SYSTEMIC Groot Zevert Vergisting (Beltrum, the Netherlands)

A short introduction to GZV

Groot Zevert Vergisting (GZV; Figure 1), located in Beltrum, the Netherlands, started its biogas production in 2004. The plant has a processing capacity of 135 kilotonnes (kt) of feedstock through mesophilic digestion per year. In 2019, GZV started with the production of biobased fertilisers and purified water from digestate. The aim is to offer a sustainable solution for the manure surplus in the region.

Drivers for Nutrient Recycling

In the Netherlands, manure production by livestock exceeds the amount that can be applied on agricultural land within the application rate limits for nitrogen (N) and phosphorus (P). The surplus of manure, about 31% of the produced amount, is exported, mostly to Germany. The transport of large volumes of manure over distances of 200–400 km is costly. Consequently, farmers are faced with high costs for manure disposal (circa €22,- per tonne of pig manure (price level 2021).

Table 1. Technical information of the biogas plant.

Characteristic	
Year of construction	2004
Maximum power output	6.5 MW_e
Digester volume	15 000 m^3
Digestion type	Mesophilic digestion
Nutrient recovery and reuse (NRR) systems	GENIUS: decanter centrifuges, microfiltration, reverse osmosis RePeat: acid leaching of phosphorus and precipitation

Figure 1. Aerial photo of the demonstration plant Groot Zevert Vergisting.

As a solution for the manure surplus in the region, GZV decided to invest in nutrient recovery and reuse (NRR) systems to process digestate into valuable biobased fertilisers:

- Reverse osmosis (RO) concentrate to be used within the region;
- Purified water which is allowed to be discharged in a nearby river;
- Low-P soil improver;
- Precipitated P salts to be used as raw material to produce fertilisers by fertiliser producing companies.

These biobased fertilisers can be used within the region and some of them can be exported over long distances against low costs as their volumes are reduced by processing.

Feedstocks

In 2018, the plant's co-digestion capacity increased from 102 to 135 kt feedstock per year. However, not the entire capacity was used in 2020 (Table 2).

Animal manure was the major substrate (76% of the feedstock mass) but the co-substrates are responsible for circa 77% of the biogas production. Pig manure was collected from about 55 pig farms within a distance of 25 km of the plant.

Table 2. Origin of GVZ's digester feedstock (2020).

Type	Origin	Mass (kt)
Manure	Pig slurry	60
	Dairy cattle slurry	2
	Paunch manure	9
Co-substrates	Residues from agro- and food industry	19
	Glycerine	3
Total		**93**

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Biogas production

In 2020 nearly 10 Mio Nm^3 of biogas were produced (Table 3). About 72% of the produced biogas was transported through a 5 km-long pipeline to a dairy processing factory. The remaining 28% of the produced biogas was on-site converted into electrical energy and heat.

Table 3. Biogas production and average biogas composition before purification for the year 2020.

Parameter	2020
CH_4 (% v/v)	55
CO_2 (% v/v)	43
H_2S (ppm)	1,000–2,000
O_2 (% v/v)	0.2
Total biogas production (Nm^3)	9.7 Mio
Biogas per tonne of feedstock ($Nm^3\ t^{-1}$)	104

Nutrient Recovery and Reuse (NRR) process

The NRR process consist of two independent NRR systems. In the GENIUS system, digestate is first separated into a solid (SF) and a liquid fraction (LF) of digestate by a decanter centrifuge. The SF of digestate is subsequently processed by the RePeat system.

The RePeat system separates the P from the organic matter through leaching with water and sulphuric acid. Two sequential leaching steps remove in total 70–90% of the P present in the ingoing digestate, thereby producing a low-P soil improver. The dissolved P subsequently precipitates through addition of lime ($Ca(OH)_2$) or magnesium hydroxide ($Mg(OH)_2$), thereby producing precipitated P salts. Part of the sulphate, which was added as sulphuric acid, precipitates with calcium as gypsum. The gypsum partly ends up in precipitated P salts and partly in a separated organic gypsum-rich sludge which can be used as fertiliser. Water is continuously reused within the process, thereby preventing the creation of a waste stream.

