Pellmeyer Biogas Plants, Eggertshofen, Munich, Germany

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CASE STUDY

Pellmeyer Biogas Plants, Eggertshofen, Munich, Germany

The biogas plants located at the Pellmeyer farm, Eggertshofen, Munich offer an insight into the way in which the German model for biogas production has changed over the past 15 years. These changes have been, and continue to be, primarily driven by the feed in tariff system described within the Erneuerbare Energien-Gesetz (EEG) first implemented in 2000 and revised in 2004 and 2009. The Pellmeyer family own and operate two anaerobic digestion plants, both located on their farm which is located to the north of Munich. The older of the two plants treats organic food wastes sourced from a number of food production and outlet facilities, whilst the second newer plant is fed entirely on energy crops including whole crop maize silage and grass silage. Mr Josef Pellmeyer is currently the president of the German Biogas Association.

A. ORGANIC WASTE TREATMENT PLANT

INTRODUCTION

Mr Josef Pellmeyer initially developed an anaerobic digestion facility at the 150 hectare family owned farm in 1996. The farm is located approximately 25 km to the north of Munich and 1.5 km to the west of Munich airport in the hamlet of Eggertshofen. The plant itself is sited within a complex of farm buildings including farm house, animal sheds (cattle), and various barns and storage sheds. There is no physical separation between the biogas plant and the other agricultural activities.

The rationale behind the development of the plant was to generate an additional income through the treatment of commercial and industrial food wastes to generate renewable electricity and heat for either on farm use (heat) or export to the local grid (electricity). Digestate would also be utilised on farm to offset mineral fertiliser use. The plant was designed by UTS although it is understood that construction of the plant was undertaken by several contractors. UTS also supplied several elements of the plant including the heat exchanger rings within the digesters, the hydraulically operated and electrically operated agitators and associated service boxes, and pumps that are designed and produced by the company.

Feedstock is sourced from a number of organic waste disposal companies. Although exact details of the sources of feedstocks could not be determined, and the exact composition of feedstocks are understood to vary according to availability, an approximate breakdown of the inputs into the plant are given in Table 1.

Although the exact nature of the food substrates treated at the site is not known, it is understood to comprise a significant liquid fraction including fats and greases.

Table 1 – Approximate breakdown of waste feedstocks used at Pellmeyer farm

Feedstock	Tonnes / Year (Approx.)	Tonnes / Day (Approx.)
Fruit and vegetable waste	437	1.197
Food waste (various)	5,196	14.23
Cereal waste	14	0.04
DAF Sludge	8,940	24.5
Cleaning water milk	52	0.12
Dairy sludge	1,267	3.47
Slurry	3,500	9.58
Manure	80	0.22
Straw, grass, hay	750	2
TOTAL	**20,236**	**55.357**

PLANT DESCRIPTION

PRE-TREATMENT AT PELLMEYER BIOGAS PLANT (WASTE)

Liquid substrates that do not contain Animal By Products (ABP) are delivered to a below ground concrete reception and mixing pit (Fig. 1). Liquid substrates which do contain ABP are delivered to a 200 m^3 above ground cylindrical tank close to the entrance of the main farm complex (Fig. 2). The conditions set by the plant operator to receive ABP substrates are that they are pumpable and meet the particle size requirements of ≤ 12 mm without further maceration.

Figure 1 – Below ground concrete reception tank for non ABP substrates

Figure 2 – Above ground cylindrical tank for substrates containing ABP material

Substrates containing ABP are subsequently pumped to a pre digestion pasteurisation unit (Fig 3 & 4). This has a volume of 27 m^3 and operates on a batch mode. Mixed substrates are treated at 70°C for a period of 1 hour. The unit was heated via the CHP engines incorporated into the plant. The pasteurisation unit could be filled and emptied from either the top or bottom of the unit and pasteurised substrates could be added to any of the three digester tanks present on site, depending on the nature of the substrate. In addition, any gases emitted during the pasteurisation unit are directed into the third of the three digesters (Fig. 4). As the substrates generally include a significant quantity of fats and greases it was noted that the pasteurisation unit and associated pipework required frequent cleaning. Digestate was used to clean the unit and pipework with all liquids then being returned to the digesters. It is understood that the temperature and residence time within the pasteurisation unit was electronically monitored.

