Chapter 2
Bioenergy Villages in Germany: Applying the Göttingen Approach of Sustainability Science to Promote Sustainable Bioenergy Projects

Peter Schmuck, Swantje Eigner-Thiel, Marianne Karpenstein-Machan, Benedikt Sauer, Hans Ruppert, Walter Girschner, and Folker Roland

Abstract This chapter describes the history of bioenergy villages in Germany between 2000 and 2008, providing an exemplifying introduction to the more detailed aspects of sustainable bioenergy use. Developed by a team of scientists at the University of Göttingen, the electricity and heat supply of an entire village was transformed from conventional to biomass energy sources between 2000 and 2005. This lighthouse project, the first "bioenergy village" in Germany, was realised through the active participation of the entire population of Jühnde, a village in Southern Lower Saxony (800 inhabitants). The technical concept comprises (1) an anaerobic digestion plant (fuelled by energy crops and liquid manure) with a

P. Schmuck (✉) • M. Karpenstein-Machan • W. Girschner
Interdisciplinary Centre for Sustainable Development (IZNE), University of Göttingen, Goldschmidtstr. 1, D-37077 Göttingen, Germany
e-mail: peterschmuck@gmx.de; mkarpen@gwdg.de

S. Eigner-Thiel
Interdisciplinary Centre for Sustainable Development (IZNE), University of Göttingen, Goldschmidtstr. 3, D-37077 Göttingen, Germany

HAWK, Büsgenweg 1a, D-37077 Göttingen, Germany
e-mail: eigner-thiel@hawk-hhg.de

B. Sauer • H. Ruppert
Interdisciplinary Centre for Sustainable Development (IZNE), University of Göttingen, Goldschmidtstr. 3, D-37077 Göttingen, Germany

Department of Sedimentology, University of Göttingen, Goldschmidtstr. 3, D-37077 Göttingen, Germany
e-mail: bsauer@gwdg.de; hrupper@gwdg.de

F. Roland
Interdisciplinary Centre for Sustainable Development (IZNE), University of Göttingen, Goldschmidtstr. 3, D-37077 Göttingen, Germany

Department of Business, University of Applied Sciences Hochschule Harz, Friedrichstraße 57-59, D-38855 Wenigerode, Germany
e-mail: froland@hs-harz.de

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combined heat and power (CHP) generator producing electricity and heat, (2) a central heating plant fired by locally produced wood chips to satisfy the additional heat demand during the winter as well as (3) a hot water pipeline delivering the heat energy to the connected households. The chapter explains the history of the project, its social implementations and the results thereof regarding the ecological, economic and social changes in the village. Furthermore, this chapter describes the successful transfer of the model to dozens of other villages in Germany. The process of developing bioenergy villages is embedded in the methodological framework of sustainability science, which is based on the principles of inter- and transdisciplinary collaboration and on participatory action research aimed at sustainable development.

Keywords Sustainability science • Action research • Bioenergy village

Within a broader sustainability framework, this chapter focuses the methodological background of our scientific approach to replace our heat and electricity supply with renewable bioenergy. The authors of this chapter, most of whom are founding members of the Interdisciplinary Centre for Sustainable Development at the University of Göttingen, initiated the complete conversion of the heat and electricity supply of Jühnde from fossil to biomass fuels. We follow an elaborated approach, which we call the "Göttingen Approach of Sustainability Science". We start with a short introduction on our understanding of "sustainable development" and "sustainability science". Thereafter, we describe how sustainability science emerged in the village of Jühnde, focussing mainly on the processes leading to the first success. The methodological basis for the ongoing project "Sustainable use of bioenergy: bridging climate protection, nature conservation and society" was partly provided by the systematic research that complemented the bioenergy village project from 2000 to 2008.

2.1 Sustainable Development

We share the view that the current environmental, social and economic problems require all societal groups of all countries to cooperate closely if the problems are to be solved (Cervinka and Schmuck 2010). If we want to find (1) alternatives to fossil and nuclear fuels with their known impact on the environment, (2) alternatives to the disparities in the distribution of resources between countries as well as within countries and (3) alternatives to the economy-driven and ever-increasing consumption of meat-based diets and automobile-centred transportation, we have to bundle our efforts as scientists and, with the cooperation of other societal groups, create new and sustainable ways of life. The concept of "sustainable development" is explained in Box 2.1

Box 2.1 The Sustainable Development Concept

Sustainable development embedded in intra and intergenerational justice may serve as a guideline (despite some limitations of the concept; see Schmuck and Schulz 2002) if it is based on at least five principles:

1. The **respect principle** maintains that all forms of life have an equal right to live (Schweitzer 1991; Gorke 1999).
2. The **precautionary principle** is aimed at avoiding irreversible human-caused changes in the balance of our biosphere/ecosphere (Komiyama and Takeuchi 2006, p. 5): “The primary objective is [...] to achieve, as soon as possible, substantial improvements in [...] the interaction between the sciences and decision-making, using the precautionary approach, where appropriate, to change the existing patterns of production and consumption and to gain time for reducing uncertainty with respect to the selection of policy options”.
3. The **principle of participation** encourages the population to take part in searching for, evaluating and implementing sustainable ways of life. Many chapters in Agenda 21 emphasise this principle, i.e.: “The primary objective is [...] to achieve, as soon as possible, substantial improvements in [...] participation of people in setting priorities and in decision-making relating to sustainable development” (UNO 1992, Chapter 35.6). “The objective is to promote broad public awareness as an essential part of a global education effort to strengthen attitudes, values and actions which are compatible with sustainable development. It is important to stress the principle of devolving authority, accountability and resources to the most appropriate level with preference given to local responsibility and control over awareness-building activities” (UNO 1992, Chapter 36.9). “Governments at the appropriate level, with the support of the relevant [...] regional organizations, should [...] launch applied research on participatory methodologies, management strategies and local organizations” (UNO 1992, Chapter 14.22). “The public should be assisted in communicating their sentiments to the scientific and technological community concerning how science and technology might be better managed to affect their lives in a beneficial way” (UNO 1992, Chapter 31.1).
4. The goal of the **efficiency principle** is to avoid wasting limited resources.
5. The **consistency principle** is aimed at replacing the use of finite resources (the actual main base of our economy) with renewable resources without any waste products, thereby following naturally occurring biospheric cycles. The input of harmful substances and nutrient matter into the ecosystem should be minimised. The state of our landscapes has to be improved to increase future generations’ living conditions.

2.2 Sustainability Science

Sustainability science, which was initially formulated by Kates et al. (2001), is a new approach to tackling today's global problems with scientific tools. The methodological principles of traditional science have to be complemented by additional principles. The classical view regards scientific activities as value-free endeavours to mainly develop and test hypotheses in laboratories in a monodisciplinary, analytical and linear way by means of basic research and with a strict division between research and application as the ideal. The main motivation to include new approaches lies in the nature of today's global problems: They are based on non-linear, highly interwoven complex processes and there are often long time lags between actions and their consequences. Therefore, the advocates of sustainability science believe that the chances of contributing substantially to solving the current global problems are greater if science (1) acts explicitly to support sustainable development, (2) tries an interdisciplinary approach and (3) if science is transdisciplinary in terms of undertaking action-oriented research. In action-oriented research, scientists apply ideas for sustainable development to a society and simultaneously investigate the interactions that occur between the members of this society once they have adopted a more sustainable approach. The following sections summarise some of the most convincing arguments for the proposed new approach within science.

2.2.1 Science for Sustainable Development

Agenda 21, an environmental plan of action drawn up by global political representatives, clearly mentions scientists as co-responsible for creating sustainable life patterns; for instance, Chapter 35, entitled "Science for sustainable development" states: "The sciences should continue to play an increasing role in providing for an improvement in the efficiency of resource utilisation and in finding new development practices, resources, and alternatives. [. . .] Thus, the sciences are increasingly being understood as an essential component in the search for feasible pathways towards sustainable development" (UNO 1992, Chapter 35.2). This new role of science is confirmed in several later scientific documents. For instance, Kates et al. (2001, p. 642) emphasise that "research itself must be focused on the character of nature-society interactions, on our ability to guide those interactions along sustainable trajectories, and on ways of promoting the social learning that will be necessary to navigate the transition to sustainability. Science must be connected to the political agenda for sustainable development". According to Clark and Dickson (2003, p. 8059), we need "international consensus on goals and targets for targeting problem-driven research in support of a sustainability transition"; Komiyama and Takeuchi (2006, p. 3) state that "sustainability science must therefore adopt a comprehensive, holistic approach to identification of problems and perspectives involving the sustainability of these global, social, and human systems. [...] The ultimate purpose of sustainability science is to contribute to the preservation and improvement of the sustainability of these three systems". To conclude, we see a growing consensus within the scientific community that science should direct its efforts explicitly to supporting sustainable development (for more details see Schmuck and Vlek 2003; Sheldon et al. 2000).

