Greimel Biogas Plants, Grüntegernbach, Bavaria, Germany

Case studies were produced following site visits undertaken during 2009 and information is therefore relevant for operating conditions at the time of visit only. Some plants now operate under different conditions to those specified within the case studies.

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CASE STUDY

Greimel Biogas Plants, Grüntegernbach, Bavaria, Germany

The biogas plants located at the Greimel farm, Grüntegernbach, Bavaria 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 Greimel family own and operate two anaerobic digestion plants, both located on their farm which is located to the north east 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, primarily whole crop maize silage. The newer energy crop plant is of an innovative design which has a smaller footprint than conventional plant designs.

A. ORGANIC WASTE TREATMENT PLANT

INTRODUCTION

The Greimel family initially developed an anaerobic digestion facility at their farm in the late 1990's, with the plant being fully commissioned in 2001. The farm is located on the outskirts of the village of Grüntegernbach approximately 45 km to the north east of Munich. Both the organic waste treatment plant and the energy crop plant are located in an area adjacent to the farm and accommodation buildings. Whilst the biogas operations are principally contained within this area it was noted that there is no physical separation between the biogas plants themselves, or between the biogas plants and the other farm buildings.

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 commercial and industrial food manufacturers, distributors and outlets. It is understood that substrates treated at the plant primarily comprise of fats, greases, sludges and bread waste. The plant treats approximately 12,000 tonnes of organic waste / food waste per year (34 t/d).

PLANT DESCRIPTION

PRE-TREATMENT AT GREIMEL BIOGAS PLANT (WASTE)

The majority of liquid substrates are delivered to a hopper (Fig. 1) which leads to a concrete below ground reception and mixing pit. When large volumes of solid material is received, this can be temporarily stored in an enclosed waste reception building (Fig. 2) before being added to the fermenter as required. Solid feedstocks can also be added directly to one of the primary digesters by means of a solids feeding hopper located above the digester.

Figure 1 – Liquid greases being delivered to the hopper leading into the below ground reception tank

Figure 2 – Waste reception building that can be used to receive solid wastes (empty at time of visit)

Following the storage / mixing tank, substrates are pumped to a pre digestion pasteurisation unit (Fig. 3). The pasteurisation plant comprises a longitudinal continuous flow pipe where substrate is heated to at least 70°C with a retention time of at least 1 hour. It was noted that at the time of visit the plant was operating at a temperature of 80°C. Temperature within the pasteurisation unit is continuously monitored.

Figure 3 – The insulated pipework running from bottom right to the centre of the image is the longitudinal continuous flow pasteurisation plant

It is noted that while the plant meets the local requirements, it would not be compliant with ABP Regulations as they are being implemented for biogas plants in the UK. Specifically, 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 be acceptable in the UK. While there were no specific measures being taken on site to guarantee maximum particle size, the plant operator requires that maximum particle size requirements are met at the location the liquid waste streams are generated (e.g. slaughterhouse). It is likely that active management of maximum particle size would be required in the UK. It is not clear whether a continuous flow pasteurisation process would be acceptable under UK ABPR Regulations.

ANAEROBIC DIGESTION STAGE

The original plant, commissioned in 2001 comprised of a series of below ground concrete tanks comprising of a two primary digesters, secondary digester and digestate and gas storage tank. The configuration of the plant has changed several times as the biogas operations at the site have developed over the past fifteen years. The plant currently comprises of two below ground primary digestion tanks (Fig 4.) (one @ 769 m³, one @ 520 m³ reactor volume), a below ground secondary digester (1,000 m³ reactor volume) and a final digestate storage with 4,000 m³.

