Factsheet
SYSTEMIC Demonstration Plant

Groot Zevert Vergisting (Beltrum, NL)

A short introduction to GZV

Groot Zevert Vergisting (GZV) is located in Beltrum, in the eastern province of Gelderland (the Netherlands). The Demonstration plant operates from 2004 and employs 40 full time equivalent (Table 1). It is a fast-growing company whose treatment capacity is 102 kt per year, making it one of the largest anaerobic digestion (AD) plant in the Netherlands. GZV has the ambition to become the first "Green Mineral Mining" Centre in the Netherlands.

Table 1. Technical information of the biogas plant.

Characteristics	
Date of construction	2004
Size	6.5 MWe
Volume	15 000 m^3
Digester type	Mesophilic digestion

Drivers for Nutrient Recycling

Intensive livestock farming has led to over-fertilization of agricultural land resulting in environmental problems due to phosphate (P) and nitrogen (N) leaching to ground- and surface waters. To prevent further accumulation of P in soils, the Dutch government has set application limits for P based on equilibrium fertilization. As a consequence, approximately 25% of the P produced by livestock farming cannot be applied within the Netherlands and therefore should be exported to neighbouring countries against high costs. Furthermore, in line with the Nitrates Directive, the yearly application of N from animal manure is limited up to 170 kg N per hectare (ha) or 250 kg N per hectare (derogation). This has led to a paradoxical situation in which farmers pay to get rid of their manure and meanwhile purchase mineral N-fertilizers to comply with crop nutrient demands. According to GZV, there is an existing demand in the region for each individual nutrient recovered from digestate except for P-rich fertilisers which need to be exported. Though the region hosts far more cows than pigs, the majority of the manure treated at GZV comes from pig farms. This is because arable farmers prefer dairy manure over pig manure due to its lower P content. Disposal costs of pig manure can be as high as 20-25 €/m^3.

Feedstocks

In 2018 the co-digestion GVZ plant will increase its treatment capacity from 102 to 135 kt substrate (Table 2).
Animal manure will be the major substrate (more than 70% of total feedstock), and pig manure will be collected from about 55 pig farms.

Table 2. Origin of GZV feedstock (2017 and 2018).

Type	Origin	Mass (2017)	Mass (2018)
Manure	Pig manure	65 kt	80 kt
	Dairy manure	2 kt	5 kt
	Slaughterhouse manure	12 kt	15 kt
Co-products	Waste dairy industry	12 kt	15 kt
	Waste feed industry	8 kt	15 kt
	Glycerin	3 kt	5 kt
Total		**102 kt**	**135 kt**

Horizon 2020

Groot Zevert Vergisting (Beltrum, NL)

Biogas production

The biogas produced every year is around 10 Mm^3 (Table 3). About 80% of the produced biogas is transported through a 5 km-long pipeline towards a milk factory (Friesland-Campina). About 20% of the produced biogas is converted to electric power and used at the site.

Table 3. Yearly biogas production and average composition before purification.

Component	
CH_4 (%)	58
CO_2 (%)	40
H_2S (ppm)	2000-3000
O_2 (%)	0.2
Total biogas production (Mm^3)	10
Biogas per tonne of feedstock (m^3/t)	75

Nutrient Recovery and Reuse (NRR) Technologies

Currently, the digestate is separated trough a decanter in a solid and liquid fraction. The liquid fraction is used as a N-fertilizer on agricultural land in the Netherlands. The solid fraction is, after a hygienization step (60 minutes at 70 °C), exported to neighbouring countries where it is used as an organic P-fertilizer. Part of the digestate is also applied directly on the field in Germany. In collaboration with Nijhuis and Wageningen UR, GZV will implement a system for NK recovery from the liquid fraction (GENIUS) and P recovery from the solid fraction (RePeat).

