

Integrated Manure and Organic Waste Management System – Ruegen Demonstration Biogas Project, Germany

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Summarize

The economy of Ruegen, Germany's largest island, is based on two main columns: Agriculture/Fishery and tourism. In the 1990's the problems arising from agricultural activities - in particular handling of the raw manure - were in the focus of public discussion: Problems, like smell, ground- and surface water pollution, uncontrolled methane emissions etc. and the arising effects on the overall island environment were seen as major reason for a reduction of tourist numbers.

For the treatment of the manure and organic waste, a large-scale biogas demonstration plant has been installed. The key-Information of the biogas plant are as follows:

- **Investor/owner of the plant:** "AEP-Alternative Dünger- und Energieproduktion Putbus GmbH" owned by five local farmers
- **Investment:** 7 Mio. Euro inclusive real estate and concrete office building. Co-financing: German/European programme for infrastructure measures
- **Start of operation:** February 1997
- **Capacity:** 100,000 t/a with approx. 60,000 t/a cow/pig manure + 40,000 t/a organic wastes (residues from fish industry, kitchen and swill etc.)
- **Biogas production:** approx. 3,8 million m³/a
- **Energy units:** CHP-units (2 x 495 kW electrical capacity, 2 x 740 kW thermal capacity each)
- **Electricity production:** approx. 8.7 GWh/a
- **Heat energy:** approx. 12.1 GWh/a
- **Fertiliser production:** 95,000 t/a

The biogas plant shows various ecological, environmental, regional and last but not least economical advantages, which will part of the presentation.

The biogas plant Pastitz is a successful example for an Integrated Waste Management Solution (IWMS) in an agricultural environment. The biogas plant combines agricultural production, economy and environment in a very effective way.

1 Introduction

In the mid-1990s, strict environmental laws were beginning to make a major impact all over Europe. In Germany, the agriculture community on Rügen, Germany's largest island, was faced with a significant environmental and economic challenge. Farm community had lived in harmony with the summer tourist community for many years, however, the island was becoming an increasingly popular tourist destination. The question was how to create an economic balance between agriculture and tourism within a constrained land mass.

Odour control and water protection were two of the main issues identified in achieving balance between the two diverse economic drivers. The answer lay in integrated Waste Management System. It offered responsible manure management, odour reduction and an economic stimulus while reducing greenhouse gas emissions.

Several large-scale agricultural processing plants located in the Rügen, had indicated a strong interest in integrated manure/waste management solutions. Organic waste from agricultural and industrial sources in the Rügen were analysed to obtain information about the quality and quantities of organic materials potentially available to the pilot biogas plant being considered for construction in the region. In addition to the analysis and estimation of potential organic matter from agricultural and industrial sources, the feasibility study had also undertaken a preliminary technical draft of the proposed plant based on maximizing the production and utilization of energy and other added value products using innovative German biomass technologies. It was feasible to build and operate a pilot biogas plant in the island, with a treatment capacity of about 270 t/d as a demonstration project in 1995.

2 The Solution

A new enterprise as Investor/owner of the biogas plant, "AEP-Alternative Dünger- und Energieproduktion Putbus GmbH", which owned by five local livestock farmers has been built. The Biogas plant to utilise surplus regional organic matter complements an ecologically oriented Mass-Energy-Cycle System. The primary goal of an integrated mass-energy-system is the effective treatment of residual organic material (manure and organic wastes) to get the renewable energy and the further utilization of the by-products. The benefits of the technology is considerable. Environmental risks associated with odour and water contamination from spreading raw manure on land are mitigated. The digested slurry used as an organic liquid fertilizer highly valued by the horticulture sector.

The thermal energy from the process is sold off and used to heated the local hospital, day-care, school and nearby homes. The electricity energy is fed back into grid where a legislated premium price is obtained from the energy companies. This "premium" energy continues to provide a significant source of revenue for the co-operative of 5 small to medium sized farmers involved in the project. For Rügen Island, the treatment of municipal and industrial residues guarantees sustainable, long-term socially and economically sound waste disposal.

Electrical and thermal energy produced by CHP units using biogas as the primary fuel supply results in green energy as a substitute for other less environmental friendly energy sources. Significant Carbon Equivalent Reduction Credits result from the technology.

The ideal combination of stakeholders in the plant includes five livestock farms is intended as a model for application of biogas technology in the Germany.

