the fertilizer, the digestate is valued due to reasons such as easier handling, gentler application, and reduced smell. Particularly, those farmers, who are performing fermentation processes using thermophilic microorganisms, described a very helpful reduction in the germination capacity of weed seeds.

Energy carrier. Finally, all the family farms valued their biogas plant implementation as a step towards independence in heat and power supply, even those who sell the entirety of their produced power for financial reasons and rebuy it. Besides benefiting from a further source of income which is regarded as crucial, common reasons for this are, for example, the fact that they have begun to deal proactively with shortages in fossil fuels and have improved the options within the farm for creating extra value and being part of upcoming value chains in the surrounding area. Especially, those who are actively embedded in a local heating infrastructure highlight a rise in collective awareness towards the challenges of future energy supply as well as a strengthening of local community spirit. The farms meet their internal heat requirements by using at least 35% up to 100% of agricultural residues, mainly slurry and manure.

Human capital is defined here as the combined skills and knowledge system of the cooperating people within the family farm. In the context of operating the biogas plant, those which were referred to most frequently comprise an internal knowledge system and internal skills.

Internal knowledge system. By consciously using the internal knowledge system, the farming families refer to knowledge which can be characterized as contextual, experimental, and integrated (following e.g. [23]). Contextual knowledge is founded on recognized and applied uniqueness of the time-spatial settings of the particular biogas plant and its operation, for example, concerning which kind of recommended energy crops and cropping system should be implemented at a height of 850 m above sea level. Experimental knowledge describes knowledge which is bound to practical skills. Its relevance has already been revealed in the family farms' descriptions of their plant planning process. Thus, visits to colleagues who operate biogas plants beforehand have been rated as one of the most important ways of getting informed. One farmer alone made 50 visits. Integrated knowledge is mainly concerned with the ability to gain an overview of, and to coordinate, complex situations, such as the interaction of the biogas plant operation with other areas of production within the family farms, not the least to unfold synergies. In the process of operating their biogas plants, this type of knowledge was relevant for the whole working process.

Internal skills. Almost all family farms rated technical skills as crucial, comprising a basic understanding of technical interrelations as well as an affinity for technology. Their relevance is demonstrated whenever handling disturbances in the technical work flow need to be assessed. They are considered very important for being able to quickly carry out minor repairs and regular maintenance work themselves as well as for always playing their part in ensuring the system operation. Further skills which are considered very important include a high degree of flexibility and spontaneity during the daily working process. About 20% of all biogas plant operating tasks have been, on average, considered as unforeseen. Another example is the importance of attentiveness, especially for the smaller farms mentioned, which refers to the impact of closely focusing on sensory impressions such as unusual odors, noises, etc. An example of a social skill which has been referred to several times in those farms which had expanded their activities in regional value chains of energy supply is the significance of the skill to communicate directly with colleagues, neighbors, etc., and either preventing or quickly solving upcoming conflicts.

Sustaining continuous innovativeness

Innovativeness is immanent for family farms due to the necessity to adapt continuously in the course of a seasonal rhythm, breaks in the weather, amendments in societal guidelines, or technical progress. Sustaining self-determined innovativeness, particularly with regard to interactions between novelties and innovations, is considered to be essential.

A novelty is defined here as an innovation within the farm which originates from the needs and expertise of the farming family. Thus, the definition follows van der Ploeg et al. [24] who describe novelties as ‘a modification of, and sometimes a break with, existing routines’ and further as a 'new insight into an existing practice or might consist of a new practice' or a new or evolved artifact. Novelties are founded 'through complex cycles of careful observation, interpretation, re-organization, and evaluation.' In order to create them, it is of crucial importance to act within day-to-day business in a very flexible and spontaneous manner. Observing the creation of novelties within a certain period of time, their interwovenness appears as a web of novelties. As such, it expresses how specific novelties are built upon each other and sometimes even complement each other [10].

An innovation is defined here in contrast to a novelty (following e.g. [24]). It comprises new practices or artifacts which are primarily founded on the knowledge and expertise of external specialists in technology and science. An innovation can be bought as a ready-made, standardized product. Its origin is often inspired by novelties.