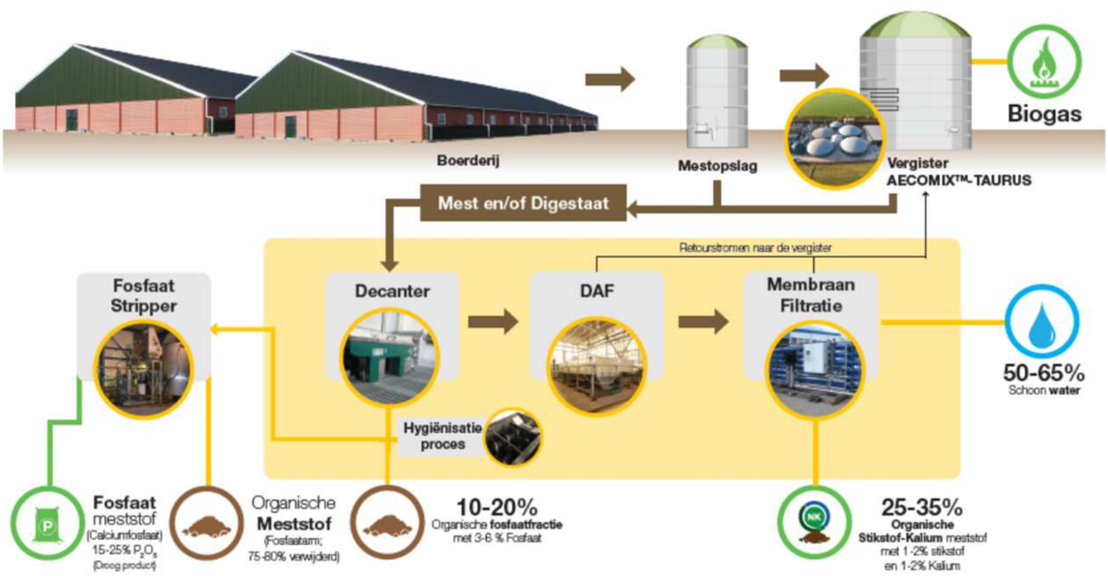
The GENIUS and Re-P-eat processes

In GENIUS-NK process, the digestate is separated into a solid and a liquid fraction by means of a decanter. The N-rich liquid fraction will be processed into a nitrogen-potassium (NK-) concentrate and clean water through a combination of DAF and membrane filtration system: micro filtration, reverse osmosis (RO) and ion-exchange(IX).

Results from pilot scale experiments indicated the following nutrient recovery efficiencies from digestate:

- 50% of total N and 56% of NH_4-N
- 56% of K
- 3% of P

The P-rich solid fraction will be treated with a P-stripper called "Re-P-eat" through a process of acid (H_2SO_4) and base $Ca(OH_2)$ addition. The products of this process will be mineral calcium phosphate (CaP) and a P-poor organic soil conditioner.



SYSTEMIC
Circular solutions for biowaste

Groot Zevert Vergisting (Beltrum, NL)

Status of construction

In 2016, GZV envisaged to invest into the GENIUS-Total concept which includes a decanter, DAF, N-stripper and Reverse Osmosis for the production of ammonium sulphate (AmS) fertilizer and concentrated K fertilizer. In 2017, after more thorough market research, it became clear that there are better market opportunities and business case for NK concentrates as compared to AmS fertilizer. It has therefore been decided to take out the N-stripper for the moment and to invest into the GENIUS concept which produces NK concentrates through a combination of flotation, micro filtration and reverse osmosis.

During year one of the SYSTEMIC project major progress has been made on the engineering and optimisation of the RePEat process based on experiences gained at the pilot installation and additional laboratory tests. The process has been further optimized based on new insights after market research in which potential customers including fertilizer producing companies (including ICL Fertilizers) and farmers have been contacted.

Products and market

In the GENIUS-Total process, N and K can be sold as separate products whereas GENUIS-NK produces a NK-concentrate.. The recovered water (50-60% of total volume) meets stringent criteria for discharging to surface water. The recovered mineral P can be exported to regions with a demand for P-fertilizers (e.g. France) or used as a feedstock for the production of triple-superphosphate at ICL Fertilizer. The P-poor organic matter can be used as soil conditioner to increase carbon contents. Product characteristics are listed in table 4.

Table 4. Expected composition of the recovered products.

	Ingoing digestate	GZV Recovered products		
		NK-fertilizer	Soil Conditioner	P-fertilizer
Dry matter (DM %)	5.8		32	82
Organic Matter (%)	65% of DM	1-3	89% of DM	45% of DM
N-total (g/kg)	6	8-15 NH_4-N	5.0	20
P_2O_5-total (g/kg)	3.5	0.2-0.4	3.2	140
K_2O-total (g/kg)	4	8-20	0.2	5
Volume (%)	100	5-10	20	2

Economic benefits

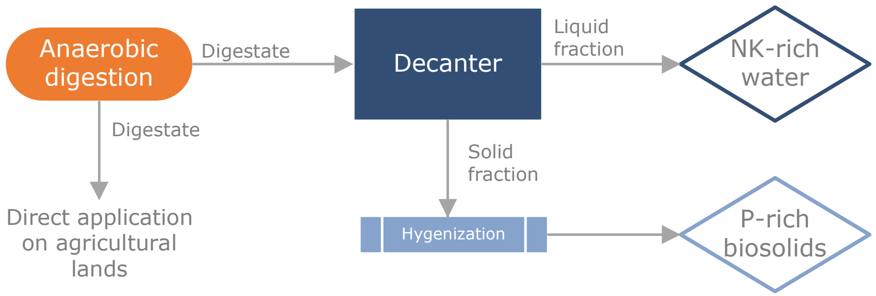
Digestate volume is reduced by 60-80%. Only small volumes of concentrated minerals need to be transported or applied on fields, leading to reduction of digestate transport cost over long distances. Nijhuis estimated that treatment costs will decrease to 13 € per cubic metre of manure processed.