The main project design:

- **Investment:** 7 Mio. Euro inclusive real estate and concrete office building. Co-financing: German/European programme for infrastructure measures

- **Capacity:** 100,000 t/a with approx. 60,000 t/a cow/pig manure + 40,000 t/a organic wastes (residues from fish industry, kitchen and swill etc.)
- **Biogas production:** approx. 3,8 million m³/a
- **Energy units:** CHP-units (2 x 495 kW electrical capacity, 2 x 740 kW thermal capacity each)
- **Electricity production:** approx. 8.7 GWh/a
- **Heat energy:** approx. 12.1 GWh/a
The electricity is sold to the public grid for a fixed rate per kWh (0.10€cent, regulated in the German Renewable Energy Law). The heat energy is sold to a nearby residential area (hot water and heating).
- **Fertiliser production:** 95,000 t/a
The farmers apply the fertiliser on there fields.
- **Storage and mixing tank:** 1,800 m³
- **Anaerobic reactor:** 2 x 2,100 m³
- **Hygienisation:** 3 x 30 m³
- **Reservoir:** 1 x 1,000 m³

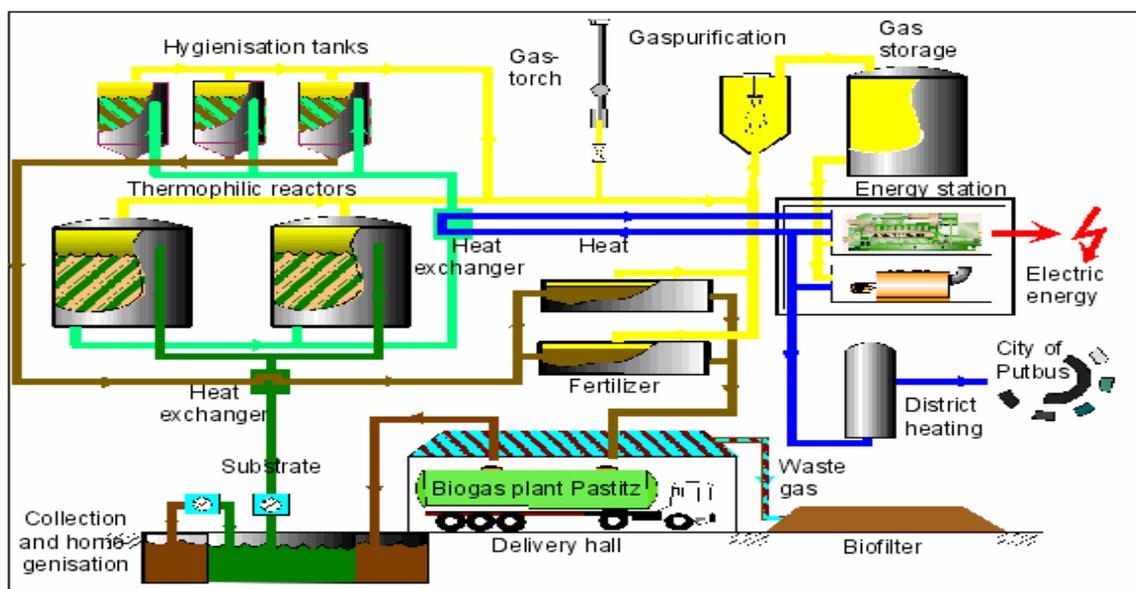


Figure 1: The flow scheme of the biogas plant Ruegen

3 The Manure/waste Management Process

Materials Handling Logistics

The livestock manure from different farms has to be brought to the biogas plant with the sludge suction vehicle with a capacity of approximately 23 m³ liquids. The vehicles are constructed so that the required filling/ emptying is carried out over the edge of the agricultural storage tanks.

To determine the optimal material and transportation logistics the following aspects must be taken into account:

- avoiding long transportation routes,
- minimizing the necessary transportation volume (in particular dead freight),
- integration and utilization of existing storage capacities of livestock operations,
- establishing interim storage capacity.

Delivery of input materials and distribution of treated manure fertilizers are provided through both company-owned transport vehicles and/or local carriage companies. Each delivery is carefully scaled and analyzed at the treatment facility. Various input materials are cut up and scientifically blended into

mixing tanks with total volume of 1,800 m³ for mixing and liquefying. The mixture substance is ideal material for the intensive anaerobic treatment and high efficient degradation process. After the fermentation process is completed, the produced fertilizer is delivered to the farm where it is stored in tanks – ready for application. During the treatment process, any excess gas from within the treatment facility is captured and cleaned by a bio-filter before it is released back into the atmosphere.