Figure 3 – Pasteurisation unit looking northwards

Figure 4 – Pasteurisation unit looking to the south west showing gas connection pipe to digester No.3

A solids feeding unit was positioned on top of digester No. 1 & 2 and was used to introduce substrates such as fruit, vegetables, straw, grass and hay (Fig. 5). Solids could be added directly to the top of either or both digesters 1 and 2 via screw threads.

Figure 5 – Double end solids feeding unit with screw thread feeds to Digesters 1 and 2

It is noted that the plant would not be compliant with ABP Regulations as they are being implemented for biogas plants in the UK. Although feedstocks are pasteurised the physical layout of the site in terms of lack of segregated clean and dirty areas and lack of separation from other farm activities would not comply with the regulations as they are implemented in the UK. While there were no specific measures being taken to guarantee maximum particle size, the plant operator requires that maximum particle size requirements are met at the location in which the liquid waste streams are generated. Active management of maximum particle size may be required in the UK.

ANAEROBIC DIGESTION STAGE

The plant comprises of three primary and secondary digestion tanks of concrete construction with a total volume of 2,800 m^3 (Figs. 6-8). It is understood that these tanks were constructed in 1996 and comprised the original primary and secondary digesters and slurry storage tank. As the plant expanded, these have now been converted to primary digestion tanks. These tanks have been landscaped such that they were partially buried. Digesters are insulated with 80 mm of polyurethane / polyisocyanurate foam. Exposed sides of the digesters were clad with wood (Fig. 8 & 9).

Figure 6 – Concrete roof of digester No. 1 with hydraulic lines to mixers and heat exchangers for dissipating excess heat

Figure 7 – Concrete roof of digester No. 2 with yellow gas collection pipes and stainless steel service boxes for hydraulic mixers

Figure 8 – Secondary Digester

Figure 9 – Insulation to roof of secondary digester

Substrates added to the digester typically contain around 7.5% dry matter and reactor temperature is maintained at 39-40 °C using heat generated from the on site CHP plant and the incoming pasteurised substrates. All three primary digesters are mechanically mixed using hydraulically operated mixing blades supplied by UTS. A service box above each mixing unit allows it to be manually lifted through an opening in the digester roof for ease of servicing.

Air is added to the headspace of the primary and secondary digesters in order to encourage the growth of sulphide oxidising bacteria at the liquid / gas interface. The amount of air added is subject to the substrates being treated at the time and is monitored on a continuous basis. Bacteria utilise the H_2S present within the headspace gas therefore reducing H_2S concentrations within the stored biogas to <200 ppm. The concentration of H_2S without the internal desulphurisation is estimated to be at ~ 1,500 ppm. Sulphur deposits were evident through the viewing windows at the top of the digesters at the time of the site visit, however, no significant problems associated with these deposits have been encountered during the operation of the plant. No other nutrients or buffers are added.

ENERGY PRODUCTION

Biogas production is variable depending on the substrates being delivered to site. Information provided at the time of site visit suggests that an average biogas yield of approximately 103 m^3 of biogas per tonne of substrate processed is achieved at the plant which corresponds to around 2.1 Mio m^3 of biogas per annum.

Biogas quality is continuously monitored using a stationary gas analyser. Although gas quality varies according to the substrates being treated, typical gas analysis is summarised in Table 2.

Table 2 – Typical gas analysis

Gas Component	Concentration (%)
CH_4	62
CO_2	36
O_2	0.6
H_2S	185 ppm

Electricity is produced using three CHP plants powered by MAN engines (Fig. 10). The CHP plants are rated at 160 kW, 190 kW and 340 kW giving a total generation capacity in the order of 690 kW. Electricity production at the site is in the order of 4,200 MWh per year. The electrical parasitic demand of the plant is approximately 6-7% leaving approximately 3,920 MWh of electricity for export.

