Factsheet
SYSTEMIC Demonstration Plant

Benas-GNS, Ottersberg (GE)

A short introduction to Benas

The Benas Demonstration plant is located in North Germany, near Bremen. The plant has a capacity of 174 kt/y, distributed over 4 digesters and 2 storage tanks (with a total volume 26000 m^3, Table 1). Benas also includes an area of 3500 hectares (ha) of arable land (1000 ha near Ottersberg), with 35 employers and its own truck fleet.

Table 1. Technical information of the biogas plant.

Characteristics	
Date of construction	2006
Size (MWe)	5.25
Volume (m^3)	26 000
Digester type	Thermophilic digestion

Drivers for nutrient recycling

Chicken manure is readily available in the region as a feedstock for biogas installations at a low gate fee. Nevertheless, due to ammonia inhibition of the anaerobic bacteria, it remains a difficult stream to digest and restrictions on nitrogen (N) application rates make hard to get rid of it after processing. This leads to high transportation cost over large distances. Benas, producing up to 400 t/d of digestate, has been hereby forced to search for a digestate treatment technology that lowers the ammonia content of the digestate, recovers N and reduces the amount of digestate for field application. The plant director owns arable land, 200 km from the Ottersberg, which is fertilized with nutrients recovered at Benas installation. Trucks bring fertilizers to these agricultural fields and drive back to Ottersberg with crops that are used as feedstock input for the digester. Benas now already benefits from investments in nutrient recovery techniques: cost reduction on field application areas, less use of mineral fertilizer on his own lands, lower production costs due to the use of gypsum for recovering ammonia, income from selling the recovered biogas fibers.

Feedstocks

The co-digestion plant treats about 103 kt substrate every year, out of which 55% is corn silage (Table 2). From 2011, the plant treats approximately 160 t/d of corn silage, 75 t/d of solid chicken manure and 50 t/d of other agricultural material. Benas is planning to decrease every year the amount of corn silage fed to the digester.

Table 2. Origin of Benas feedstock (2017).

Type	Mass
Corn silage	58 kt
Chicken manure	27 kt
Other solids	18 kt
Total	**103 kt**

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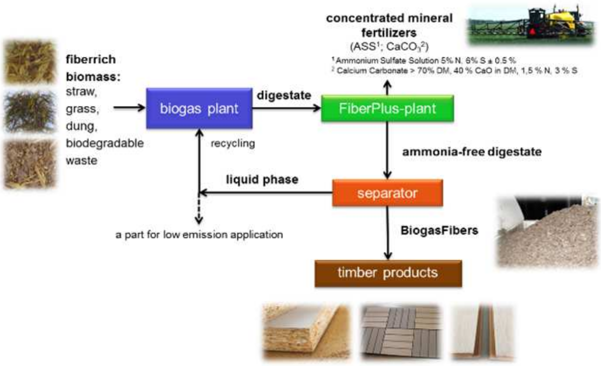
Biogas production

The biogas produced every year is around 20 Mm^3 (Table 3). In terms of energy production, the plant generates 28580 MW/y of thermal energy, out of which 25% is consumed by the stripping unit and the remaining part is used for cooling stripping gas and biogas, heating the digesters, drying wood and corn silage and heating rooms in the building. The CHP engine also creates 23610 MW/y of electricity: less than 2% is necessary for the operation of the stripping unit (400 MWh/y), the rest is sent to the national grid.

Table 3. Yearly biogas production (2017) and average composition before purification.

Component	
CH_4 (%)	53
CO_2 (%)	46
H_2S (ppm)	83
O_2 (%)	0.1
Total biogas production (Mm^3)	20
Biogas per tonne of feedstock (m^3/t)	194



Nutrient Recovery & Reuse (NRR) technology

In 2017, the demonstration plant produced around 75 kt of digestate that after being stored undergo a separation step, resulting in a liquid and solid fraction discharged on agricultural land. An internal recycle of about 75 kt of digestate is used as substrate for the FiberPlus plant for removing ammonia (detailed description below). In this approach, ammonia and carbon dioxide are brought into contact with gypsum to form ammonium sulphate (AmS) and calcium carbonate (lime).