2.2.2 Interdisciplinary Approach

Komiyama and Takeuchi (2006, pp. 4–5) believe that sustainability science "can help resolve one of the fundamental dilemmas of contemporary scholarship – the inability of our overly specialised disciplines to offer comprehensive solutions to the conditions that threaten the sustainability of global, social, and human systems" by replacing "the current piecemeal approach with one that can develop and apply comprehensive solutions to these problems". Likewise, Kates et al. (2001, p. 641) see the success of the new approach as dependent on close collaboration between scientists: "Progress in sustainability science will require fostering problem-driven, interdisciplinary research". In Agenda 21, the "Science for Sustainability" chapter also stresses the interdisciplinarity of research as a precondition for solving global problems. Specifically, the social sciences are seen as an indispensable part of interdisciplinary teams: "The primary objective is [...] to achieve, as soon as possible, substantial improvements in [...] cooperation between scientists by promoting interdisciplinary research programmes and activities" (UNO 1992, Chapter 35.6). "The scientific and technological means include [...] supporting new scientific research programmes, including their socio-economic and human aspects, at the community, national, subregional, regional and global levels, to complement and encourage synergies between traditional and conventional scientific knowledge and practices and strengthening interdisciplinary research related to environmental degradation and rehabilitation" (UNO 1992, Chapter 35.9).

"Social processes are subject to multiple variations across time and space, regions and culture. They both affect and are influenced by changing environmental conditions. Human factors are key driving forces in these intricate sets of relationships and exert their influence directly on global change. Therefore, the study of the human dimensions of the causes and consequences of environmental change and of more sustainable development paths is essential" (UNO 1992, Chapter 35.10).

2.2.3 Transdisciplinary Approach

In broad terms, transdisciplinarity means the close collaboration between (interdisciplinary interconnected) groups of scientists on the one hand and the broad public on the other. The necessity of such a collaboration is cogently expressed by Kates et al.: “In a world put at risk by the unintended consequences of scientific progress, participatory procedures involving scientists, stakeholders, advocates, active citizens, and users of knowledge are critically needed” (2001, p. 641). Similarly, Clark and Dickson (2003, p. 8059) argue that “the multiple movements [. . .] with the goal of creating and applying knowledge in support of decision making for sustainable development [. . .] are grounded in the belief that for such knowledge to be truly useful it generally needs to be “coproduced” through close collaboration between scholars and practitioners”. Moreover, Komiyama and Takeuchi (2006, p. 5) conclude that “[i]f sustainability science is to contribute practical solutions to the problems we face, cooperation among researchers, industry, and the general public is imperative”. In Chapters 31 and 35 of Agenda 21, we find that such argumentations are particularly relevant when “the cooperative relationship existing between the scientific and technological community and the general public should be extended and deepened into a full partnership” (UNO 1992, Chapter 31); or when the “participation of people in setting priorities and in decision-making relating to sustainable development” is required (UNO 1992, Chapter 35).

The transdisciplinary approach implies that scientists following this new approach have a double role. In addition to the classical role of the analyser of objective data patterns, scientists today also form part of social groups that conjointly create and apply demonstration models for new production, distribution and consumption patterns. Research and application take place simultaneously. Kates et al. argue that “pertinent actions are not ordered linearly in the familiar sequence of scientific inquiry, where action lies outside the research domain. In areas like climate change, scientific exploration, and practical application must occur simultaneously. They tend to influence and become entangled with each other” (2001, p. 641).

According to Clark and Dickson (2003, pp. 8059–8060), scientists have new roles. They argue that “perhaps the strongest message to emerge from dialogues induced by the Johannesburg Summit was that the research community needs to complement its historic role in identifying problems of sustainability with a greater willingness to join with the development and other communities to work on practical solutions to those problems. This means bringing our science and technology to bear on the highest-priority goals of a sustainability transition, with those goals defined not by scientists alone but rather through a dialogue between scientists and the people engaged in the practice of meeting human needs while conserving the earth’s life support systems and reducing hunger and poverty. [. . .] The commitment of sustainability science to problem-driven agenda setting does not mean that it has been confined to ‘applied’ research. Indeed, the pursuit of practical solutions to the pressing challenges of sustainability has driven the field to tackle an array of fundamental questions”.

This new kind of close interconnectedness of basic and applied research seems to be an important and unavoidable characteristic of sustainability science, as Komiyama and Takeuchi (2006, p. 5) explicate: “One problem unique to sustainability science lies in the process of shifting from the stage of phenomena identification and analysis to that of problem solving. For sustainability science this process necessarily differs from the conventional transition from basic to applied research, because solutions to problems may have to be sought before those problems have been sufficiently analysed or even identified. Global warming is the prime example of this dilemma. Future scenarios predicted by various models of global warming remain unverifiable, yet the search for solutions cannot wait. [...] What is demanded of sustainability science is not only the development of scientifically sound models for predicting future scenarios and evaluating the effects of different countermeasures and solutions but also effective management of the process by which these forecasts and evaluations are accepted by society, to generate the social reforms necessary to ensure global sustainability".

To summarise this section, the advocates of sustainability science call for science and scientists to accept a double role within society: Instead of restricting their role to producing scientific knowledge (Role A), scientists are *additionally* invited to apply that knowledge in transdisciplinary teams to solve urgent global problems (Role B). This does not mean that science's traditional role, which lies in its objective methodology (Role A), is abandoned: The new scientist does not fill either the one *or* the other role, but can apply, combine and balance both roles.

2.3 The Göttingen Approach of Sustainability Science

In this section, we describe how we integrated the defining characteristics of sustainable development and sustainability science into our approach. It consists of seven elements comprising the specific tasks scientists have to fulfil during the research cycle. The approach requires a group of scientists willing to cooperate and who share an intrinsic sustainability motivation. The first task is defined as the traditional scientist's role (traditional research producing scientific knowledge, Role A). The other six tasks comprise different practical problem-solving activities (the application of scientific knowledge in inter- and transdisciplinary teams, Role B) that occur consecutively (Fig. 2.1).

The research activities are distributed over the whole cycle, whereas the problem-solving activities are modelled consecutively. The detailed description starts with the latter.

2.3.1 Problem-Solving Activities

2.3.1.1 Select a Critical Global Problem

Problem-solving activities start with the selection of a problem. If the global level is taken into consideration in this early phase, the more serious problems will be given priority. When the urgency of certain global problems, such as climate change, water crises, etc. is examined, one concludes that the world scientists should focus

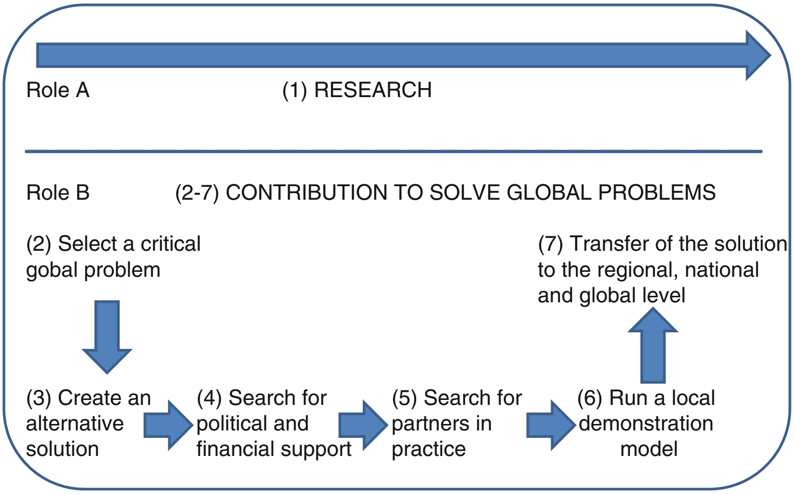

Fig. 2.1 Seven elements of the Göttingen approach to sustainability science

their energy on the most pressing problems if they want to prevent other catastrophes, like the oil disaster in the Gulf of Mexico in 2010, the nuclear disaster in Fukushima in 2011, or the increased melting of the Arctic ice.

2.3.1.2 Formulate Alternative Solutions Starting at a Regional Level

When formulating possible solutions to a global problem, the regional level seems to be an appropriate place to start, because scientists usually have neither the power nor the will to change world politics directly. Therefore, the creative process could be started in the area in which an active group of scientists live and work.

2.3.1.3 Find Political and Financial Support

The vast majority of scientists are mostly specialists in specific science subjects and are not explicitly assigned or have the financial means to pursue inter- and transdisciplinary sustainability science. Therefore, political and financial support is needed for sustainability projects. In order to obtain this support, it is helpful to refer to international and, where applicable, national political agreements regarding the promotion of sustainable development. Here, Agenda 21 again serves as an example as it contains many paragraphs on the energy sector; For instance, "governments [. . .] with the cooperation of [. . .] non-governmental organizations, should [. . .] promote the research, development, transfer and use of technologies and practices for environmentally sound energy systems, including new and renewable energy systems" (UNO 1992, Chapter 9.12). In Article 20a of the

German constitution, entitled "Protection of the natural bases of life", the following formulation is found: "Mindful also of its responsibility toward future generations, the state shall protect the natural bases of life through legislation and, in accordance with law and justice, through executive and judicial action, all within the framework of the constitutional order" (Federal Ministry of the Interior 1998).