Figure 10 – One of three CHP engines

Heat generated by the CHP engines is used to heat the primary and secondary digesters, the final storage tanks and the pasteurisation unit. Heat generation is approximately 4,500 MWh/yr with a parasitic heat use within the plant of approximately 25%. Surplus heat is used to heat the farm buildings and living quarters (600 m³) adjacent to the plant.

DIGESTATE

Digestate is stored within two above ground digestate storage tank. The first digestate holding tank (Fig. 11) has a volume of 3,600 m³ and the second digestate holding tank (Fig. 12) has a volume of 5,400 m^3. These above ground tanks are of concrete construction, insulated with 80 mm of extruded polystyrene and clad with box profile plastic coated metal. The first digestate holding tank is heated and both tanks are mechanically mixed and incorporate head space gas storage under a flexible centrally supported membrane roof. Gas generated within the digesters is also collected and stored within the headspace of the digestate storage tanks.

Figure 11 – First digestate storage tank with flexible membrane roof, yellow gas collection pipe and service box for mechanical mixer

Figure 12 – Digestate storage tank with flexible membrane roof and mechanical mixing

Digestate is stored within the holding tanks for 180 days. Digestate production is in excess for the requirement of the Pellmeyer farm alone, and therefore adjacent farmers utilise the digestate produced at the biogas plant as a source of nutrients. Approximately 25% of the digestate is used on the operators own land, with 75% being utilised by others. At the time of the visit, no charge was levied for the utilisation of the digestate. Specialist local agricultural contracting companies were utilised in order to provide the necessary plant and logistics required to spread the digestate within the relatively short timeframe where weather and crop conditions are favourable. The usual method of bringing the digestate to land is with the dribble bar hose applicator.

The crops grown on the lands fertilized with the digestate are maize, wheat, winter barley and hay. The yield of the harvests has not changed since digestates have been applied to land, but the operator has noted that the soil condition has been improved with the use of digestate. With the exception of some nitrogen, no additional fertilizer had to be purchased.

The plant operator has indicated that typical nutrient content of the digestate is as indicated in Table 3.

Table 3 – Typical Nutrient Content of 1 m^3 Digestate Produced at Pellmeyer Biogas Plant

	% (Dry Matter)	% (Fresh Matter)
Dry Matter	3.67	
Organic Dry Matter	2.74	
N	12.4	0.5
P_2O_5	4.48	0.18
K_2O	3.8	0.15
MgO	4.1	0.17

The digestate is not separated or treated in any way prior to spreading. Land application rates are calculated on the basis of chemical analysis of the digestate, nutrient requirements of the crop and analysis of the soil.

WATER AND WASTEWATER TREATMENT

No fresh water is added to the digestion process primarily because many of the feedstocks have a relatively high water content and no further water addition is therefore required. There are no water or wastewater treatment processes undertaken at the plant.

COSTS AND ECONOMICS

Information regarding the cost and economics of the plant were not available at the time of site visit. Capital costs are somewhat difficult to determine as the plant was developed in several stages between 1996 and 2004 with different organisations being used for the design and construction of the plant. UTS, who undertook the design of the plant and provided pumps and mixing technologies indicated that an equivalent plant today would cost in the order of 3 Million Euro.

Similarly, the income generated by the plant is not clear. Gate fees for the organic wastes delivered to site vary according to individual negotiations with waste generators.

The income generated from the sale of electricity generated at the plant had been subject to the feed in tariff agreed at the commissioning of the plant in 1996. It is now operating according to the EEG 2000. An approximate price achieved per kWh of electricity generated is 0.10 Euro / kWh.

LESSONS LEARNED

In operating and expanding the plant since 1996 significant experience has been gained by Mr Pellmeyer. This is especially the case as inputs into the plant can vary greatly. For example, when input materials that are high in carbohydrates and proteins are being treated, it may be beneficial to add fibrous material like straw in order to avoid foaming.

The support of specialist companies is also utilised in order to address any specific technical or biological problems associated with the plant.

The level of daily supervision of the plant is estimated to be an average of 3.5 hours per day which includes loading, inspection and maintenance work.

The operator has to comply with the health and safety regulations from the Accident Prevention & Insurance Association in conjunction with the German Biogas Association.