Photo 1: Input materials transportation



Photo 2: Fermented manure transportation

Anaerobic Fermentation Process

The anaerobic treatment process is the most important phase in the overall system. With the aid of anaerobic technology, via the breaking down of micro-organisms, organic waste is converted into biogas which can be used for the production of electrical energy and heat. Via fermentation the homogeneity of the substrate is improved and the odour and CO₂ emissions are reduced. Processing of all forms of substrate such as manure, biomass, organic household waste, sewage sludge, etc is possible.

According to yield most biogas from the livestock manure and organic waste, the Completely Stirred Tank Reactor (CSTR) has been considered as the anaerobic treatment step. In this step, the pre-treated material is heated to approximately 55°C by means of a heat exchanger and is continuously fed into the two thermophil operating biogas reactors. The substrate is then fed into the hygienisation tanks (3 x 30 m³) and is heated to a temperature of 70°C for one hour. All required energy is sourced from within the biogas plant and the whole process is automatically controlled by a PCL-system. Co-fermentation of manure and organic residues in the biogas plant is a completely nature biological process than produces nutrient rich fertilisers. The hygienisation process kills possible harmful pathogenic agents and allows the environmentally friendly treatment of nature nutrients.

The CSTR reactor has a total volume of 4,200 m³ (2 x 2,100 m³) with a diameter of 14 m respectively, and is a cylindrical steel tank. The two reactors will be built and work in parallel. The operating temperature for the CSTR reactor is 53 – 55 °C with a hydraulic retention time of 15 days. Under the normal conditions the CSTR reactor will have a organic loading rate of 8 – 10 KgTS/m³.d. The TS removal rates has reached more than 60%, and the biogas production is approximately 10,000 m³ per day with methane content of 60 – 70%. It is proved that this reactor is more suitable for treatment of high TS contained original substrate such like livestock, organic waste and sludge than other reactor types due to its completely mixing and circulation principle. Gentle stirring of the substratum is guaranteed by the mechanical mixer, and to get maximum biogas production. Owing to the special wall-heating system, the distribution of temperature in the digestion tank is optimal and even.

The fermented material which is nearly neutral in smell, is stored in several covered tanks (1,000 m³). These installations function as cooling tanks and interim storage for the fertilizer as it awaits for distribution. The generated biogas from the continuous fermentation process and storage tanks is captured and fed into the biogas storage tank after it has undergone a bio-filter proprietary cleaning process. The gas storage tank ensures a continuous gas supply for the energy centre.



Photo 3: Biogas plant Riegen



Photo 4: Anaerobic digesters

The main operating parameters of the biogas plant are:

- Input amount:	274 m ³ /d
- Hydraulic retention time (HRT):	15 d
- PH in methane reactors:	7,0 – 8,0
- TS – loading rate:	8 –10 Kg ts/m ³ .d
- VS – removal rate:	70 – 80%
- CH ₄ – production rate:	0,25 - 0,35 m ³ CH ₄ / kg VS.d
- CH ₄ – content in biogas:	60 – 70%
- Biogas production:	10,000 m ³ /d

4 Energy Concept

The biogas with methane content of between 60 to 70% can be used to produce heat and electric power in two combined heating and power generation units. The CHP units will be installed in a special building including all necessary instruments and connection to external power units.

The produced biogas is cleaned and desulfurized (H₂S approximately 20 ppm) in a specialized multistage biological process for the removal of hydrogen sulphate in the biogas. Thereafter, the cleaned biogas is used for the two generation of combined heat and power (CHP unit) with total capacity of 990 kW (2 x 495 kW). The fermentation process consumes about 15 – 20% of produced energy. Surplus electricity energy is delivered to local utility power grid as “green energy” for distribution to about 3,000 households. Surplus heat (thermal) energy is delivered to the City of Putbus as heating supply to approximately 630 households. Under German conditions the heat transport is feasible if the pipeline system is not longer than 2km.