Looking at the period between the initial operation of the biogas plant and the end of 2010, all family farms indicate a 'web of interrelated novelties' [10]. Figure 4 illustrates an extracted web of interrelated novelties with innovations which have been implemented during the same time horizon delineated around it. The specific web refers to one of the explored cases which had an initial operation of a 60-KWel biogas plant in 2003 and is operating a 300-KWel plant today.

Capacity for self-regulation

The delineated factors of action within all the surveyed family farms are based on their capacity for self-regulation. This capacity is about acting with a high level of initiative from within the farm as a living system. It is also about self-guidance since the deciding factors of action cannot be found in any common societal strategy or political program. Two mechanisms which have been observed within all family farms are linked to both applying an underlying guidance model and consciously dealing with triggers of development.

Applying an underlying guidance model

The guidance model that the family farms more or less consciously referred to consists of, *inter alia*, values which have several functions in regulating a socio-economic system (e.g. [11,12]). These values (1) create a meaningful context of action and as such align the behavioral possibilities of a farm; (2) limit a farm's many behavioral possibilities, for example, when favoring or excluding certain methods of cultivating energy crops; and (3) influence a farm's relationships, such as in dealing with cooperation partners. Within the surveyed family farms, values of importance include an innovative spirit, respectful and esteeming interactions among each other and towards the farming animals, enjoying daily work or taking personal responsibility in thinking, and acting within both the context of the family and of the surrounding neighbors.

The guidance model further revealed a goal orientation based on benefits the farms want to achieve for themselves and within their surrounding region.[h] Common examples have been (1) on the economic level, the interest in creating regional value chains, such as providing self-produced heat for a local supply network; (2) on the social level, the interest in contributing to a secure supply with basic commodities such as food and energy; and (3) on

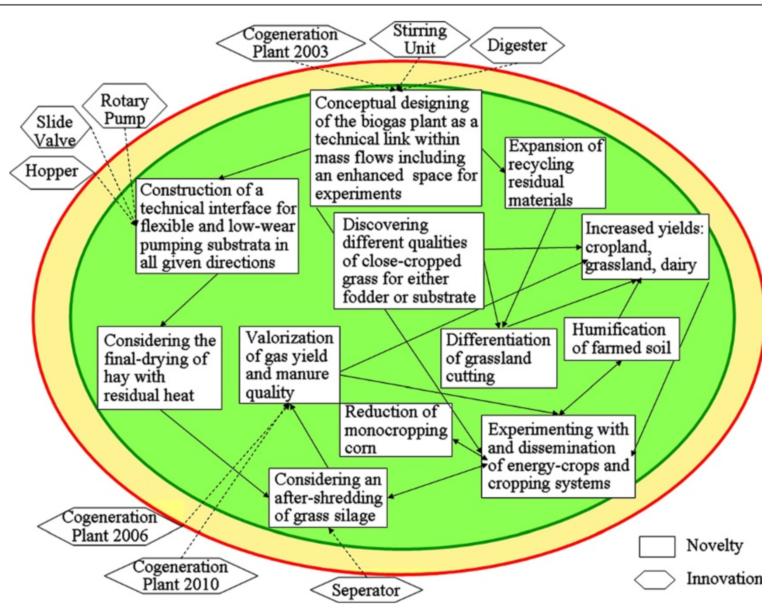

Figure 4 **Exemplary web of novelties surrounded by a variety of implemented innovations.**

the ecological level, the interest in proactively protecting long-term soil fertility.

In none of the observed family farms, the guiding model was completely clear in the beginning, but it was increasingly revealed in the feedback process of reviewing the surveyed results within each case.

Consciously dealing with triggers of development

Firstly, the development of most surveyed family farms reflects the common trend of quantitative growth at the farm level. Within the biogas plant operation period, this trend manifests itself, for example, in the undertaking of several extensions of the plant capacity, strongly influenced by amendments of the German Renewable Energy Law and in particular the introduction of the bonus for fermenting renewable raw materials in 2006 of 6 cents/kWh. Another example can be found in the increase of cultivated acreage by several hectares which has been carried out within the farm.