The LF of digestate is further processed by the rest of the GENIUS system: a second decanter centrifuge, a microfiltration (MF) unit, two RO units placed in series and ion exchangers. The following end products are thereby produced: RO concentrate, rich in N and potassium (K), purified water and a blend of the SF of the second decanter centrifuge and MF concentrate.

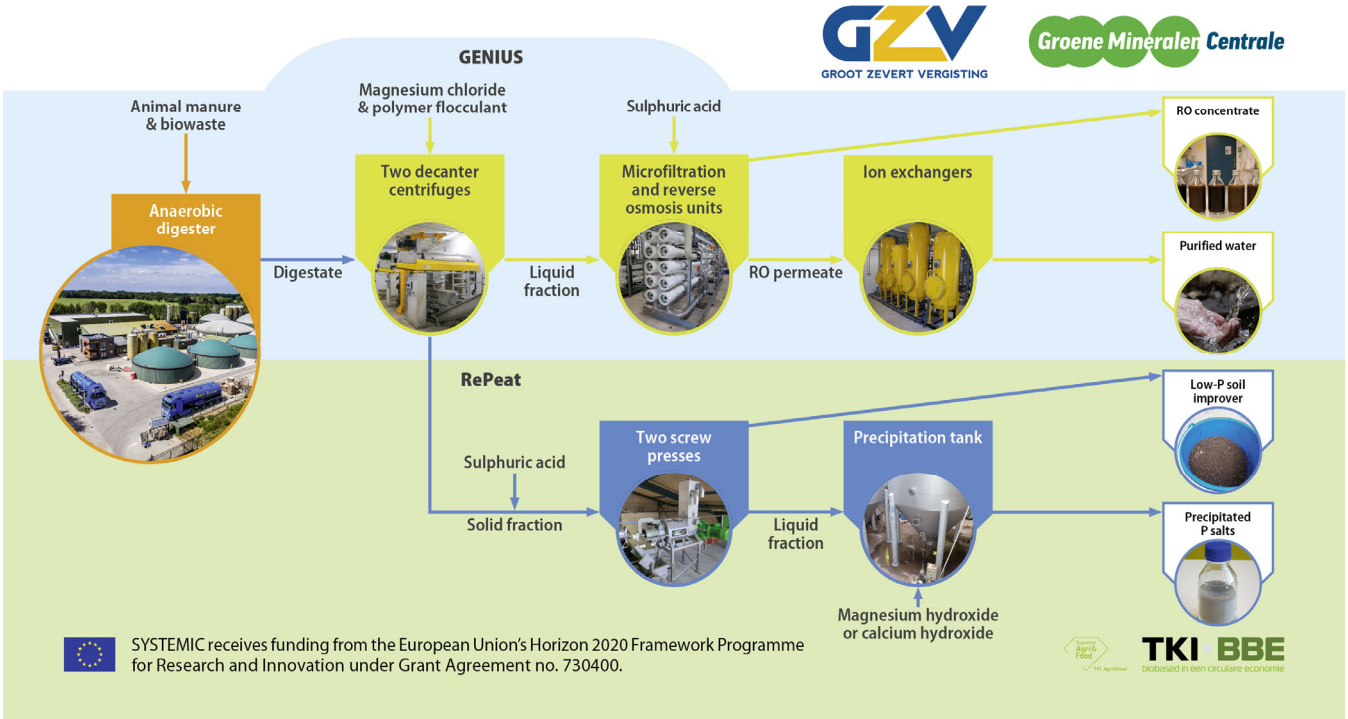

Figure 2. Simplified process flow diagram of Groot Zevert Vergisting's nutrient recovery and reuse systems.

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Status of construction

Construction of the RePeat system was finalised in early 2020 and it has since then been used to produce low-P soil improver on demand. It has a processing capacity of two tonnes of SF of digestate per hour. Further improvements to reduce consumption of sulphuric acid and increase the dry matter content of the precipitated P salts are still foreseen. The GENIUS system has been in operation since January 2019. In the years thereafter, GZV and Nijhuis Industries have further improved the achieved separation efficiencies of the system. The performance of both the RePeat and GENIUS systems was monitored by Wageningen Environmental Research.