Photo 5: Bio-filter for biogas cleaning



Photo 6: Co-generation unit (JMS 312)

5 Environmental Effects

The anaerobic biological processing of residual organic matter makes the implementation of a decentralised, closed substances-energy cycle possible. Incorporating the Integrated Waste Management System (IWMS) into livestock operations will allow an environmentally sustainable treatment of agricultural wastes and residues. By generating the regenerative energy carrier biogas, fossil resources can be protected and harmful emissions endangering the environment minimized. Furthermore, the anaerobic treatment improves the material- and application-qualities of the fermented manure and thus enables an environmental friendly agricultural usage of the organic wastes and residues. Further advantages result from the decentralised nature of the energy generation and the processing of organic wastes and residues of various origins. Thus, long transportation and distribution distances for the transport of input and output materials are avoided.

The following positive environmental advantages are achieved through the anaerobic treatment:

- Reduction of emissions of odorous substances during storage or distribution,
- Hygienization and destruction of germs, pathogenic agents and weed seeds,
- Increase of the fertilizer value enables an improved, tailor-made spreading of fertilizer avoiding “over-fertilization”,
- Minimizing the nitrogen loss through washing-out of nitrate into ground and/or surface water,
- Safeguarding of water resources due to recycling and reuse of process water,
- No over-acidification of the ground in comparison to raw manure,
- Minimizing of the CO₂-emissions by substituting the fossil fuel substances,
- Minimizing of the CH₄-, ammonia- and nitrous oxide emissions, and
- CO₂-neutral process.

GREENHOUSE GAS AND AIR POLLUTION

Apart from the problems of odour and water pollution, the storage of raw manure in open lagoons and the field spreading can cause major air and groundwater pollution. In particular, the uncontrolled emissions of green house gases are of major importance.

In particular, uncontrolled methane emissions from agricultural activities are a major source of greenhouse gas emissions. Comprehensive international scientific research has been undertaken in the last decade. The research has shown that the concentration of methane in the atmosphere has doubled from 800 ppbv to almost 1,600 ppbv since 1850¹. The IPCC (Intergovernmental Panel on Climatic Change) states a 21x higher potential of methane than CO₂ within a 100 years time frame. That means 1 kg of methane has the same effect as 21 kg of CO₂ within a timeframe of 100 years. Apart from this direct effect, the experts also see an indirect effect, because the chemical transmission of methane in the atmosphere causes the generation of other trace gases, which also have a negative climatic effect. Some researches suggest 30%, while other researches claim 100% of the direct effect as additional indirect effect.

Major sources for methane emissions in the island Ruegen are the digestion of the ruminants and other herbivorous breeding animals as well as the storage of the animal excrements. Reducing the number of animals, hence, decreasing livestock activities of farmers, can only reduce the emissions due to the digestion process of the animals. Nevertheless, the emissions from storage and application of manure can be significantly reduced due to the treatment within a biogas system.

Through the controlled degassing of the organic matter in the biogas plant, methane is not released uncontrollably into the atmosphere. Biogas is used in the CHP unit (combined heat power generation). The carbon dioxide (CO₂) in the biogas results from a natural circulation and has no harmful effects on the environment. The carbon dioxide (CO₂) that is released is the same as what was absorbed from the

¹ Biogas Journal, German Biogas Association, No.3/1998, „Climatic effects of biogas plant“, M. Rünzi

atmosphere by the plants. Organic matter such as plants absorb carbon dioxide (CO₂) from the atmosphere for growing and releases it again into the environment either during the anaerobic disintegration or during the combustion of methane from the anaerobic disintegration. Thus, no “additional” carbon dioxide (CO₂) is generated. Whereas during the combustion of the fossil fuel, carbon dioxide (CO₂) is released that has been fixed for several millions of years in the earth’s surface and was thus withdrawn from circulation.

According to information from German Environmental Ministry, the project emission factor is 0.55 t CO₂ per MWh² electric power and baseline emission factor 0.8 per MWh². Methane has a 21 times higher greenhouse gas potential than CO₂. Whereas through utilization of a m³ biogas to generate electricity about 2 kWh electric power can be generated. The following theoretical CO₂ emission potential has been estimated for the biogas plant in Ruegen:

Biogas plant with input 274 m³/d (174 m³/d manure and 100 m³/d organic waste)

Biogas production: 3,800,000 m³/yr = 2,470,000 m³ CH₄/yr = 1754 t CH₄/yr
 Electrical energy: 8,700,000 kWh/yr
 Biogas amount: 10,000 m³/d
 Methane content; 65%

Calculation of estimated CO₂ emission potential: $(ER_e) = (E_{eBLtotal}) - (E_{eptotal})$