A highly interesting observation made within the surveyed family farms was their recognition and handling of triggers of development which challenged the farms' internal development in qualitative ways and specifically, with regard to the research question, the qualitative development of the biogas plant operation. Some of the most important triggers observed in this context consisted of situations which are (1) recognized as critical in securing the biogas plant as a stable link within the whole farm processes of production and (2) then used to reconsider related actions or habits and either to adjust or to change them. Subsequently, one of the stipulations of the biogas plant as a stable link is the guarantee that the combustion engine is able to convert biogas for more than 8,000 h a year while keeping a justified and continuously improving ratio of effort to reward.

Some of the common critical situations that the family farms experienced included (1) external incidents such as the continuous rise of unstable fossil fuel prices with its peak in the middle of 2008. It has caused rising awareness of reducing dependencies of fossil fuel-based external inputs such as chemical fertilizers and pesticides[i] and the continuous use of digestate as an effective fertilizer. (2) Internal incidents which could be directly linked to previous approaches. A relevant example which was observed several times is the experience of excessive efforts for maintenance and repair of specific plant equipment, especially those with moving parts (e.g., engines, stirring units). In the case of having chosen an engine that did not meet the farm's expectations, this experience was used to enhance awareness with regard to the suitability of equipment to the farm's needs as well as their technical maturity and quality of service. In the case of equipment that was severely strained, efforts in technical fine-tuning have been improved, such as decreasing the speed of the stirring units. (3) Internal incidents which could not be directly linked to specific previous procedures. A common example of this was disturbances which occurred at inconvenient times. This refers to time frames which have been reserved for resting or which make it difficult to receive assistance, such as the beginning of the weekend or holidays like Christmas or Easter. In many cases, this experience led to improvements of the internal repair shop as well as the development of internal technical skills.

Overall, the farms' enlargements in scale followed a step-by-step growth. The delineated triggers of development have been used for consciously incorporating phases with an explicit focus on qualitative growth.

Triggers for development are accompanied by constraints on development. All the surveyed family farms experienced external constraints, such as licensing requirements, which are deemed to be at times arbitrary and a hindrance to the effective working of the farm. Not all but many of the surveyed farms experienced internal constraints as well. Examples observed include a work overload, which led to a lack of time to pause and reflect upon internal development processes. Another example reveals personal doubts in the ability to cope with the perceived pressure to continuously increase the scale of the farm in the long run, for example, in the means of handling the situation of a continuously reduced number of farms in the surrounding regions which are seen as significant cooperation partners.

Conclusions

As described at the beginning of the paper, there is a contrast in Germany between the manifold potentials of biogas plants, on the one hand, and the number of unwelcome side effects which accompany the fast and steady growth of biogas plants, on the other. This is a situation which reveals the complex challenge of implementing biogas plants in a sustainable manner. The surveyed family farms master this challenge in rural areas of Germany.

To start with, all of the surveyed family farms use their biogas plants for a transformation process from fossil fuel-based energy to renewable energy on a regional level. This is done, for example, by producing power and heat from local organic substrates, by focusing on electricity as a high-value product for transportation, and by making use of a large amount of the self-produced heat. For heating purposes within the farm and partly as a base load for local heating networks within the surrounding region as well, the farms are able to reach a level of heat usage well above the national average. Even though all of the surveyed family farms are still more or less dependent on a fossil fuel-based type of agriculture in certain regards, for example, due to their high degree of mechanization, all of them proactively implement approaches to reduce those dependencies and to intensify their connections to a renewable resource base. To minimize a fossil fuel-based type of agriculture, the farms invest in improved ratios of effort to reward, for example, in weed control, by using the reduced germination ability of digested weed seeds in a targeted manner. They further experiment with alternative crops and cropping methods such as grass from grasslands and clover-grass, which are integrated in existing crop rotation, as opposed to simply monocropping corn.

The actions mentioned correspond with research approaches on improving the ratio of effort to reward in substrate production by cultivation of energy-producing crops from cropping systems which utilize existing potentials and synergy effects [25,26]. The general aspects of such actions can be further linked to many pieces of research which specifically look for solutions in farming that can cope with the rapid decline of fossil resources[j] [27] and the sustainability of renewable resources [28-30].