Products and market

The produced RO concentrate has an average N content of 6.9 g N kg^{-1} of which >90% is NH_4-N, thereby meeting the proposed RENURE criteria. The RO concentrate is blended with other liquid N fertilisers (urea and ammonium sulphate solution) and used as an alternative for synthetic fertilisers on arable land and grass land in the region of the plant. About 20% of the digestate mass is converted into purified water, which can be discharged to surface water. In 2019, the SF of digestate was trucked to Germany. From 2020 onwards it is processed into a low-P soil improver and precipitated P salts. The low-P soil improver is applied on sandy soils in the region of the plant. GZV also investigates its use as an alternative for peat in potting soil and mushroom substrate. The precipitated P salts are yet recovered as a sludge which needs further dewatering and drying after which it can be used as a raw material in the fertiliser industry.

Table 4. Composition of the ingoing digestate and produced end products at Groot Zevert Vergisting (2020 – 2021).

	Digestate	GENIUS			RePeat	
		RO concentrate	Solid fraction of digestate	Purified water	Low-P soil improver	Precipitated P salts[a]
Dry matter (g kg^{-1})	81	37	313	n.a.	284	159
Organic matter (g kg^{-1})	59	14	242	n.a.	252	73
Total N (g kg^{-1})	7.3	8.1	12	0.00028	5.9	6.9
Total P (g kg^{-1})	1.7	0.15	8.9	<0.0001	1.9	8.8
Total K (g kg^{-1})	4.5	7.9	4.6	<0.0004	1.8	2.3
Total S (g kg^{-1})	0.67	1.5	1.9	0.0029	5.8	12

[a] *Precipitated phosphorous salts before further dewatering and drying.*

Economic benefits

Long distance transport of digestate or SF of digestate to Germany is costly. Implementation of the GENIUS and RePeat systems has enabled GZV to dispose of their products to farmers in the region of the plant and to discharge part of the digestate mass, in the form of purified water, to surface water. Thereby GZV saves on costs for transport.

Sustainability goals

GZV is committed to reaching the following targets:

- Production of biogas from animal manure and residues from the agro- and food industry and offering a sustainable disposal solution for the surplus of animal manure in the region.
- Reduction of long-distance transport of digestate and its end products.
- Replacement of synthetic N fertiliser by a biobased mineral fertiliser blend, containing 10–15 g L^{-1} N-NH_4 and 10–15 g L^{-1} K_2O, made from the RO concentrate.
- Replacement of peat in potting soil or in substrate for the growing of mushrooms by the low-P soil improver.

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Monitoring data: total mass flows

Total mass (Figure 3) flows were calculated for the GENIUS system of GZV for the period September 2020 – February 2021. This was done to evaluate the overall performance of the plant and the separation efficiencies of the individual process units. $MgCl_2$ was added to the ingoing digestate to improve separation of P by the first decanter centrifuge. The first decanter centrifuge separated 63% of the ingoing P to the SF of digestate. Together, the first and second decanter centrifuge removed 88% of the P from the ingoing digestate. The MF unit removed 86% of the remaining P as well as 90% of the remaining organic N. This however resulted in a large volume of MF concentrate, a sludge, that was disposed of mixed with the SF of the second decanter centrifuge. The MF permeate was concentrated by a factor 2.0 by the two subsequent RO units placed in series. Half of the produced purified water was reused within the process. Every tonne of ingoing digestate resulted in 15 kg of SF of digestate, 35 kg of sludge (trucked off-site), 31 kg of RO concentrate and 18 kg of discharged/evaporated purified water. Water production was lower than envisaged and production of sludge was larger than envisaged.