There are two ways for scientists to become active in sustainability science: The one is to wait until governments or funding agencies create funding programmes for sustainability research. However, it is also possible for scientists to take the first step, meaning they need to share their sustainability research ideas with political authorities, which is what happened in the bioenergy village project under discussion. This is described in more detail in the next section.

2.3.1.4 Search for Practice Partners

The next step comprises motivating practice partners outside the research community to collaborate on the sustainability project.

2.3.1.5 Run a Pilot Project on the Local Level

During a project's implementation, scientists are focused on providing practitioners with scientifically based advice. Clark and Dickson (2003, p. 8059) express this idea as follows: "The transcendent challenge is to help promote the relatively 'local' (place or enterprise-based) dialogues from which meaningful priorities can emerge, and to put in place the local support systems that will allow those priorities to be implemented".

2.3.1.6 Transfer to the Regional, National and Global Level

After realising the pilot project successfully, an additional task could be to actively support the transfer of the model to other regions and, where applicable, to other countries.

2.3.2 Research Activities

The results of traditional research are, if available, a more or less suitable base for problem-solving activities. Thus, when selecting a critical problem to investigate, researchers should consider which global problems are the most harmful (the group of scientists' competence fields will, of course, limit this) to ensure they tackle only very relevant problems. The researchers' actual scientific knowledge of the - problem fields should then be assessed. These fields include, among others, water, energy, health, agriculture and biodiversity (the WEHAB priority targets as defined at the Johannesburg Summit; Clark and Dickson 2003, p. 8060). During the later problem-solving process, scientific and technological knowledge should guide all the individual steps. Before the first demonstration of the alternative solution models are held, hypotheses regarding the consequences – in, for instance, longitudinal designs – should be posited and tested if possible. This would mean that new scientific knowledge can be produced from such alternative demonstration models.

2.4 Application of the Göttingen Approach in the Bioenergy Field

In the following sections, we describe the implementation of our approach within a specific problem field. Following the notion of the two roles of those scientists who accept the challenge of sustainability science, we start with the problem-solving activities to provide some background to the research activities and results that follow. However, when implementing a project in practice, the problem-solving and the research activities are closely interwoven and sometimes occur simultaneously. However, the linear sequence of the text requires us to discuss these two aspects separately.

2.4.1 Specific Problem-Solving Activities

At the University of Göttingen, scientists from seven disciplines (sociologists, psychologists, political scientists, economists, agronomists, agrarian economists, biologists and geologists), who share the intention to contribute actively to sustainable development, came together for two days during the spring of 1997 for a "future workshop" (Zukunftswerkstatt). The goal of this workshop was to initiate a model project in the field of sustainable development, demonstrating that it is possible to change our ways of life and enable future generations to have a good life. Robert Jungk developed the "future workshop" concept in the 1970s (Jungk and Müllert 1991) in order to exploit modern societies' democratic potential and creativity to solve their problems. This workshop concept is often used in communal processes in Europe, but has not been widely used in scientific settings, probably because many members of the scientific community still undervalue the systematic inclusion of emotions and intuitions. Such a workshop mainly comprises three phases: the criticism phase, the phantasy phase and the realisation phase.

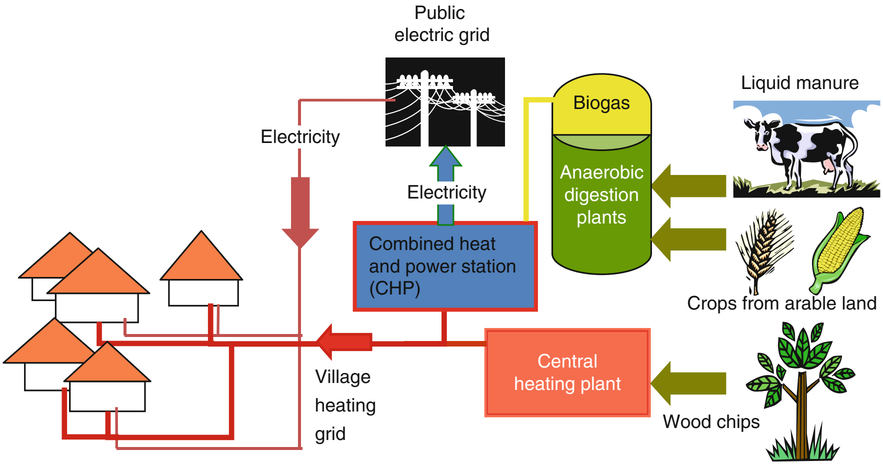

Fig. 2.2 Heat and electricity production and distribution in a bioenergy village

2.4.1.1 Select a Critical Global Problem: The Side Effects of Exploiting Fossil and Nuclear Energy Resources

During the criticism phase, actual problems and challenges are outlined and one problem field, which combines the interests and competencies of the group of persons present, is selected. In our case, we decided to focus on energy production and distribution questions, because we agreed that there are unsolved problems of energy production based on fossil and nuclear resources (mainly their finite nature and the side effects of their waste products such as carbon dioxide and nuclear waste). Furthermore, they are causally interconnected with many other adverse effects (e.g., climate change, decreased biodiversity, and socially unfair distribution patterns).

2.4.1.2 Formulate an Alternative Solution at a Regional Level

The second phase of the future workshop is a phantasy and brainstorming process enriched by creativity-evoking activities, like game-playing, listening to music, meditation, dreaming, or drawing pictures of one's visions for the future. Here, the goal is to foster the participants' creative processes to find alternative solutions to the specified problems. The method was successful: During the first day, the idea of a "bioenergy village" emerged: Motivating an entire village to participate in a collective effort to convert the village's energy supply – based on non-renewable sources – into one that uses locally available biomass to provide electricity and heat (see Fig. 2.2); to plan the necessary processes and help the villagers implement them.

In the concluding phase of the workshop – the realisation phase – the goal is to formulate the concrete steps required to put the idea into practice. Here, we agreed that the most important step would be to obtain political and financial support from the authorities outside the University.

2.4.1.3 Obtain Political and Financial Support

In 1998, after many further in-depth discussions on the very complex problems and their interconnectedness, a research project was formulated. Since there was no viable funding programme for our idea, we sent the project proposal to ten funding agencies and German ministries. All of them dismissed the proposal as unrealistic: It was considered too unlikely that a whole village would accept such a transformation. However, refusing to give up, we contacted leading people in the German Ministry for Food, Agriculture and Consumer Protection (BMELV) to convince them of our cause.

In 2000 – the industrialisation of the German agriculture over the previous decades had already led to a dramatic decrease in rural employment – the BMELV decided to back the project financially as it appreciated the project's potential to provide sustainable employment in the countryside. The Ministry wanted us to first choose a model village to demonstrate that our idea would work both economically and socially. If this succeeded, we would subsequently be allowed to apply the idea to other villages to revitalise the role of agriculture in Germany's labour market. The project kicked off in October 2000.

2.4.1.4 Search for Practice Partners: Village Competition

From 2000 to 2002, the first project phase was focussed on identifying a suitable village in the Göttingen rural district that would possibly participate in the project. A kick-off meeting with local politicians and some press publicity resulted (unexpectedly) in several villages showing a great interest in participating in the project. The project team then presented the idea to 17 interested villages; four of these, which had particularly suitable criteria, such as a broad agricultural base and social coherence, were formally invited to apply to be partner villages for the model project. This led to a competition – which we had not foreseen – between the four villages, indicating the villagers' strong motivation to transform their villages into ones with renewable energy sources with our support. In these four villages, an engineering company developed concepts for the technical implementation. On the basis of these technical concepts and the suitability criteria developed by the group of scientists, the village Jühnde – located 12 km southwest of Göttingen and with a population of 800 inhabitants at that time – was selected as our model village as it had the best prerequisites for the transformation into a bioenergy village.

2.4.1.5 Run a Pilot Project on the Local Level: The Transformation Process in the Bioenergy Village Jühnde

Between 2002 and 2004, preparations were undertaken to technically install a new infrastructure in Jühnde. During this phase, the scientists' main role was to develop and offer technical, economic and social support. Furthermore, the project not only required the villagers to install the technical equipment in the village themselves, but also to plan the details of the conversion project. Consequently, the residents were involved in the planning process and worked on site from the very beginning. After the initial general meetings with all the villagers, eight working groups were formed. In these working groups, several relevant project aspects, which the university's team proposed and initially moderated, were discussed: agricultural resources, electricity production, heat production, the heat distribution grid, the form that the company to be founded would take, the housing technique, public relations and the energy crop cultivation.