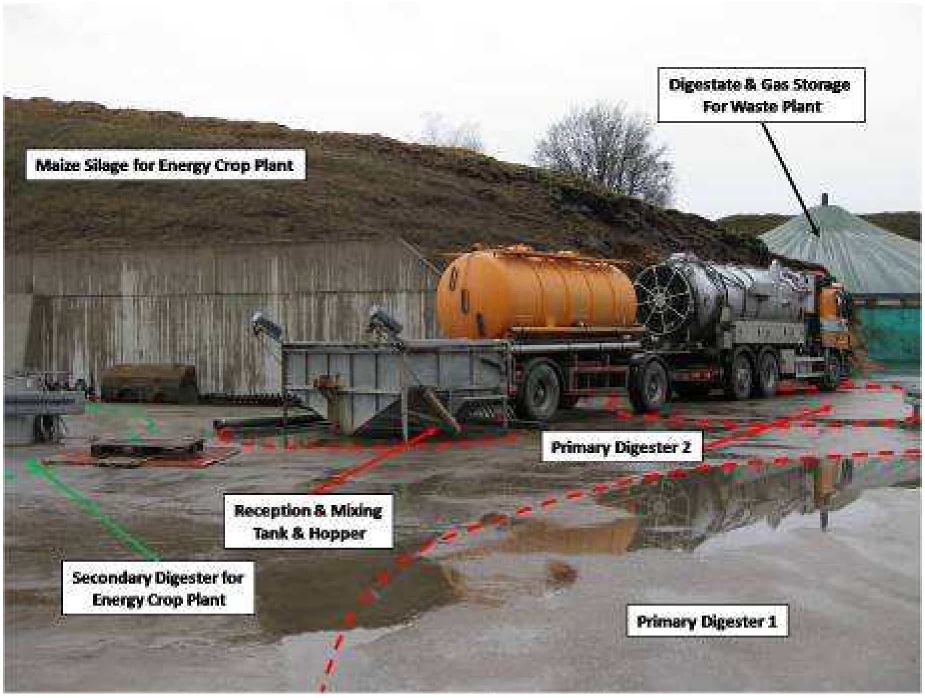

Figure 4 – Layout of Waste Treatment plant at the Greimel Biogas Plant

Substrates added to the digester typically contain around 7% 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. 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.

No nutrients or any other buffers or chemicals are added to the substrates during the digestion process.

Air is added to the headspace of the primary digesters in order to encourage the growth of sulphide oxidising bacteria at the liquid / gas interface. These bacteria utilise the H_2S present within the headspace gas therefore reducing H_2S concentrations within the stored biogas to <200 ppm.

Gas storage is provided in the digestate storage tank which incorporates a flexible membrane roof.

ENERGY PRODUCTION

Gas production is variable according to the substrates being delivered to site. Information provided at the time of site visit suggests that an average gas yield of approximately 250 m^3 / hr which corresponds to around 2.15 million m^3 of biogas per annum.

Electricity is produced using two CHP plants powered by MAN engines. The CHP plants are rated at 150kW and 350 kW giving a total generation capacity in the order of 500 kW. Electricity production at the site is in the order of 4,000 MWh per year. The electrical parasitic demand of the plant is approximately 6-7% leaving approximately 3,720 MWh of electricity for export.

Heat generated by the CHP engines is used to heat the primary and secondary digesters, the pasteurisation unit and heat the farm buildings adjacent to the plant. Heat is also used to dry wood that is sold for domestic heating purposes. Depending on the substrates being treated, heat generation is approximately 4,500 MWh/yr with a parasitic heat use within the plant of approximately 25%.

DIGESTATE

Digestate is stored within a 4,000 m^3 above ground digestate storage tank (Fig. 5). This is of concrete construction and is covered with a flexible membrane to allow storage of gas. Although not directly measured it is estimated that <10% of the total volume of biogas generated is emitted from the digestate within the store. Digestate within the storage tank is mixed to avoid settlement and the formation of layers. There is no additional treatment or separation or dewatering of the digestate post digestion and storage.

Digestate is tankered and spread to the fields of Greimel and others which are utilised for maize, wheat, rye and grass production. Spreading of digestate is limited by standard EU rules for spreading of slurry and application of fertilisers to land, and maximum nitrogen levels for the soil have been set (210 g/m^2 for Greimel fields). Digestate is therefore analysed approximately four times per year, and soils are similarly monitored in order to calculate appropriate application rates.

A typical analysis of the Greimel digestate from the organic waste plant (feed-stock at the time: 45% food waste, 30% fats and greases, 25% slaughterhouse waste) is as follows (analysis from 16.09.09):

- Dry matter 3.9%
- Inert particles > 2 mm: 0.01% of DM (here: metal)
- Salinity: 21.6 g KCl/l
- pH value: 8.0
- Total nitrogen: 0.56% of FM / 14.20% of DM
- NH_4-N: 0.45% of FM / 12.00% of DM
- P_2O_5: 0.21% of FM / 5.34% of DM
- K_2O: 0.3% of FM / 7.70% of DM
- MgO: 0.03% of FM / 0.82% of DM
- CaO: 0.21% of FM / 5.49% of DM
- Organic substances: 2.5% of FM / 63.5% of DM
- Germinable seeds and plants: 0/l
- Salmonella: 0 / 50 g

Since Greimel (and some of his neighbours) are using the digestate as fertilizer, they have reduced the use of mineral fertilizer to an absolute minimum. The digestate of the organic waste plant in particular has a high fertilizer value. Greimel has also noticed a positive effect for the soil due to the structural material still present in the digestate.