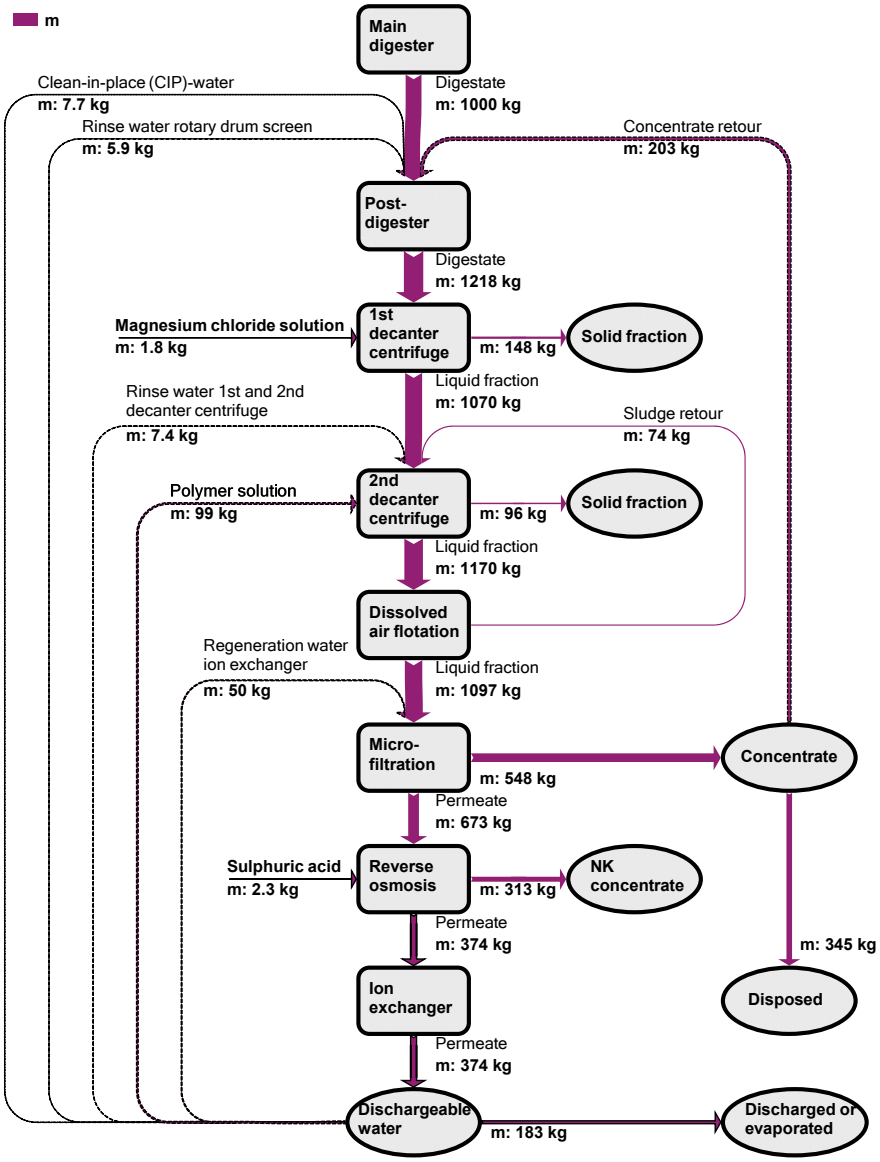

Figure 3 Total mass (m) flows of the GENIUS system at Groot Zevert Vergisting in kg per 1000 kg of processed digestate.

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Monitoring data: total mass flows

Total mass (Figure 4) flows were calculated for the RePeat system of GZV for the period September 2020 – July 2021. Of the P in the ingoing SF of digestate, 70% ended up in the precipitated P salts and respectively only 16% and 14% in the low-P soil improver and the sludge of the lamella clarifier. Every tonne of ingoing SF of digestate resulted in 970 kg of low-P soil improver, 512 kg of sludge (trucked off-site) and 793 kg of precipitated P salts due to addition of RO permeate. The DM content of the precipitated P salts is 18% which is lower than envisaged. The sludge of the lamella clarifier is a by-product consisting of fine organic matter. The sludge volume needs to be reduced to increase the economic profits. Overall, P separation efficiency of the RePeat system was as envisaged. Further optimization is needed to decrease the volume of sludge and precipitated P salts. GZV investigates possibilities to sell the low-P soil improver as an alternative for peat in potting soil or in substrate for the growing of mushrooms.