The results of the groups' work had to be communicated to the villagers. The university team suggested establishing a central planning group comprising the heads of the specific planning groups and the local authorities, for example, the mayor, members of the district council, the chairpersons of village clubs, etc. When formed, the inhabitants would legitimise the group by public acclamation. During the subsequent planning phase, the central planning group made important decisions; for example it decided on the location and the power capacity of the energy plants as well as determined the prices of the biomass and heat energy. The combination of planning processes at different levels within (1) the specific planning groups and (2) the central planning group, as well as (3) the regular inhabitants meetings led to a transparent and very powerful participatory process. By implementing a planning procedure based on intensive village participation, the scientists ensured that the project would become the villagers' venture, although they had conceived the idea. The plan worked: The villagers accepted responsibility for the project and required less and less support from the university team.

After the green energy plants (see more information on energy plants in Chap. 4) have been harvested, they are chopped and stored on three concrete plates, where the plant material, due to its compaction and the subsequent lack of air, is transformed into silage. If properly stored, silage is stable for many months. The technical equipment responsible for using silage to ultimately produce electricity and heat in Jühnde, was installed between 2004 and 2005 and consists of three main components:

1. A combined heat and power (CHP) generator with an electric capacity of 680 kW that produces electricity and space heat by burning biogas. The capacity is adapted to the required electricity and heat output to run the plant economically. Biogas is generated from biodegradable organic matter in an anaerobic digestion plant. The plant contains two fermentation units with a combined capacity of 7,800 m^3. Over the course of two months, micro-organisms enzymatically digest liquid manure (about 10,000 m^3/year) and crops cultivated on approximately 220 ha of arable land around Jühnde under anaerobic conditions

and transform these into biogas. The CHP unit converts the energy content of the biogas into roughly 35 % electricity and 50 % usable heat energy. The electricity is fed into the national electricity grid. German law guaranteed a feeding-in price of about 17 Eurocent/kWh in 2004 for 20 years (BMU 2004), thus promoting energy production from biomass. The CHP station's heat output is partly used for the digestion process. However, most of the heat can be used for space heating and to meet about 75 % of the village households' hot water demand. In summer, surplus heat is used to dry wood chips and cereals. Consequently, renewable fuels replace fossil fuels, like oil, gas, coal and nuclear power, as sources of heat and electricity.

2. In winter, a central combustion furnace with a thermal capacity of 550 kW, fired by locally produced wood chips, provides the additional heat energy required in the Central European climatic conditions. The capacity of the wood chip plant covers the peak heat demand in winter. Furthermore, an oil-fired peak load boiler with a capacity of 1,600 kW has been installed to provide heat for the peak load in winter and if the biomass plants were to fail and during their routine maintenances. Less than 5 % of the heat demand is covered by oil. The whole system is therefore highly reliable.
3. The heat energy from the plant is fed into a 5.5 km long hot water grid, which delivers the heat energy to the connected households in the village. The heat transfer in the houses occurs through heat exchangers (with a heat meter included), which have replaced the individual heating systems.

2.4.1.6 Publicising the Project on a Regional, National and Global Level

The successful outcome of the model project, which was completed in 2005, has been widely communicated via public relations activities (mass media, scientific publications and practical guides for formulating the generalised principles for the conversion process from fossil fuels to bioenergy). This has attracted the interest of many of Germany's rural population, especially farmers and local politicians, such as mayors and district administrators. Consequently, inspired by the successful implementation of the first bioenergy village in Germany, several other activities were initiated:

Between 2006 and 2009, again with the university team's support, four other villages in the Göttingen district (Reiffenhausen, Wollbrandshausen, Krebeck and Barlissen) followed the Jühnde model and installed similar communally organised bioenergy systems (for details see Wüste et al. 2011). In 2010, a process was started to initiate bioenergy villages in the biosphere sanctuary region Schorfheide in the federal state of Brandenburg. Five villages in the region showed interest in the conversion. The governments of the federal states Baden-Württemberg, Mecklenburg-Vorpommern and Brandenburg decided to support the development of bioenergy villages financially. In 2008, following the success of the bioenergy villages, the German government started a grant programme to support bioenergy regions: 210 regions in Germany applied for support. From 2009 to 2012, networking activities in 25 bioenergy regions in Germany were supported financially.

In two federal competitions held in 2010 and 2012, 35 and 41 individual villages respectively competed for the prize that the German government offered for the "most innovative bioenergy village" in Germany. This is indicative of the many German villages following our, or a similar, project model.

2.4.2 Selected Research Activities and Results

Between 2000 and 2008, before, during and after the communal transformation process in Jühnde, scientific analyses were undertaken of the ecological, economical, and social changes in the village. The essential research results are outlined in the following sections (for more details see Karpenstein-Machan and Schmuck 2007, 2010):

2.4.2.1 Natural Science: Reduction of Greenhouse Gas Emissions

The programme "Globales Emissions-Modell Integrated Systems (GEMIS)" Version 4.5 (Ökoinstitut 2008) was used to calculate the decrease in the greenhouse gas emissions in Jühnde after it changed to bioenergy supply. With this programme, it is possible to calculate the greenhouse gas emissions of various energy production models. The energy used (a) for the construction of the biogas plant and the other structures such as the silage plates (e.g., concrete, PVC granulate, rock wool and steel), (b) for the production and transport of the energy crops and manure to the biogas plant and to recycle the digestion residues on the fields and (c) for the maintenance of the processes in the fermentation plant (electricity and heat) is transformed into comparable accumulated CO_2 equivalents. For example, the production of corn silage needs energy to provide the seed, to transport it, to till the cropland, to sow the grains, to fertilise (including the energy required to produce and supply the fertiliser), to apply pesticides, to harvest, to transport it to the silage plate, etc. The cumulated energy demand can be converted into CO_2 equivalents and can be compared with emissions from conventional power stations that deliver the same amount of electricity.

The 2007 electricity and heat production data were used to calculate the decrease in greenhouse gas emissions in Jühnde (Sauer 2009). In 2007, 4,933 MWh of electricity and 3,956 MWh of heat were generated (Friehe 2007). Subsequently, 3,379 MWh of waste heat from the CHP was turned into useful heat, while the wood chip heating plant produced and an additional 577 MWh of heat. Only the amount of heat that was actually used to heat the households and the digester was included in the calculation. The total amount of generated electricity was included because it is fed into the public power grid and fully consumed completely. The less heat is wasted – especially during summer – the more CO_2 equivalents can be saved.

Table 2.1 shows a comparison between the greenhouse gas emissions from Jühnde's bioenergy facilities and those of other power plants.

Table 2.1 Comparison between the CO_2-equivalent emissions of the Jühnde bioenergy facilities and those of other power plants (From GEMIS; Öko-Institute 2008)

Electricity generation	Emissions of 4,933 MWh electricity (CO_2 equivalents in tons)
Coal-fired power plant 2005	5,396
Gas-fired power plant 2005	2,116
Brown-coal-fired power plant (Rhenish) 2005	6,158
Nuclear power plant 2000[a]	158
Electricity mix Germany 2005	3,213
Bioenergy facility Jühnde	267
Avoidance in Jühnde compared to the German electricity mix	−2,946
Heat generation	**Emissions of 3,956 MWh heat (CO_2 equivalents in tons)**
Oil heating system 2005	1,486
	Emissions of 577 MWh heat (CO_2 equivalents in tons) (heat from CHP plant already subtracted)
Chip wood heating plant Jühnde and heating grid	20
Avoidance in Jühnde compared to oil heating	−1,467
Avoidance in Jühnde regarding electricity and heat	−4,413

[a]The low value of nuclear power plants is misleading, because the storage/processing of spent nuclear fuel and the decommissioning of the plant are NOT included as there are no reliable data on these aspects. There is currently no final storage space for nuclear waste in Germany. Just the auxiliary energy used to store nuclear waste for at least 100,000 years would counteract the good CO_2-emission value of nuclear power

The Jühnde CO_2 emission data for electricity production were compared with the whole of Germany's 2005 electricity emissions data. As 3,379 MWh of heat from the CHP are used at Jühnde, these emissions are already calculated at the electricity side. With regard to heat production, Jühnde only emits CO_2 equivalents of 577 MWh, which the wood chip heating plant and the heating grid generate. However, in comparison, a village the size of Jühnde and mainly using fossil fuel heating systems would consume 3,956 MWh of heat.

In sum, the conversion of Jühnde into a bioenergy village prevents about 4,400 t of CO_2 equivalents every year. Approximately, 440 persons in Jühnde are connected to the heat grid. If we attribute the decrease in greenhouse gas emissions to these people, everyone has saved 10 t of CO_2 equivalents annually. In 2007, the average total greenhouse gas emission in Germany was around 11.9 t of CO_2 equivalents per capita and year (data from the Umweltbundesamt 2012). Compared to the average German, Jühnde showed an 84 % decrease in greenhouse gas emissions per capita. An ecologically acceptable worldwide annual average lies around 2.5 t per capita. The balance for Jühnde is very favourable, because approximately 2.5 times more electricity is generated than the village uses. Therefore, it also prevents others from emitting greenhouse gas emissions.