(ER_e) = estimated total CO₂ emission reduction through the project
 $(E_{eBLtotal})$ = estimated total CO₂ emission through the baseline level
 $(E_{eptotal})$ = estimated total CO₂ project emission

$(E_{eBLtotal}) = (8,700 \text{ MWh} \times 0.8) + (1,754 \text{ t CH}_4 \times 21) = 43,794.00 \text{ t CO}_2\text{equiv./yr}$
 $(E_{eptotal}) = 8,700 \text{ MWh} \times 0.55 = 4,785.00 \text{ t CO}_2\text{equiv./yr}$
 $(ER_e) = 43,794.00 - 4,785.00 = 39,009.00 \text{ t CO}_2\text{equiv./yr}$

In total we have a CO₂-saving potential of about 39,009.00 t CO₂equiv./yr for the biogas plant.

The pilot biogas project in the island Ruegen can make a major contribution to climate improvement as well as contribute to sustainable development of added value opportunities in the area.

In conclusion, biogas plants have two main impacts as they relate to greenhouse gas problems:

1. Substitution of electricity produced from using fossil resources. Hence, reduction of CO₂ emissions which originate from fossil resources.
2. Utilisation of methane that has a 21 times higher “greenhouse effect potential” than CO₂. This means, the avoidance of uncontrolled methane emissions from manure.

In summary, the biogas system provides three critical environmental advantages:

1. The negative environmental effects of organic wastes can be significantly reduced through the processing of the liquid manure.
2. Valuable substances and nutrients are maintained and are returned in a profitable form to the soil.
3. Biogas generates renewable and sustainable clean energy.

² Source: „Leitfaden für emissionsbezogene JI- und CDM-Projekte, Band II: PDD-Erstellung“

6 Effects on Agriculture and Regional Development

DIRECT ADVANTAGES

Through the treatment of organic substances through the biogas system, the quality of the fertilizer (i.e. liquid manure) can be improved considerably. The previous complex problems related to raw liquid manure (e.g. odour, hygiene, nitrogen-emission, etc.) are reduced or eliminated. The nutrients penetrate the soil much faster and are absorbed much more easily by the plant roots.

The fermentation process leads to a homogenisation of the liquid manure. Contrary to raw manure, the fermented liquid manure exhibits a very regular structure as well as a smaller size of particles. Thus, the flow property of the digested liquid manure is improved and the potential risk of contamination is reduced or prevented following spreading.

MANAGEMENT ADVANTAGES

In respect to the management of liquid manure, similar advantages result due to this treatment. The application of digested manure is better managed since quantities and qualities are well known in advance of field application. When spreading raw liquid manure, there is always the risk of an over-fertilization. When using fermented liquid manure the risk of excessive nutrients or violating application guidelines can be minimized.

IMPACT ON REGIONAL DEVELOPMENT

Established the pilot biogas plant in the City of Putbus in the island Ruegen had both positive environmental and economic impacts in the region. The pilot biogas plant in the City provides livestock producers with a more sustainable and environmental-friendly processing option for disposing raw manure. This region has some livestock enterprises and references as tourism region. There is growing public pressure throughout Ruegen against the practice of spreading raw manure on grain and pasture land especially in areas where urban population is encroaching on agricultural lands. This is making it more difficult to establish new or expand existing intensive livestock operations. Without acceptable manure/waste treatment options for disposing raw manure, livestock expansion in the island will cease and in many instances contract.

The marketing of electrical energy has been deregulated, making the sale of electricity from alternative sources more economically and environmentally attractive. A more open market for the sale of electricity has created “green energy”, opportunities for farmers choosing to process livestock manure through biogas plant with CHP-units. There will be increasing focus on green energy options as the full impact of German’s signing of the Kyoto Protocol starts to be felt by the traditional energy sectors especially the coal generation segment. The increasing value of green energy in combination with Carbon Equivalent Reduction Credits will undoubtedly increase the viability of biogas plants

The combination of anaerobic digestion of livestock and industrial wastes through a integrated waste treatment biogas plant offers locally based sustainable employment and investment opportunities in new value added industries. As the newer technologies are proven to be economically viable, resistance to changing the way agriculture carries out its business will also change. Large agricultural processing plants in the Island depend on primary agriculture to provide the raw materials used for secondary processing.

In conclusion, IWMS creates a strong partnership among livestock producers, private industry and local governments that benefits all parties. Due to its decentralised structure the biogas concept is an effective contributor to the local community and regional economic development.