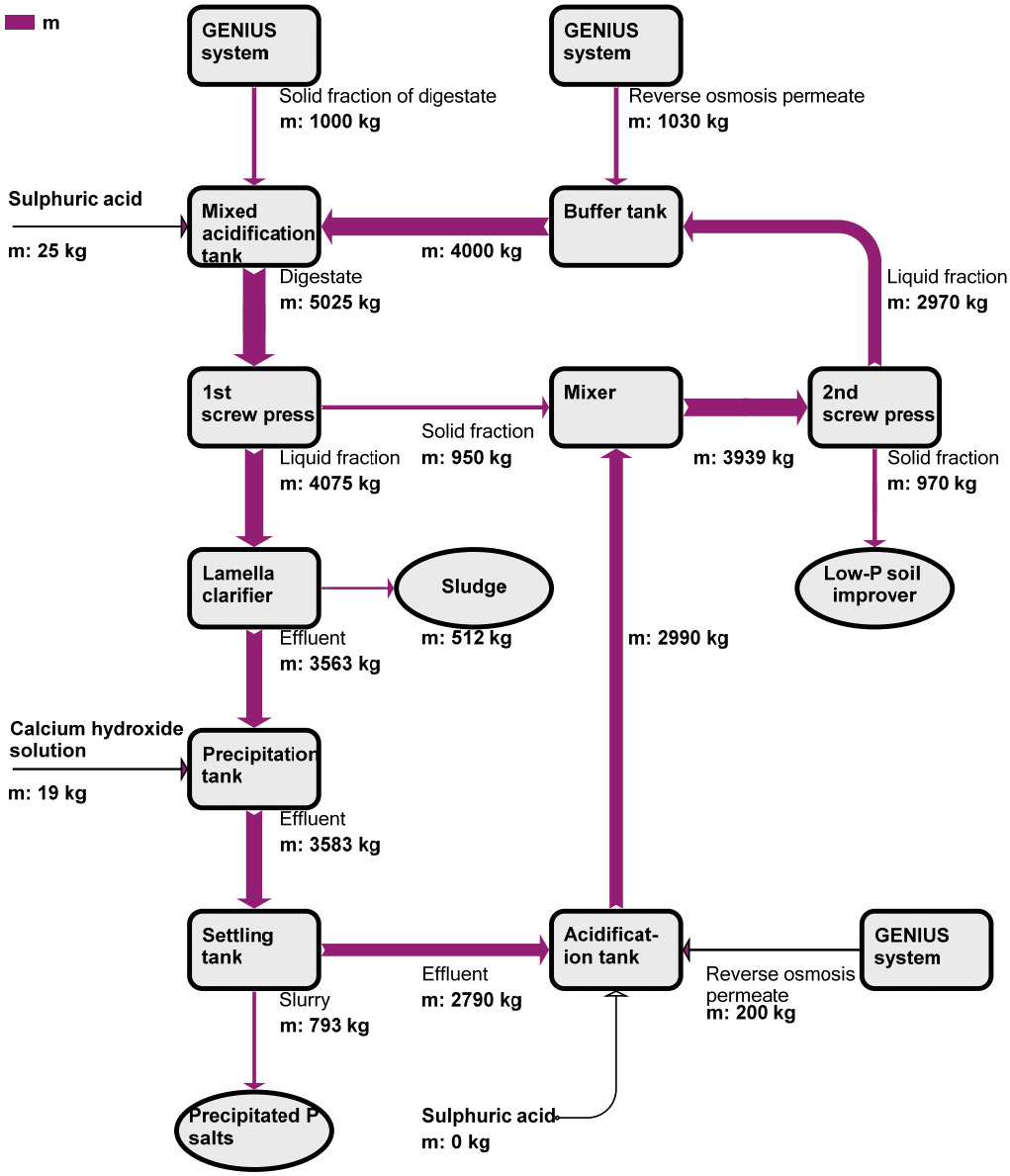

Figure 4 Total mass (m) flows of the RePeat system at Groot Zevert Vergisting in kg per 1000 kg of processed solid fraction of digestate.