Sustainability goals

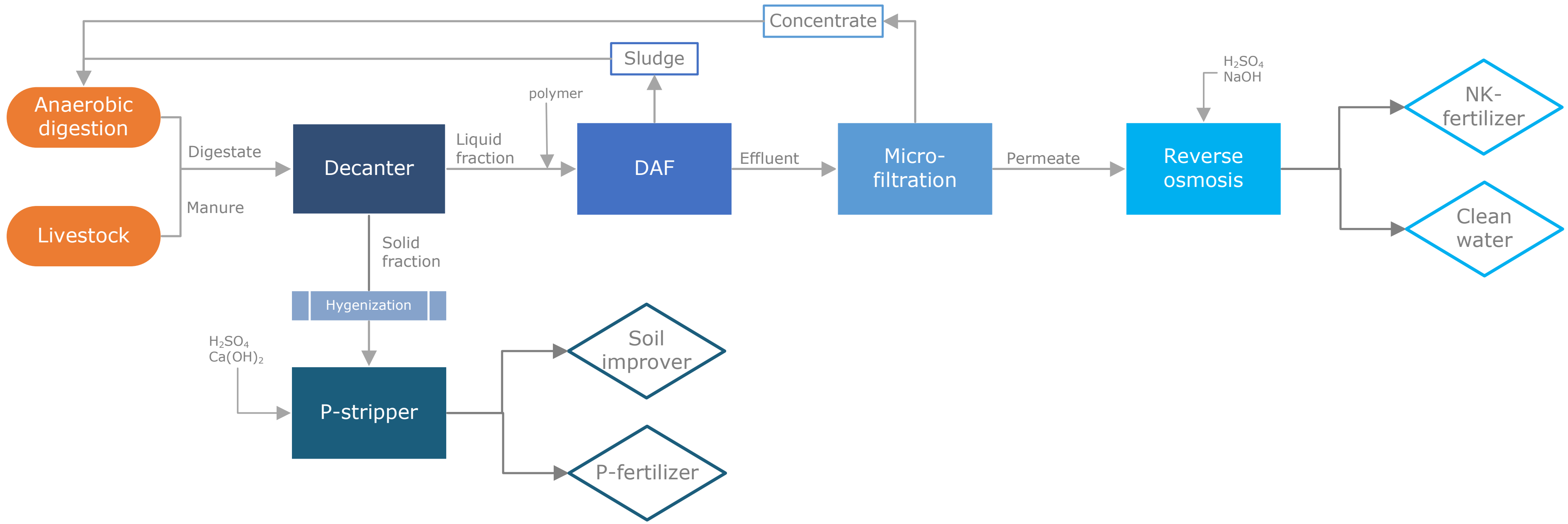
GZV is committed to reach to following targets:

- Reduce CO_2 emissions related to manure transport and the production of mineral N-fertilizer.
- Prevent losses of P, a non-renewable and potentially scarce mineral.
- Increase the carbon-content of soils: nutrient-poor digestate after treatment can be applied in the nearby region as a soil conditioner to improve soil quality for food production.

Annex 1: Groot Zevert Vergisting Demonstration installation – Beltrum (NL)



Current process



Envisaged process in phase 1 of GENIUS

Technical specifications:

Current process

Name	Type	Treatment capacity (m^3/h)	Power consumption (kW)	Heat requirement (kW)
Decanter	Mechanical separation	16	24	-

Envisaged process

Name	Type	Treatment capacity (m^3/h)	Power consumption (kW)	Heat requirement (kW)
Decanter	Mechanical separation	28	36	-
DAF	Mechanical separation	32	17.6	-
Hygenisation	IR	3	48	320
P-stripper	Stripping	3	25-50*	500
Micro-filtration	Membrane filtration	25	225	-
Reverse Osmosis	Membrane filtration	20	62	-

*estimated data

AM Power (Pittem, BE)

A short introduction to AM Power

AM Power is located in the western part of Flanders (Belgium), a region characterized by an excess of animal manure and yet a high market demand for formulated synthetic fertilizer. The demonstration plant is the largest biogas installation in Belgium: it has a treatment capacity of 180 kt/y spread over five digesters, for the production of 7.5 MW of electricity (Table 1).