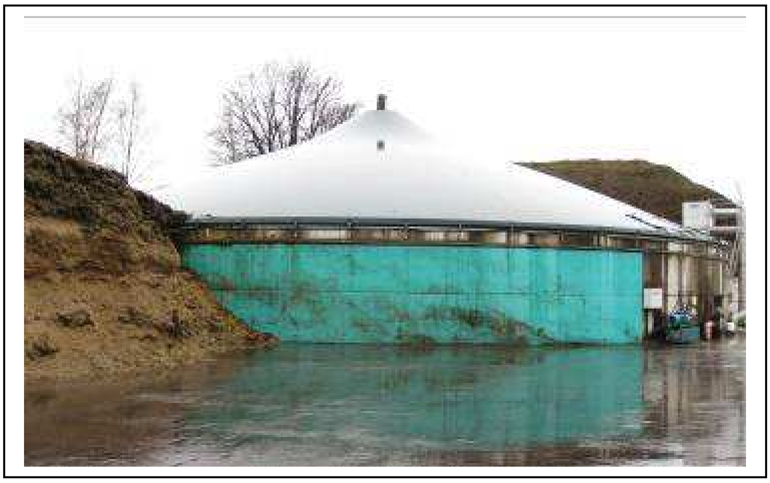

Figure 5 – Digestate storage tank for waste treatment plant with adjacent maize silage for energy crop plant

WATER AND WASTEWATER TREATMENT

Other than a limited amount of washdown water, 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. As such 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 2001 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 3-4 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. According to Greimel, the average gate fee for food wastes received at the site equalizes to 0 Euro / tonne.

The income generated from the sale of electricity generated at the plant will be subject to the feed in tariff agreed at the commissioning of the plant in 2001. This has been modified since the plant was initially established (acc. to the EEG 2004). An approximate price achieved per kWh of electricity generated is 0.11-0.12 Euro / kWh (excl. heat usage bonus).

Similarly any tariff reward associated with the utilisation of heat generated at the site will have been initially set in 2001 at a level of 0.02 Euro / kWh. Heat generated at the plant also offsets the use of other forms of heat energy and therefore also provides a further saving. The heat is also used to dry woodchips which are then sold for domestic heating use, providing the process heat for the energy crop plant, and the heating of the farmhouse and workshop. It can therefore be seen that the effective utilisation of the heat generated at the plant contributes significantly to the economic viability of the plant and allows other business opportunities to be exploited.

B. ENERGY CROP ANAEROBIC DIGESTION PLANT

INTRODUCTION

In 2008, a second anaerobic digestion plant was commissioned at the Greimel farm. The rationale behind this plant is to take advantage of the high tariffs offered by the German government for the generation of renewable energy using energy crops. The plant utilises energy crops grown on the Greimel and neighbouring farms as well as locally sourced chicken manure to generate electricity which is exported to the grid. Heat is utilised for drying of woodchips and provides thermal energy to a district heating network (~ 1.5 Million kWh_{th}/a) with private and industrial users. The plant is located within the same area of the farm that is occupied by the waste processing AD facility, but due to the limited space available it utilises a novel ‘ring in ring’ design described below. Digestate produce at the plant is utilised on the Greimel farm and neighbouring properties as a nutrient source. 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 12,000 t/a of biomass, mainly maize silage and min. 30% of chicken manure.

PLANT DESCRIPTION

PRE-TREATMENT AT GREIMEL BIOGAS PLANT (ENERGY CROP)

Other than the silaging of energy crops, feedstocks for the plant do not require any significant pre-treatment (the average particle size is 5 mm with a maximum of 10 mm). Maize and silage is stored in the open (uncovered) clamps (Fig. 6) and 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. 7). Feedstocks are added to the primary digester by the automated feeder approximately every hour. Feedstocks are added at a rate of approximately 1.5 tonnes per hour.

Figure 6 – Maize silage within clamp. Outer ring of primary digester with mixer service box in foreground

Figure 7 – Solids feeding unit which introduced feedstock into the primary digester via a screw thread

ANAEROBIC DIGESTION STAGE

The plant incorporates an innovative 'ring in ring' design where the digestate and gas storage tank is located within the circumference of the primary digester. This allows a smaller footprint for the plant.