2.4.2.2 Agriculture

Since 2005, three types of organic substances have been used to generate enough power to satisfy Jühnde's electricity and heat energy needs: (1) energy crops, cultivated on arable land to produce electricity and heat energy in a biogas plant, (2) liquid manure from husbandry farms and (3) wood chips mainly burned in a central heating plant during winter. About 80 % of the total produced energy is generated from annually cultivated crops fermented in the biogas plant. This means that energy crops and their sustainable cultivation are very important for the village's energy concept. Therefore, this section is mainly focussed on sustainable energy crop cultivation and the relevant advising of the farmers.

Energy crop cultivation can contribute positively to achieving climate goals. However, if not implemented carefully, it could exacerbate the degradation of land, water bodies and ecosystems as well as increase the greenhouse gas emissions, leading to the citizens' rejection of the initiative.

The energy cultivation concepts regarding biogas use differ from cultivation concepts regarding food crops (Karpenstein-Machan 1997, 2002, 2005). The selection of crops, varieties, seed densities, harvest time and fertilisation have to be managed to gain a high fermentable biomass yield. To sustainably manage these, the following criteria were included in the energy crop cultivation concept implemented in Jühnde:

- A high diversity of crops – no monoculture
- Reduce agricultural pesticides
- Avoid nitrate and pesticide leaching to groundwater
- Avoid soil erosion and humus degradation
- Optimise nutrient recycling
- Optimise crop yields
- Optimise the energy input–output ratio of energy crop cultivation.

Locally adapted and environmentally friendly concepts for energy crop production were developed and tested over many years at the University of Kassel-Witzenhausen (Scheffer and Stülpnagel 1993; Karpenstein-Machan 2003, 2005, Karpenstein-Machan and Stülpnagel 2000). These new concepts were implemented in the crop rotations of the food and feed crops in the Jühnde district.

Furthermore, part of the energy crop farmland is located in the water protection area of the Jühnde district. Scheffer and Stülpnagel's (1993) "double-cropping system" with its more balanced nutrient extraction was tested on different soils to investigate whether the ground water quality could be improved by decreasing the leaching of nutrients.

Another goal was to integrate all the available liquid manure from husbandry into the fermentation process to avoid further climate-change-relevant gas emissions from the husbandry farms. Nutrient recycling was thus optimised and the consumption of mineral fertiliser reduced.

Energy balances of the crop cultivation and the operation of the biogas plant had been made to get information about efficiency of energy production.

The following sections describe selected results, starting with crop rotation.

Crop Rotation

Before the implementation of the biogas plant, the Jühnde farmers' produce consisted of 72 % winter cereals – mainly winter wheat and winter barley –, 20 % winter rape and 8 % maize. After the implementation of the energy plants, the wheat and barley cultivation for the market was reduced to 11 % and replaced with triticale and rye cultivation for the biogas plant. The maize cultivation area in the district was expanded to 11 % and the winter rape cultivation area to 22 %.

On fairly fertile soils that have a German soil fertility number higher than 40 (the best fertility number is 100), the farmers changed their crop rotation from winter rape – winter wheat – winter wheat – winter barley to a more diverse rotation of winter rape – winter wheat – energy winter triticale – green manures (mustard) – maize. Owing to the early harvest of winter triticale for biogas production, a second crop is feasible in the same year. In Jühnde, mustard or other green manure crops were sown to cover the soil during winter, thus preventing soil erosion and nitrate leaching. In the following year, energy maize could be sown between the stubbles of the dead green manure (which is killed by frost) with minimum tillage. On less fertile soils (with a soil fertility number lower than 40), the crop rotation winter rape – winter wheat – winter barley was changed to winter rape – energy winter triticale – energy winter rye – winter barley.

On both soil types, winter wheat and winter barley were replaced with energy crops. The replacement of wheat and barley in the crop rotation improves the environment. The replaced crops, which were extensively cultivated in the district, required several pesticide and herbicide applications as well as treatments against diseases. Replacing these with triticale and rye, two rarely cultivated and healthier crops, improved the crop rotation in Jühnde.

Optimal Harvest Time for Digestion

Biogas is the final product of an anaerobic transformation process caused by bacteria in the fermenter. The anaerobic bacteria only develop stable life communities under ideal environmental conditions, i.e. an optimal temperature, pH value and nutrient composition in the fermenter. Such conditions are a prerequisite for high gas yields. Given these requirements, the feeding of the biogas plant with energy plants plays a central role. In order to supply the biogas plant with easily degradable substrates rich in energy, annual crops should be harvested at the milk-ripe stage or early dough ripeness when the whole plant contains 25–35 % dry matter (Karpenstein-Machan 2005). This ensures that the bacteria can easily

Table 2.2 Nitrogen fertilisation in kg N/ha regarding the percentage of area treated with pesticides and the number of pesticide treatments applied to the energy crop cultivation (triticale and energy maize) compared with that applied to winter wheat for grain production and fodder maize

Crops	N fertilisation (digestate and mineral N)	Growth regulator	Herbicides	Fungicides	Insecticides	Treatments
	kg N ha^{-1}	% of area				Numbers
Energy triticale	152	58	68	58	17	2–3
Winter wheat grain production	196	100	100	100	88	6–7
Energy maize	146		100	0	20	1–2
Fodder maize	170		100	0	20	1–2

degrade the green plants' organic substance. At this stage of their development, the plants' lignification is not yet very advanced.

To meet these requirements for digestion, the optimal harvest time for triticale, wheat, rye and oats was explored in Jühnde area. We looked for a high dry matter yield in combination with a dry matter content of about 30 %. Samples of winter crops were taken from the beginning of June until the end of July at different stages of their development. All tested cereals still showed high dry matter increments in June, which lasted until the beginning of July.

With 16 t of dry matter per hectare, the highest biomass yields were reached at the end of June with a dry matter content of 32 %, which is still optimal for digestion. After this time, the dry matter yield declined in triticale, rye and wheat, while the dry matter content increased to 40 %, which is suboptimal for digestion. The younger oat plants reached the highest dry matter yield later – in the middle of July – amounting to 17 t of dry matter per hectare.

Regarding both parameters – high dry matter yield and optimal dry matter content – we can conclude that, under the specific climatic conditions of the hilly areas of southern Lower Saxony, the optimal harvest time for winter cereals is from the end of June until mid-July.

Regarding maize cultivation, the development of the crop is limited by the vegetation time in autumn. Location-adapted varieties, which reach the milk-ripe/dough stage of development in autumn, should be chosen for cultivation. These varieties can be harvested at the end of their vegetation time – which is normally mid-October for maize in the climatic conditions of southern Lower Saxony.

Pesticide Use and Fertilisation of Energy Crop Cultivation

Table 2.2 shows a comparison between the nitrogen fertilisation and pesticide use in conventional crops – like winter wheat for grain production, or maize for fodder production – and in crops for energy production (triticale and maize). These data were provided by Jühnde farmers who produce biomass for the biogas plant. In the energy triticale, the nitrogen fertilisation was 44 kg N/ha lower than in the wheat production for grain use. Only two fertilisation treatments were applied to energy crops while three were applied to wheat grain production. Digestate from the biogas plant was used for the first intensive application. The second nitrogen application was less intensive and was applied by means of mineral fertiliser. A comparison of the pesticide use shows that fewer pesticides were applied to energy triticale production than to wheat grain production. The use of insecticides, fungicides and growth regulators was specifically reduced. This result indicates that far fewer pesticide treatments were applied to energy triticale. Many tests have shown that, in winter, the application of herbicides, fungicides and growth regulators to energy producing winter cereals rarely increases the biomass yield and is mostly not economically feasible (Sodikin 1994; Karpenstein-Machan 1997, 2002; FNR 2008).

The pesticide treatments of maize for fodder and energy production are very similar. Compared to the winter cereal production, the treatments are generally on a lower level as the plant health of the maize is still good. The amount of nitrogen fertiliser applied to energy maize is lower than that applied to maize for fodder production.

Concluding our analysis of the pesticide and nitrogen applications, we point out the positive aspects of energy crop production in the Jühnde district's water protection area. In the long term, this means that the quality of the drinking water from the water protection area can be improved by the cultivation of energy crops. The area's water protection administration is aware of these reduced applications and promotes the cultivation of winter crops for biomass energy. Further ecological and economical improvements could be realised in the district if the farmers were to eliminate growth regulators and reduce herbicide input. The application of growth regulators on marginal soils is critical and can lead to a biomass yield decrease, especially under drought conditions in early summer (Karpenstein-Machan 1994). Furthermore, a shorter culm leads to lower biomass yields (von Buttlar 1996). However, farmers fear crop lodging and therefore apply growth regulators. The use of varieties with stable culms and an adapted nitrogen fertiliser input are preferred means of fertilisation and prevent crop lodging.

Yield and Yield Stability

The energy crops triticale and maize have been cultivated in the Jühnde district as a fodder for the biogas plant since 2004. Within three years, the yearly average yield of the triticale biomass was 11.1 t of dry matter per hectare (1.8 t/ha standard deviation). The maize yields were 12.6 t of dry matter per hectare and year, but with a much higher standard deviation (4.7 t/ha).