Modified stripping process for N removal (FiberPlus process)

In 2003, GNS developed and patented the Modified Stripping Process in which ammonia is stripped from digestate without any use of acids, bases or external stripping media (Table 4). The process requires the addition of Flue Gas Desulphurisation-gypsum (FGD-gypsum) to produce two marketable fertilizers: AmS 25% solution and solid lime (70% dry matter, DM). Moreover, the process does not require any external heat source and relies solely on the exhaust heat from the CHP engine, with an average consumption of 100 kWh/m^3 of digestate. The gypsum used for the process comes from FGD of coal power plants.
From 2007/2008 this type of stripper was installed at Benas and from 2011 the plant recycles N-depleted digestate back to the digester to increase its DM content. There are several advantages of the described system:

- The plant reaches a recovery rate of 80% of ammonia contained in the digestate, which is approximately 200 t/y.
- Ammonia inhibition is circumvented, increasing the biogas yield by 8%.
- Since 10/2016 the process has been further implemented with the FiberPlus System for the production of ammonia-free fibers suitable for different applications in the fiber and timber industries (i.e. fiberboard).
- Emissions and loss of N are reduced.

Table 4. Technical specification of the Modified Stripping Process.

Technical information	
Digestate input	5-25 m^3/h
Ammonia input	3-5 g/l
DM input	5-12.5 %
Strip efficiency	70-85%
AmS output	5-40 t/d
Lime output	1.5-14 t/d

Results from material balances performed during August 2017 indicated the following nutrient recovery efficiencies from digestate treated in the FiberPlus system:

- 67% of NH_4-N as AmS and 6% of NH_4-N as Lime;
- 6% of P and 5% of K as fibers.

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Status of construction

In order to make the electricity production more flexible, Benas has started the construction of an additional storage tank with a volume capacity of 12 100 m³ (ensuring the storage of a biogas production of 8870 m³). The subsequent step will be the introduction of two additional CHPs with 3 MW electricity production each (planned for November 2018).
In order to meet the new discharging limits imposed by the German Fertilizer Regulation, different NRR technologies have been implemented at Benas. N recovery is achieved by means of the FiberPlus N-stripper developed by GNS, while P is removed in the form of fibers. However, the latter does not ensure high recovery rates and therefore it is not optimal for the treatment of P-rich substrates. Since mid-2017, GNS started with investigation on how to selectively separate P. Separation experiments are ongoing to understand to which extent is possible to separate P compounds using simple methods. Among other approaches, the dissolution of P in acid and re-precipitation into a P-concentrate was also studied.

Products and market

In 2017, the FiberPlus plant received around 75 kt of digestate, which was transformed into 1 kt of solid calcium carbonate, 3.6 kt of AS in solution and 1.1 kt of biogas fibers. Product characteristics are listed in Table 5.
The AmS solution is recommended by GNS as a good fertilizer for several reasons:

- AmS neutral pH is well tolerated by plants,
- AmS concentration of 25% avoids evaporative crystallization, making it a suitable for direct application on crops and
- AmS solution can be used for producing mineral fertilizer solutions or for upgrading manure or digestate low in N content.

Also, the use of lime has multiple advantages:

- Calcium is an important plant nutrient,
- Lime increases soil pH, enhances nutrient availability without causing alkalinisation because it dissolves only in acid soils and
- Lime improves soil structure and biological activity.

Table 5. Composition of the recovered products (2017).

	Calcium carbonate	Ammonium sulphate	Biogas fibers
Dry matter (DM) (%)	70-78	25	50-90
pH (25°C)	7,5	7,5	5-7
CaO in DM (%)	40		
NH_4-N (g/kg)	15-20	48-57	0.02-0.6
S (g/kg)	18-22	56-65	1,2

Economic benefits

GNS calculated that the replacement of conventional fertilizer with AmS and lime would generate a saved economic cost around 300000 €/y (Table 6). In addition, the sale of fibers is estimated around 82000 €/y. Finally, storage and transport costs will decrease with the implementation of the N stripper. This will reduce the N content in digestate, by-passing restrictions on N application rates.

Table 6. Saved economic costs.

Saved cost	€/y
Use of AmS solution	244 000
Use of calcium carbonate	63 000
Income from fibers	82 000
Total Saved Cost	**389 000**

Additional sources of income may be represented by:

- Digestate recycling after stripping and consequent higher biogas yield,
- Increase of chicken manure as substrate at lower prices (up to 50% of actual incoming N is contained in the dry chicken dung) and
- Efficient heat utilization.

Sustainability goals

Benas is committed to reach the following targets:

- Decrease greenhouse gas emissions by lowering CO_2 emissions from digestate transportation and
- Reduce ammonia, nitrate and nitrous oxide emissions.