The plant comprises of a below ground primary digester which is 38 m in diameter and 6.0 m deep with a total volume of 4,397 m^3. The remaining volume within the primary digester is taken up by part of the digestate storage tank (Fig. 8 & 9). The digester is of concrete construction with 80 mm of extruded polystyrene insulation. The primary digester is internally heated using stainless steel heating pipes containing hot water heated by the CHP plant. Reactor temperature is maintained at 39-40 °C. The primary digester is mixed using 4 No. electrical mechanical mixers. These can be accessed via service boxes positioned on the roof of the primary digester (i.e. at ground level). Feedstocks entering the digesters would be anticipated to contain approximately 30% Total Solids of which 95% comprise Volatile Solids. The plant is designed to operate at a volatile solids loading rate of 3 kg VS m^3/d. Hydraulic retention time within the plant (i.e. within the primary and secondary digester and allowing for recirculation) is ~ 70-80 days.

Figure 8 & 9 – Top of primary digester (Outer ring) with mixer service box.
Above ground section of digestate & gas storage (Inner ring) also visible.

The secondary digester is located adjacent to the primary digester (Fig. 10). It comprises a below ground concrete tank 22 m in diameter and 6.0 m deep with a total volume of 2,280 m^3. This tank was originally the primary digester of the waste processing plant described above before the site was re-configured to incorporate the energy crop plant. The secondary fermenter is mixed using two electrically powered mechanical mixers accessed via service boxes located on the digester roof (i.e. at ground level).

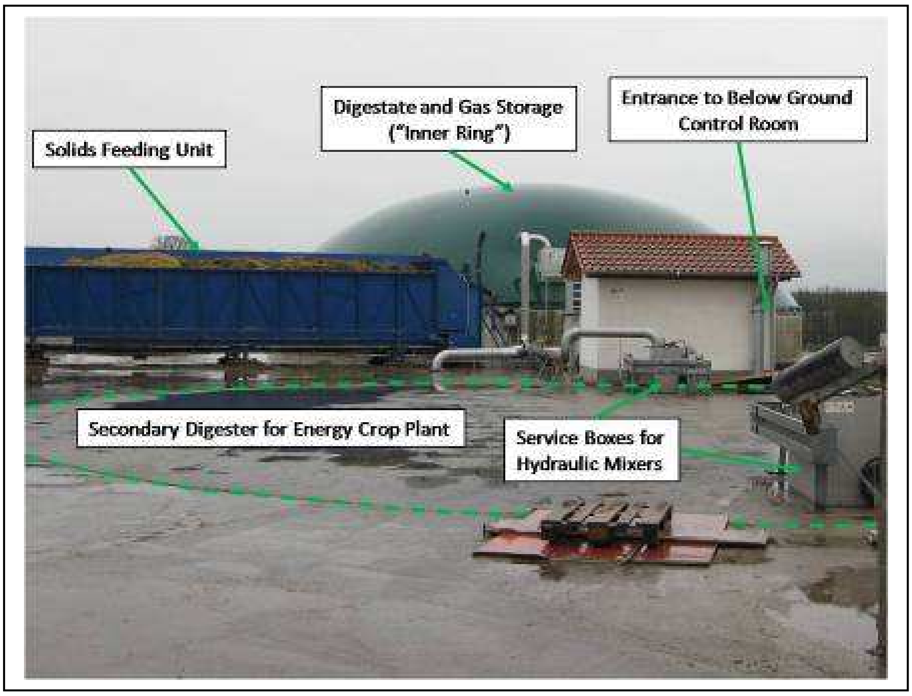

Figure 10 – Secondary digester of energy crop plant in foreground. Solids feeder and entrance to control room in centre ground. Digestate and gas storage tank visible in background

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.

A multi level below ground control room is located between the primary and secondary digesters. This houses the central pumping station which controls the movement of substrates between the digesters (Fig. 11). The control room also houses the heating manifold which distributes heat to the various digesters. The whole process is monitored centrally from a control room located adjacent to the solids waste reception area. This primarily uses visual interfaces which are controlled on a touch screen (Fig. 12).

Figure 11 – Central pumping station which controls the flow of substrate between digesters and stores

Figure 12 – One of the visual interfaces of the central control and monitoring software. Touch screen control allows various operational parameters to be changed and monitored

ENERGY PRODUCTION

Biogas is produced at the plant at a rate of approximately 300 m^3 / hr. This corresponds to an annual gas production of approximately 2,630,000 m^3 / yr.

Gas quality is continuously monitored using a stationary gas analyser (Fig. 13). Although gas quality varies according to the substrates being treated, typical gas analysis at the time of visit was as in Table 1.