Triticale cultivation was mainly planted in soils with lower fertility (fertility numbers 30–50) and the maize was cultivated in soils with higher fertility (fertility numbers above 50). The correlation between the yield and the soil fertility was low with regard to triticale and high regarding maize. This shows that triticale is adaptable to a wider range of soils. More than 40 % of the soils in the Jühnde district have soil fertility numbers below 40. Therefore, the cultivation of winter triticale as an energy crop is a good option with many ecological benefits. Furthermore, triticale's high yield stability is an important safeguard for the adequate supply of biomass for the biogas plant.

Double-Cropping System

To optimise the ecological effect of energy crop rotation, an ecologically-oriented cultivation system was developed at the University of Kassel (Scheffer and Stuelpnagel 1993; Karpenstein-Machan 2001, 2005). It is based on a diverse crop rotation system, with several winter and summer crops. In moderate climates with a growing period of six months or more (days with mean temperatures of over 10 °C), two crops (C3 and C4 crops) per year are feasible, as both crops are harvested in the milk-ripe stage of development. This double cropping system can reach high annual biomass yields per hectare (Schuette 1991; Scheffer and Stuelpnagel 1993; Karpenstein-Machan 1997; Graß and Scheffer 2003). However, the climatic conditions and soil quality should be sufficiently adequate to realise a high annual biomass yield of more than 20 t/ha.

The double-cropping system was tested under Jühnde's climatic conditions (elevation: 270–375 m above sea level; a mean yearly temperature of 7.9 °C; a yearly precipitation of 800 mm) with a shorter vegetation time (155–160 days). In contrast to the original double-cropping system with a C3 crop (winter rye) and a C4 crop (maize) (Scheffer and Stuelpnagel 1993), the double-cropping system in the Jühnde district was tested with two C3 crops due to the shorter vegetation time. The first crop was winter triticale, the most yield-stable crop, while sunflowers, summer rye and mustard were tested as a second crop.

To realise a high biomass yield from the first crop, triticale was harvested in the beginning of July when it was at its highest biomass yield during its milk-ripe stage with a dry matter content of 34–36 %. Sunflowers, summer rye and mustard were sown with minimum tillage immediately after the triticale harvest. These crops were harvested at the beginning of October. Triticale had a dry matter yield of 13 t, while the second crops yielded between 6 and 7 t of dry matter per hectare and year. Consequently, two crops per year realised nearly 20 t of dry matter per hectare. Whereas a satisfactory dry matter content of 30 % was achieved with the summer rye, the sunflower and mustard only reached a dry matter content of 20 %, which is insufficient for silaging. To avoid plant juices percolating through the harvest and silage, the dry matter contents in biomass should be at least 28 %. Under Jühnde's climatic conditions, the double-cropping system with two C3 crops can be recommended on fertile soils with a water storage capacity of 200 l/m^3 or more. In addition to its ecological advantages, the double-cropping system can contribute to a more efficient use of arable land and help prevent strong competition for land.

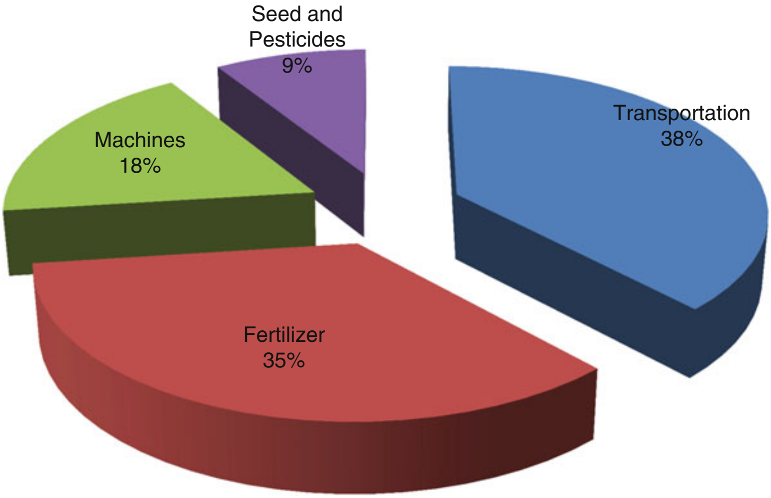

Fig. 2.3 Distribution of fossil energy input (in %) for cultivation of crops, transportation and silaging of biomass

Energy Balances of Energy Crop Production

An energy balance was undertaken regarding the energy crops' cultivation, transportation and silaging. Three years' cultivation (2005–2007) data on the Jühnde district were taken into account. All the supply chain data regarding farm energy inputs – fuels for field work and transportation, lubricants, machines, fertilisers, seeds and pesticides as well as silaging – were taken into account (see Fig. 2.3). According to these calculations, the energy input/output ratio was 1:19 for triticale and 1:18 for maize. Transportation and fertiliser are the main energy inputs. Farmers fertilise energy crops with digestate and mineral fertiliser, therefore fertiliser is still a main input factor. The production of mineral fertiliser is very energy intensive. In spite of higher yields in maize, the input/output ratio is better in triticale as it requires a lower energy input, especially of phosphate fertiliser. This "under root fertilisation" with mineral phosphate leads to a higher energy input in maize cultivation. This ratio shows that the cultivation system can replace fossil energy with renewable energy on a remarkable scale. Owing to the higher mean yields in maize, the net energy output was 230 GJ/ha for maize and 200 GJ/ha for triticale.

Energy Balance of the Biogas Plant

A further calculation was done to estimate the total fossil energy input necessary to operate the energy plant and its production (operating energy) as well as to deliver the crops and liquid manure the energy plant. This calculation is called the cumulated energy input (CEI). The calculation estimates an economic lifetime of 20 years (see Fig. 2.4).

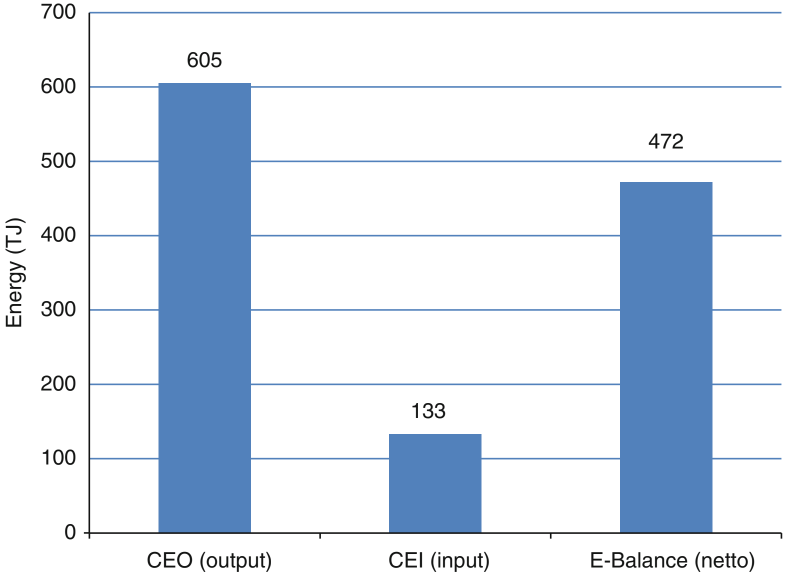

Fig. 2.4 Energy balance of the biogas plant in Jühnde (2005–2007) calculated for an economic life-time of 20 years

To calculate the cumulated energy output (CEO), we took the produced electricity and the used heat energy over a period of twenty years into account. The cumulated energy production, which is divided by the cumulated energy input, is called the harvest index. The harvest index for the biogas plant in Jühnde is 4.5. This means we need 1 kWh of fossil energy to produce 4.5 kWh of bioenergy (electricity and heat energy). After running for 21 weeks, all the fossil energy input for the biogas plant's production is amortised and, after 5 years, all the fossil energy input is amortised for a period of 20 years.

2.4.2.3 Psychology

The following section focuses on selected psychological aspects of the project. The main question was how to successfully motivate the inhabitants of rural areas to participate in such a conversion process. Consequently, the social success factors established in similar projects were analysed and then applied to the own project. Furthermore, psychological hypotheses were tested regarding the changes in the psychological variables – for example, social support, self-reported environmental behaviour, self-efficacy and well-being – as a result of the villagers' activities. Below, the results are reported of a longitudinal study (both before and after the conversion) of a broad sample of villagers – who answered a questionnaire – and a subgroup of the villagers – with whom we had a semi-structured interview – who were extraordinarily engaged in the project over a longer period (see also Schmuck 2013; Eigner-Thiel 2005).

Social Success Factors to Motivate People for a Collective Climate Protection Project

The social success factors established in climate protection projects similar to that of the Jühnde project were analysed with regard to motivating the inhabitants of rural areas to participate collectively (for details, see Eigner and Schmuck 2002) and then successfully applied in Jühnde.