B. ENERGY CROP ANAEROBIC DIGESTION PLANT

INTRODUCTION

In 2006, a second anaerobic digestion plant was commissioned at the Pellmeyer farm. The plant is owned and operated by Biomasse Kraftwerk Eggertshofen GmbH and Co. The rationale behind this plant was to take advantage of the high tariffs offered by the German government for the generation of renewable energy using energy crops. The plant would therefore utilise energy crops grown on the 150 ha Pellmeyer farm along with other biomass sourced locally. Electricity generated would be exported to the grid. Heat would be utilised again for drying of woodchips. The plant was located some 700 m to the south of the farm house and waste treatment AD plant, and is located adjacent to a small composting plant (also owned by the Pellmeyer family). Digestate produced at the new energy crop fed plant are utilised on adjacent properties as previously described. The plant was designed by UTS who also supplied various technology elements such as mixers, pumps and pumping stations.

Feedstock for the plant comprises approximately 9,000 t/a of maize silage (Fig. 13) which is grown on site at the Pellmeyer farm. A further 3,600 t/a of grass is imported to the plant sourced from the adjacent farms. This is also silaged (Fig. 14) in order to provide a year round supply.

Figure 13 – Maize silage feedstock

Figure 14 – Grass silage feedstock

PLANT DESCRIPTION

PRE-TREATMENT AT PELLMEYER BIOGAS PLANT (ENERGY CROPS)

Other than the silaging of energy crops, feedstocks for the plant do not require any significant pre-treatment. Maize and grass silage is stored in the open (uncovered) on hardstanding areas to the north of the fermenters. A front loader is used to transport silage from the clamp to an automated solids feeder (Fig. 15) which transfers feedstock to the two primary digesters via a conveyer belt system (Fig. 16). Feedstocks are added to the primary digesters at a rate of approximately 25 t maize silage per day and 10 t grass silage per day.

Figure 15 – Solids feeder unit with digestate storage tank visible to rear

Figure 16 – Solids feeder discharging silage to conveyer

ANAEROBIC DIGESTION STAGE

The plant comprises of two primary digesters (Fig. 17) each with a volume of 1,527 m^3 (i.e. 3054 m^3 total volume). These are above ground tanks of concrete construction, insulated with 80 mm of extruded polystyrene and externally clad with plastic coated box section cladding. Primary fermenters are internally heated using stainless steel heating rings.

The plant also includes a secondary digester (Fig. 18) with a volume of 2,281 m^3. Construction is as per the primary digesters described above.

Figure 17 – Conveyer leading to one of two primary digesters (green). Adjacent concrete structure is the central control room housing pumping and heating manifolds and monitoring and control equipment.

Figure 18 – General site layout showing one of two primary digesters to the far left, secondary fermenter and solids feeder in the centre and digestate storage to the right.

Digester temperatures are maintained at 39-40°C using heat from the CHP engines. Feedstocks entering the digesters would be anticipated to contain approximately 33% Total Solids of which 95% comprise Volatile Solids. The designed loading rate for the plant is 3 kg VS/m^3.d. Fermenters are mechanically mixed using hydraulically powered mixers supplied by UTS (3 No. per fermenter). Retention time in the primary and secondary digesters totals 70-80 days.

Biogas is desulphurised through the addition of a controlled amount of air into primary and secondary digesters to encourage the growth of sulphide oxidising bacteria at the gas / substrate interface. Air is added subject to the measured H_2S concentration with the aim of reducing concentrations to <100 ppm.

Nutrients are added at a rate of 400 ml / d (a mix of trace elements, some salts and iron).

Figure 20 – Hydraulic compressors located in central control room with hydraulic lines which link to hydraulic mixing motors in digesters.

Figure 21 – Heating manifold located in central control room which distributes heated water to digesters.

A central control room located between the primary and secondary digesters houses the central pumping station which controls the movement of substrates between the digesters. The control room also houses the hydraulic compressors (Fig. 20) which provide power to the hydraulic mixing systems, the heating manifold (Fig. 21) which distributes heat to the various digesters and the CPU control system which monitors the plant operation. Parameters monitored include temperature, liquid level, gas pressure, gas quality values and CHP performance.