Table 1 – Typical gas analysis

Gas Component	Concentration (%)
CH_4	57*
CO_2	-
O_2	0
H_2S	50 ppm

* Gas quality analyser was indicating 57% CH_4 content although anticipated concentration is generally 52-53%

Electricity is generated using two engines (700 kW and 300 kW) giving a total generating capacity of 1 MW. Electrical energy production for the plant is approximately 8,000 MWh / yr with an internal parasitic demand of approximately 5%. Thermal energy production for the plant is 9,000 MWh / yr with an internal parasitic demand of approximately 10-15%. Heat generated at the plant is used to dry wood (Fig. 14) which is sold for domestic heating purposes, and to provide thermal energy for a district heating system for 44 heat users (private and industry).

Fig 13 – Stationary gas analyser monitoring the quality of gas produced by the digestion process prior to combustion within the CHP units

Fig 14 – The large metal duct on the right of the image directs heat to the covered containers for the drying of wood

DIGESTATE

Digestate is stored within the inner ring of the 'ring in ring' arrangement. This comprises a circular concrete tank with a diameter of 22.0 m. The base of the tank is 6.24 m below ground (i.e. the same as the primary digester) but the overall wall height of the tank is 8.31 m such that 2.07 m of tank wall is visible above ground (Fig. 15). The tank is capped with a flexible membrane quarter dome roof where up to 600 m^3 of biogas is stored (Fig. 15 & 16). Contents of the digestate storage tank are mixed using two electrically operated mechanical mixers.

Fig 15 – The above ground section of the "Inner Ring" digestate store with quarter dome gas storage above. The stainless steel box is the service box for the internal hydraulic mixer, and the stainless steel

Fig 16 – The gas storage dome represents the only visible indication of the biogas plant from the public highway. The remainder of the plant has been landscaped to minimise visual impact pipe is for gas extraction

As per the waste treatment AD plant the digestate produced is utilised on the Greimel farm to grow more energy crops. Surplus digestate is utilised on neighbouring farms with no cost associated with the sale of the digestate.

A typical analysis of the Greimel digestate from the energy crop plant (feed-stock at the time: 100% energy crops (analysis from 16.09.09)) is as follows:

- Dry matter 13.4%
- Total nitrogen: 0.95% of FM / 7.06% of DM
- NH_4-N: 5,960 mg/l FM
- P_2O_5: 0.49% of FM / 3.63% of DM
- K_2O: 0.66% of FM / 4.93% of DM
- MgO: 0.15% of FM / 1.13% of DM
- Organic substances: 10.2% of FM / 76% of DM
- Cu: 6.16 mg/kg FM / 46.0 mg/kg DM
- Zn: 41.8 mg/kg FM / 312.0 mg/kg DM

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 pumped to the organic waste AD plant.

COSTS AND ECONOMICS

Capital costs for the plant are understood to have been approximately 3.5 million Euro.

Tariffs for the energy generated at the plant are per the EEG2009. The tariffs generated at the plant are therefore summarised in Table 4 below:

Table 4 – Tariffs According to EEG 2009 (relevant for the Greimel plant)

EEG 2009 Tariff Element	Cent / kWh_e (or kWh_{th} if stated)
Basic Compensation (up to 150 kW)	11.67
Basic Compensation (150-500 kW)	9.18
Basic Compensation (over 500 kW)	8.25
Clean Air Bonus (up to 500 kW)	1.0
Energy Crop Bonus	7.0 up to 150 kW 4.0 from 500 kW up to 5 MW
Manure Bonus	4.0 up to 150 kW 1.0 from 150 up to 500 kW
Heat Utilisation Bonus	3.0 kWh_{th}
Degression	1.0%

Each kWh of electricity generated at the site would therefore attract a total tariff of 21-22 Euro Cents giving a gross income of approximately 1,700,000 Euros per year, and each kWh of heat would attract a further 3 Euro Cents giving a potential gross income of 270,000 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. As the use of energy crops as a feedstock become more financially attractive, the waste treatment plant could be re-engineered to allow the primary digester to form part of a new energy crop digestion plant. An innovative 'ring in ring' design allowed the remainder of the energy crop plant to be developed in a limited area with little visual impact.

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 Greimel farm described above is typical of the majority of AD plants present in Germany.

ACKNOWLEDGEMENTS

Information presented within this case study was gathered during a site visit to the plant in December 2009 with subsequent correspondence between the plant designer and owner.

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