Visiting model sites. Firstly, by visiting model sites fears can be decreased and prejudices eliminated regarding the technical equipment that needs to be installed. Success stories disseminated by important, accepted and favoured people in a particular village may also contribute to this process. In Jühnde, the villagers' interest was piqued after they had visited the first well-functioning bioenergy site. These experiences are congruent with the empirical findings of Mosler (1998), Aronson and O'Leary (1983) and Schuster and Marx (1998).

Being for something, not against it. Moreover, it is important that the aim of the project is formulated positively and constructively. A project's objective should be directed *for* something, not *against* persons or corporations. In Jühnde, for example, the active group called itself the "initiative for a bioenergy village" and not the "initiative against nuclear energy". This positive view is also advocated by Csikszentmihalyi (1993) and Richter (see Schmuck et al. 1997, p. 11), because this "pro-attitude" motivates people to solve conflicts, to love and help others and preserve nature, whereas a "contra-attitude" often has a destructive outcome.

Setting realistic goals. Another suggestion is to not set lofty goals; for example, instead of trying to change the energy politics in Germany, rather focus on a smaller region or a village, as was done in Jühnde. This is in line with self-efficacy research findings (Bandura 1982). Achieving smaller goals from time to time and experiencing success engender feelings of internal control, which motivate people to continue pursuing a distant goal.

Well-established advocates. It is important to ensure that prominent villagers (like the local bank director) support the project, at least ideologically. If well-established people with broad recognition and respect in the local population support the project, it will be considered more important and will be taken more seriously. In Jühnde, the most popular major advocated the bioenergy idea, which is one of the reasons why so many people participated in the conversion process.

Good contact with the local media. Having good contact with the local newspapers is of great benefit, because these are usually read and the contents discussed by most people in the district. In the district of Göttingen, the local newspapers regularly reported on the search for a suitable village. This motivated several villages to compete to become the first bioenergy village. Moreover, using plausible, easily understood terms or symbols for initiatives or projects is good for publicity.

Having a person in charge of a village district. The village should be divided into several districts. In Jühnde, for example, this was done according to the streets, with a person was in charge of disseminating information and providing an overview of the households' willingness to participate in the common heat supply. Having such a person in charge of a small district can increase a feeling of unity.

"Neutral" approach. In projects where many persons have to be motivated, it is beneficial to get the politicians of different parties involved; a "neutral" approach has been shown to be effective. This was also confirmed in our experience of mobilising the villages in the district of Göttingen: The University's neutral stance was a good basis for persuading and motivating people.

Spreading information orally. Initiators should provide informational stalls at markets or festivals attended by many people, and where they can talk face-to-face and provide additional written material. In Jühnde, such stalls were set up at nearly each festivity attended by many people and where doubts and concerns could be minimised through personal communication. Furthermore, the involvement of the local clubs and societies as well as the involvement of the council and municipality are important success factors (see also Mieneke and Midden 1991; Scherhorn et al. 1999).

Festivities. Public festivities should also be used to transfer ideas and stimulate others to participate in a project. Herzog (1997) found this type of participation to be a critical factor. In the villages around Göttingen, the inhabitants decorated wagons for the parish fair very creatively with elements pertaining "bioenergy", such as a little wood-fired oven, etc.

Personal contact. Another successful way to mobilise individuals is to contact them *personally*; for example, by going from house to house and informing them. In Jühnde, the initiators elaborated this strategy by selecting a particular person from the initiative group to speak to the residents of each house. In some cases, listening to the daily events may help create a trusting atmosphere that increases understanding and willingness to participate in an energy project. Individuals' doubts and scruples should always be taken seriously and should receive careful consideration. The personal approach is one of the most important ways to motivate people. This is consistent with research findings on face-to-face contact, which is considered more effective than written material (Ammann et al. 1997; Gonzales et al. 1988; Burn and Oskamp 1986). Furthermore, best-practice analyses found that personal contact is more efficient than impersonal contact, such as sending out mail (Fischer and Kallen 1995; Hennicke et al. 1997; Schuster and Marx 1998). If impersonal forms of information are used (e.g., posters and mail), it is more convincing if specific persons write about their experiences and state their names and addresses than if only technical or financial information is given (Schmittknecht 1998).

Authenticity and conviction. Technical details are often unimportant when one wishes to persuade people. Personal conviction and authenticity, as well as plausible arguments for engagement in the project are often more important.

One of the residents in Jühnde mentioned: “We also live in this village, and we would not plead for an electricity supply that is not reliable”. Furthermore, it is important to point out how the project will benefit the region. Another successful approach could be to get the children involved, which will in turn lead to more parents being involved (Herzog 1997). In Jühnde, this was realised by means of a drawing competition for children with the “bioenergy village” as the topic.

Humour. Whatever strategy is used, it is good to make people laugh in order to open to new ideas; fantasy and humour also promote open-mindedness toward ideas. The inhabitants of Jühnde, for example, learned about bioenergy villages through a few theatre projects. Emphasising the positive aspects of a particular project’s consequences can also be helpful. In the case of Jühnde, natural, economic and social scientists gave introductory presentations that pointed out the benefits (see also Csikszentmihalyi 1993, and Richter, cited in Schmuck et al. 1997).

The Impact of the Collective Engagement in a Bioenergy Village on Different Psychological Levels: Results from a Questionnaire Study

Schmuck and Sheldon (2001) collected data from several research groups all over the world that demonstrated that self-transcending life goals directed at social and environmental thriving tend to serve individual well-being. Furthermore, empirical findings show that social belongingness contributes to health and well-being (Baumeister and Leary 1995) and that high rates of self-efficacy are positively related to health (Bengel et al. 1998).

Given that many of the Jühnde inhabitants participated in the planning and conversion process and were engaged in different working groups – for example, one for “public relations”, one for “technique” and one for “biomass production” –, we expected positive changes in the mentioned psychological variables (for details see Eigner-Thiel 2005).

1. To examine these questions, a 14-pages questionnaire, which included the mentioned variables’ and the environmental behaviour’s scales, was distributed (a) to the 238 households in Jühnde and (b) to 240 households in a comparable control village. The design was a longitudinal study of the two villages. Data were collected before the conversion in 2001, and after the conversion in 2007. The following differences were found: Self-efficacy was higher in the converted village (both temporal measurements) and the self-reported environmental behaviour had increased over the period (both villages). Neither the other variables, nor the expected interactions (villages and time) showed significant effects.
2. Satisfaction with the heat supply from biomass. The people of Jühnde linked to the heat supply system were also asked to what extent they were satisfied with this system. On the whole, 89 % said they were “very satisfied”, 11 % were “satisfied”, while nobody was “dissatisfied”.
3. Furthermore, the people in Jühnde were asked how they felt about the large number of visitors they had received (in 2007 around 8,000). A total of 78 %

chose the answer option: "This makes me proud, it stimulates me"; the visitors did not bother 16 %, 4 % did chose not to answer, and 2 % had been bothered by the visitors.

The Impact of the Collective Engagement in a Bioenergy Village on Different Psychological Variables: Results from an Interview Study

In a semi-structured interview study (according to Witzel 2000) with 11 persons belonging to the subgroup of bioenergy villagers who had been particularly engaged in the project over a longer period (e.g., as a representative of a working group), evidence was found of an increase in social support and well-being during the project implementation. For details on the interview manual and the analysis of the interviews, see Eigner-Thiel (2005) and Eigner-Thiel et al. (2004). The results of the interviews are described in the following paragraphs:

Group-feeling: Most of the interviewees (10 out of 11) said that they got to know and value many others in the village through the project. Prejudices concerning neighbours were partly diminished. Especially people who had only recently moved to the village valued this outcome: They felt better integrated into the village community after the project. Even long-time residents, who had already known many people in the village before the project, said that the contents of their discussions within the village were more profound after the bioenergy project and that their conversations were no longer merely small-talk. The village community was described as "more interesting" since the project had started. A greater feeling of oneness also became evident in statements like "*We* were on the TV last week" or "*We* have indeed realised the project".

Environmental behaviour: Most of the interviewees said that their environmental behaviour had already been very proactive before the project had started (9 out of 11). Examples of their behaviour were: "not tossing anything out of the car window", "not leaving old refrigerators in the forest" and "not wasting electricity". Only a few people said that they had further changed their behaviour (2 out of 11): One person, for example, reported that since the project, he obtained electricity from a more expensive eco-provider and had also bought a gas-driven car.

Self-efficacy: Concerning the question of whether an individual can do anything about climate protection, most of the interviewed persons (8) answered that they alone could not do anything. However, their experience of being a tourist guide in their biogas plants was very positive and gave them the feeling that they had sparked something in others. Only two persons felt that new developments should only be driven by politicians.