ENERGY PRODUCTION

Biogas is produced at the plant at a rate of approximately 220 m^3 biogas per tonne of substrate treated. This corresponds to an annual biogas production of approximately 2,810,949 m^3/yr. Biogas quality is constantly monitored at the plant and average CH_4 concentrations within the biogas is 53%.

Biogas is collected from the primary, secondary and digestate storage tanks and passed via gas cooling pipework to reduce moisture content. Gas condensate is collected within a sump.

Electricity is generated using two 370 kW CHP plants (Fig. 22 & 23) driven by MAN gas powered engines, giving a total generation capacity of 840 kW. Electrical energy production for the plant is 5,800 MWh / yr with an internal parasitic demand of approximately 10% (incl. CHP usage). Thermal energy production for the plant is 5,000 MWh / yr with an internal parasitic demand of approximately 25%. Any excess thermal energy is either used to dry wood chips or vented to atmosphere via a heat exchangers located at the CHP building.

Figures 22 and 23 – CHP engines used at the energy crop plant

DIGESTATE

Digestate is stored within an above ground concrete tank with a volume of 5,609 m^3 (Fig. 18). This tank has also been insulated and has the ability to be heated, although this is not undertaken during the normal operation of the plant. The digestate storage tank also includes a flexible membrane roof which acts as the biogas storage for the plant. Contents of the digestate storage tank are mixed.

As per the waste treatment AD plant the digestate produced is utilised on adjacent farms to grow more energy crops, put onto land is with the dribble bar hose applicator. The digestate is stored for 180 days. As with the digestate from the waste plant crop yields have remained unchanged since applying digestate to land, although improvements in the soil condition have been noted.

A typical analysis of the digestate is as follows:

	% (Dry Matter)	**% (Fresh Matter)**
Dry Matter	5.8	
N		0.30
NH_4		0.19
P_2O_5		0.15
K_2O		0.40

WATER AND WASTEWATER TREATMENT

The plant does not utilise any fresh water within the digestion process. Site surface waters and runoff, particularly from the silage storage areas, are collected within a central sump and then stored within an above ground concrete tank with a storage volume of 923 m^3. Via the central pumping station this water is then spread to the adjacent fields, it is not used in the digestion process.

COSTS AND ECONOMICS

Capital costs for the plant are understood to have been approximately 3.0 million Euro.

Tariffs for the energy generated at the plant are per the EEG2004. The tariffs generated at the plant are therefore summarised in Table 4 below:

Table 4 – Tariffs According to EEG 2004

EEG 2004 Tariff Element	**Cent / kWh_e (or kWh_{th} if stated)**
Basic Compensation (up to 150 kW)	11.5
Basic Compensation (150-500 kW)	9.9
Basic Compensation (over 500 kW)	8.9
Energy Crop Bonus	6.0
Technology Bonus	2.0
Heat Utilisation Bonus	2.0 kWh_{th}
Degression	1.5%

Each kWh of electricity generated at the site would therefore attract a total tariff of 16.9 Euro Cents giving a gross income of approximately 980,200 Euros per year, and each kWh of heat would attract a further 2 Euro Cents (multiplied with the CHP coefficient) giving a gross income of 120,000 Euros per year.

DISCUSSION AND CONCLUSIONS

The case study provides an overview of how the biogas industry has evolved in Germany. Initial development of the industry in the mid 1990's was focussed on the treatment of organic wastes, primarily driven by the requirement to meet landfill diversion targets. The treatment capacity of the small plant developed at the Pellmeyer farm was quickly exceeded. Due to the flexibility of the process and the design of the plant, capacity could be increased by converting secondary fermenter and digestate storage tanks into primary digesters, and additional secondary fermenter and digestate storage capacity added.

As landfill diversion targets were met within Germany, the focus for biogas plants shifted from one of providing treatment capacity for organic wastes towards the generation of renewable energy using energy crops. Since 2000 the feed in tariffs associated with the EEG has allowed the development of small to medium scale, farm based AD plants, and since this time thousands of such plants have been constructed across Germany. As such the energy crop based plant located at the Pellmeyer farm described above is typical of the majority of AD plants present in Germany.

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