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Monitoring data: energy balance

In 2020 the plant produced 47,837 MWh energy in the form of biogas (Figure 5) of which 72% was sold to a nearby dairy processing factory via a 5-km long pipeline. The majority of the remaining biogas was converted into 5,597 MWh electrical energy and 3,623 MWh of usable thermal energy by the combined heat and power (CHP) installation. Of this electrical energy 32% was sold via the grid and 68% was used on-site for the anaerobic digestion (AD) plant and the NRR systems GENIUS and RePeat. The thermal energy was used on-site for heating of the digesters and buildings and for hygienisation of the digestate in the post-digester.

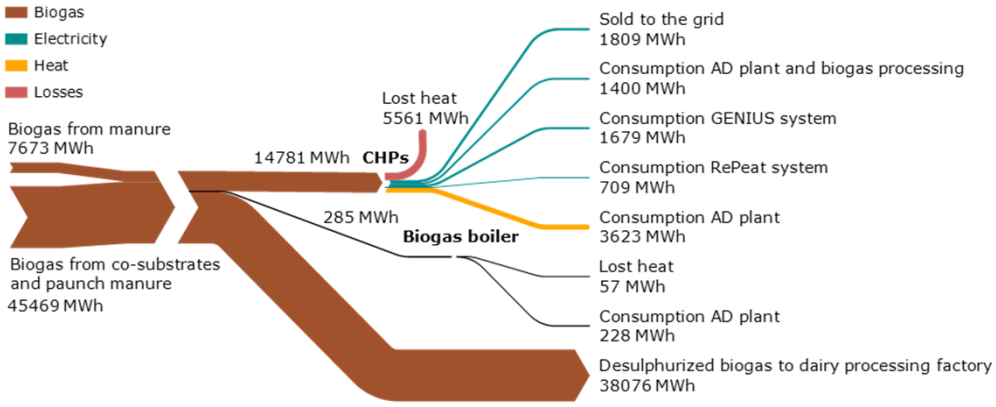

Figure 5 Energy balance of the anaerobic digestion (AD) and nutrient recovery and reuse systems at Groot Zevert Vergisting for the year 2020.

Key Performance Indicators (KPIs)

Economic KPIs are simple tools to gain insight into a company's economic performance:

KPI$_1$: EBIT (Earnings Before Interest and Taxes) margin as % of revenues.
KPI$_2$: EBITA (Earnings Before, Interest, Taxes and Amortisation) margin as % of revenues.
KPI$_3$: Substrate (financial) productivity → total gross revenues per tonne of feedstock.
KPI$_4$: Biogas (financial) productivity → net revenues of biogas (energy / green certificates) per cubic meter of biogas delivered.
KPI$_5$: Digestate (financial) productivity → net costs/revenues generated by digestate per tonne of feedstock.

Table 7. Economic KPIs of Groot Zevert Vergistings's plant.

KPI	
EBIT margin	12%
EBITA margin	49%
Substrate productivity	€34.52 / tonne feedstock
Biogas productivity	€0.32 / Nm^3 biogas
Digestate productivity	€-3.63 / tonne feedstock

Compared to the other SYSTEMIC demonstration plants, GZV has a relatively high biogas financial productivity. Processing and disposal of digestate is still costly because GZV does not generate revenues from all produced biobased fertilisers yet. Still, digestate financial productivity is higher than for most of the other SYSTEMIC demonstration plants. The produced RO concentrate is blended into Green Meadow Fertiliser (GWM). The farmer to whom the GWM is delivered pays for the amount of N he or she receives. From these revenues GZV pays the storage, transport and field application of the GWM on the farmer's land.

More information on the economic KPI analysis is available in deliverable D2.4: *'Final report on the development and application of economic key performance indicators (KPIs)'.*

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