Well-Being: "If it had not been fun, I would not have engaged in this project". This, or a similar statement, was the answer most of the interviewees (10 out of 11) gave regarding the question of whether or not they had considered the project fun. Their reasons for enjoying it were, for example, that they could act from conviction; this was described as an intrinsic motivation during the processes' good and less good times. Some of them felt that taking responsibility for the project and getting to know their personal boundaries were very fulfilling. For many of the interviewees, it was very liberating to see the village community implement plans. Moreover, it was heartening to learn more about the different functions of the working groups (e.g., techniques for running households, operating companies and cultivating energy crops). The interviewees felt that finding solutions to difficult problems (e.g., where to place the biogas plant in the village) was exciting. Some of those involved also found observing and participating in different forms of learning and the presentation that the university group members shared with the inhabitants fascinating.

Some of the interviewees also referred to the negative consequences of the involvement; for example, “having less time for the family”. However, even those who had negative experiences felt that the positive aspects had had a greater impact. Guiding tourists through the energy plants allowed them to share their acquired knowledge and was reported to be fun. Today, the interviewees are proud to see their village and the news about its pioneering activities on the Internet or on German television. Helping other interested villages become a bioenergy village was also considered fun. When asked how the project impacted their life satisfaction, one group (five people) responded: “Yes, this project has totally affected my contentment with life”, which means that the experience had given their lives additional meaning. Persons from this group described the project as one of the highlights of their life; they feel as if they are part of something really big and important, which makes them proud. These experiences are expected to have a lifelong impact. The other group (six persons) was pleased that the biogas plants were built, that they are functioning and that the project was implemented successfully. However, they stated that, in their life, there are still matters that are more important than the project, for example, their family. Interestingly, one person said that he felt physically quite exhausted throughout the project, but that he nevertheless felt a mental or spiritual contentment as a result of his engagement in the project.

On the whole, the mentioned positive psychological consequences (more details in Eigner-Thiel et al. 2004; Eigner-Thiel and Schmuck 2010) can serve as a driver to transfer the idea to other villages. If the inhabitants of other villages see the potential psychological gains from this collective action, it could be a strong motivation to spread the idea of bioenergy villages, thereby supporting ecological and economical movements. We focus on the economical movements on in the next section.

2.4.2.4 Financial and Economic Aspects

One of the aims of this project was for all the stakeholders (e.g., households/heat customers, farmers, the operating company and the region) to benefit from the bioenergy village project. This meant that no one would suffer economic disadvantages from participating in the project.

Perspective of the Households/Heat Customers

The ways in which electricity was supplied to the houses have remained the same. To calculate the heating costs (of heating the rooms and water in the houses), three components have to be taken into account: the costs of the heat supply (which depends on the amount of heat required), the connection fee (in Jühnde 1,000 EUR per heat customer) and individual conversion costs (a one-time payment of approximately 2,600 EUR per household to install the new heating system). The operating company guaranteed a fixed buying price for energy until 2008, which refers to the price of heating oil at the time of contracting (0.35 EUR/l). Since the oil price rose at that time (e.g., 0.95 EUR/l in August 2008), an average household saved 1,800 EUR in heating costs annually.

Perspective of the Farmers

Cultivating crops for energy production is an alternative way for farmers to generate income besides the traditional markets for foods and animal feed. This can be an advantage for the farmers because these markets' prices fluctuate heavily over time. Producing biomass for energy will therefore lead to a constant basis income.

The operating company and the farmers agreed upon a price for the biomass that equalled the farmers' winter wheat profit. A potential problem could therefore be that the Jühnde bioenergy plant can only be run profitably if the operating company pays a price that is comparable with a price for winter wheat of 185 EUR/t. The average production costs of a ton of winter wheat amount to approximately 130 EUR. The associated market price fluctuated between 120 EUR/t and 290 EUR/t from 2005 to 2008. In this situation, it would be reasonable to agree on long-term supply contracts that set the prices for wheat in a range between 130 EUR/t and 185 EUR/t. This would smooth out the volatility of prices in the world markets for both the farmers and the operating company. Unfortunately, in real life, it is not so easy to close long-term supply contracts.

Perspective of the Operating Company

The owners of the operating company in Jühnde are farmers, villagers and (a few) external shareholders. Consequently, the profits remain in the region. If only external investors held the shares, the price of the heat provision would have been much higher and the price of the biomass would have been lower to allow the operating company to maximise its profits. This would have meant high payouts to the investors with the money lost to the region.

In Jühnde, the operating company invested a total of 5.4 million EUR: 2.9 million EUR in biogas and electric power production, 0.9 million EUR in the central heating plant and 1.6 million EUR in the hot water grid. This sum was financed by means of equity capital (0.5 million EUR), government grants (1.5 million EUR) and loans (about 3.4 million EUR).

Perspective of the Region

In the Jühnde project, 58 % of the invested sum was given to regional companies, and most of the annual turnover (80 %) remained in the region too. This clarifies that the installation of a bioenergy village supports local economic cycles. On the whole, the stakeholders of the Jühnde project have gained their expected economic benefits.

2.5 Conclusions

This chapter showed that sustainability science principles can be successfully applied to initiate renewable energy solutions in German communities. In the Göttingen Approach, sustainability science is not only based on interdisciplinary research, but preferably on transdisciplinary research. This kind of science should not be an end in itself, but should initiate, and contribute to, the solution of actual practical problems in cooperation with active practice partners from outside the scientific community. Typical consecutive steps for such activities can be: (1) Select a critical global problem; (2) formulate alternative solutions starting at a regional level; (3) find political and financial support; (4) search for practice partners; (5) run a pilot project on a local or regional level; and (6) transfer the successfully accomplished pilot project to other regions or to national or international levels, if applicable. The scientists should accompany and investigate all the individual steps during the project realization. New scientific knowledge can be produced from such alternative demonstration models. The double role of scientists within sustainability research is one approach to cope with the challenges of the global ecological crisis.

The application of our sustainability approach in the bioenergy field comprised the following elements: (a) Communicate the side effects of exploiting and applying fossil and nuclear energy resources within the scientist group; (b) find and elaborate an attractive alternative energy supply at a regional level (bioenergy village concept); (c) convince political and financial supporters; (d) search for partners in the region and in villages; (e) run a pilot project to transform a village's conventional heat and electricity supply into a renewable energy basis with the villagers as the main actors (the bioenergy village is born); and (f) bring the successful lighthouse project to the media's attention on a regional, national and global level to motivate other villages or regions to attempt similar projects.

The important research results can be summarised as follows:

- The transformation of the heat and electricity supply of the bioenergy village Jühnde by means of crops, manure and wood decreased the greenhouse gas emissions by 84 % when compared to Germany's average total emission in 2007. The energy balances of the crop production show that their energy input/output ratio was 1:19 for triticale and 1:18 for maize. The harvest index for heat and electricity production in the Jühnde biogas plant is convincing: 1 kWh of fossil energy input produces 4.5 kWh of bioenergy.

- New, locally adapted and environmentally friendly concepts for the parallel cultivation of food, feed and energy crops, such as crop rotation and double-cropping systems, create a high crop diversity (no monoculture), which may enrich the landscape and increase the population's acceptance.
- The reduction of pesticide use during the energy crop cultivation and the more balanced nutrient cycles lessen the translocation of pesticides and nitrate to surface and ground water, which is especially important in water protection areas.
- The new concept also decreases soil erosion and humus degradation; even the build-up of soil humus and the corresponding carbon fixation are possible.
- By harvesting energy crops several weeks earlier than food crops, the farmers' workload becomes more balanced.
- Energy production is an additional way for farmers to generate income. If the owners of the operating company are mainly local farmers and villagers, the profits remain in the region. In Jühnde, 58 % of the invested sum was given to local companies and 80 % of the annual turnover has remained in the region, thus supporting the local economic cycles.

All these positive aspects help to convince and motivate citizens – especially environmentalist, farmers, etc. – to follow the bioenergetic pathway. The following social and psychological motivating actions were used in Jühnde: (a) Visit model sites with successful installations together with the citizens; (b) formulate positive and constructive, but objective, arguments in favour of the project; (c) inspire well-established people with broad recognition and who are respected for the project; (d) involve local clubs and societies and the parish, as well as the council and the municipality; (e) use festivities and other similar events to transfer the ideas and stimulate people to participate in the project; humour, authenticity and objectivity are important ingredients to convict people; (f) have someone in charge of the dissemination of information; (g) also spread the information orally and contact individuals personally; and (h) establish and cultivate good contact with the local media.

The evaluation of a questionnaire shows that the self-efficacy and self-reported environmental behaviour in the bioenergy village increased and that all the inhabitants of Jühnde who are linked to the hot water grid are very satisfied (89 %) or satisfied (11 %) with the heat supply by means of biomass.

On average, 11 Jühnde interviewees engaged in the project perceived a better group feeling and integration into the village, more profound communication, a greater feeling of unity and well-being.

Altogether, the implementation of the bioenergy village was a success story not only for the villagers and farmers in Jühnde, but it also formed the basis for hundreds of other communities in Germany that realized similar or other renewable energy projects decentrally (Schmuck et al. 2006; Ruppert et al. 2008). The trans-regional, national and international interest in Jühnde was very high. In 2007, more than 8,000 visitors (mostly in the form of groups) arrived to familiarise themselves with Jühnde, the first bioenergy village in Germany.

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