Furthermore, each surveyed family farm uses their biogas plant for closing organic mass flow cycles and creating value in their rural surroundings. An important starting point is the fact that within each specific farm, producing and reproducing activities are strongly tied together due to the strong linkages of biogas plant operation with further areas of production such as dairy farming or crop production and grassland usage. Applying the more stable organic carbon which is not converted within the fermentation process for soil fertilization and cultivation purposes is thus an example of tight mass flow cycles within the farms. Within their regions, the farms systematically establish value chains and regional mass flow cycles while purchasing substrates from farms nearby. Especially among farms they are cooperating with, they significantly contribute to a relationship of trust as a result of mutual economic strengthening. By using and developing internal skills, such as technical solutions for ensuring the work flow of the biogas plants, they contribute to enjoying daily work and providing a central basis for team spirit among colleagues.

The findings on the farms' involvement in such new forms of energy production correspond with research on current transition processes of Europe's agricultural systems and countryside towards rural development [31,32]. The significance of regional energy supply tasks as impulses for overall regional development processes can be found in research with a focus on the development of bioenergy villages or bioregions [33,34]. These pieces of research also show the impact of regional economic cycles and value chains built on endogenous resources.

For operating biogas plants as a part of overall sustainable development processes within their farms as well as within their surroundings, the surveyed family farms proactively use and develop their internal sphere of influence. In doing so, they show how several of the many potentials of biogas plant operation can be realized simultaneously and linked to a common whole. Furthermore, they show how unwelcome side effects of biogas plant operation can proactively be avoided or overcome and solved by the users themselves. The strategies they use within the exemplary context of biogas production and usage reflect a regrounding in a peasant type of agriculture - a development which is currently being observed as a worldwide repeasantization [10].

The influence of Germany's fast and steady growth of biogas plants in number and capacity on the national development of peasant family farms is multi-faceted. Whether individual promising approaches will extend to a national level remains to be seen.[k] In general, the number of family farms in Germany is declining rapidly. Many have been giving way to a structural change which is leading towards continuously expanding units of production as part of an agricultural modernization concept spanning decades.[l] It is a trend that is pursued within Germany's biogas branch development, for example, due to the situation that financially influential investors from outside the farming sector are gaining rapid influence or due to national high-tech strategies within the bioenergy sector which are, e.g., formulated in current political documents on governance strategies, such as Germany's National Biomass Action Plan [4]. Expanding the application of biogas plants in a sustainable manner by making use of current repeasantization processes is an approach which, to date, seems to be hardly noticed and considerably underestimated.

Endnotes

[a]Biogas in Germany is mainly produced from agricultural biomass. The two main input materials are animal excrements (45% mass fraction) and energy crops (46% mass fraction).

[b]Biogas is one of several bioenergies the National Biomass Action Plan is pursuing.

[c]Thiering and Bahrs [8] delineate a requirement of 80% of Germany's available farmland in order to realize the theoretical potential of 3.5 billion m^3 of methane from Germany's annual amount of slurry and manure that is principally available. They assume an average mixture in fermented mass fraction of 35% manure/slurry and 65% energy crops in order to realistically realize a plant's economic efficiency.

[d]This is the Ph.D. Project ‘Der Betrieb von Biogasanlagen als Bestandteil nachhaltiger Entwicklung im ländlichen Raum - interne Einflussnahme landwirtschaftlicher Familienunternehmen in Deutschland und Ansätze zu

ihrer Stärkung' within the Postgraduate Program 'Microenergy Systems.'

[e]Further synergies have been found in the interaction with areas such as market gardening, guesthouse, and farm shop operation.

[f]Its energy output is rather small compared to that of corn silage which is about eight times as high.

[g]Especially the conventional farmers showed an unprecedented experimentation in the process of building up humus actively, with the objective of having energy-rich substrata like corn at their disposal in the long run.

[h]The importance of a business' societal benefits for its overall sustainable development can also be found in Kanatschnig [11].

[i]In conventional farms.

[j]According to the 2010 World Energy Outlook by the International Energy Agency, a rapid decline in crude oil producing fields started in 2009.

[k]A critical look at the current trend of Germany's biogas sector can be found in Trojecka [35].

[l]The agricultural workforce in Germany declined from 24% in 1950 to 2.5% in 2000 [36]. Germany's farms have seen a steady decline since 2000 at a rate of 2.5% per year, mostly in family farms which make up 93.5% of all farms in Germany [37].

Competing interests
The author declares that she has no competing interests.

Author's information
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