Table 1. Technical information of the biogas plant.

Characteristics	
Date of construction	2011
Size (MWe)	7.5
Volume (m^3)	20 000
Digester type	Thermophilic digestion

Drivers for Nutrient Recycling

AM Power has always been experimenting and investing in innovation towards the recovery of nutrients. A long time ago they already envisaged the importance and benefits of moving towards a circular economy. Getting rid of the digestate represents an important cost for biowaste treatment plants. On top of this, the agro food industry in Flanders realizes that their waste streams are valuable and thus demand a gate fee to biogas plants for intake of their waste.

Competition between biogas plants makes it difficult to get the turnover break even. AM Power believes that nutrient recovery can be a way to balance this again.
AM Power generates every year 160 kt of digestate and strives to treat it in a cost effective, efficient and relatively simple way, without losing the nutrients. The plant has developed a technological solution for the recovery of nutrients into valuable fertilizers, which will be further implemented.

Feedstocks

The co-digestion plant treats about 180 kt of feedstock every year out of which almost 90% is organic biological waste (i.e. food waste). Co-substrates include animal manure and energy maize (Table 2).

Table 2. Origin of AM Power feedstock (2017).

Type	Mass
Organic biological waste	160 kt
Manure	15 kt
Maize	5 kt
Total	**180 kt**

Horizon 2020

AM Power (Pittem, BE)

Biogas production

The biogas produced every year (including digesters and post-digester) is around 30 Mm³ (Table 3). The biogas is converted by a CHP engine into electrical and thermal energy. The amount of heat and electricity produced is respectively 7360 and 7435 kW.

Table 3. Yearly biogas production and average composition before purification.

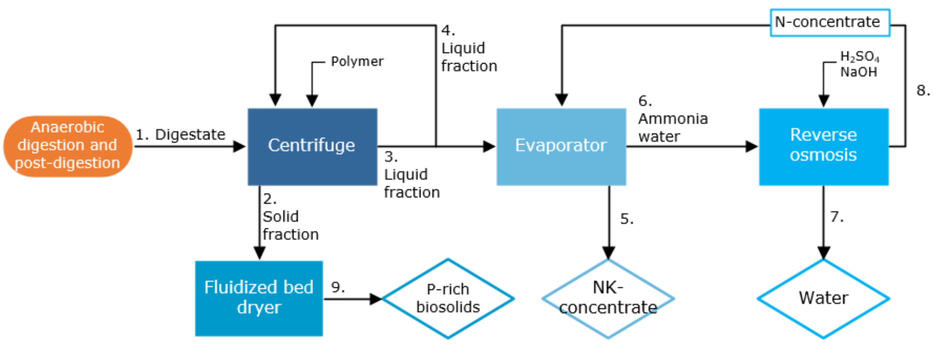
Component	
CH_4 (%)	56
CO_2(%)	43
H_2S (ppm)	50
O_2 (%)	0.1
Total biogas production (Mm^3)	30
Biogas per tonne of feedstock (m^3/t)	170

Nutrient Recovery and Reuse (NRR) Technology

Currently the process works as follows:

- Organic wastes are collected and homogenized in a mixing unit to a substance with a dry matter (DM) content of approximately 20%.
- Homogenized feedstock is hydrolysed in a separate unit (with a retention time of 3 days) and fed to a thermophilic digester.
- Digestate (9% DM) is sent to a centrifuge for solid/liquid separation. Coagulation and flocculation are favoured by the addition of polymer and iron sulphate.
- The solid fraction that contains 90-95% of the initially separated total phosphorous (P) is dried, while the liquid fraction is sent to a flotation and reverse osmosis (RO) unit. Drying of solid fraction is accomplished by recycling waste heat from CHP engines and it requires around 2600 kWh. The resulting product is exported to France.
- Before the RO, a flotation step (DAF) reduces the DM content of the liquid fraction to 1.6 - 1.7% DM. The RO step requires the addition of acid (H_2SO_4) to the influent to ensure a good membrane separation. The resulting concentrate is rich in nitrogen and potassium (N and K) and is used as a fertilizer on local agricultural land.

<u>The envisaged process includes a continuous multiple effect vacuum evaporator prior the RO, thus increasing the recovery of nutrients from digestate.</u> The vapour contains ammonia, which is condensed as ammonia water and is subsequently pumped to the RO unit. Moreover, the flotation step will not be necessary anymore. The investment of the evaporator and adaptation of the process amounted to 2 M€**.**



AM Power (Pittem, BE)

Status of construction

Am Power has defined all the technical specification for the installation of the new evaporator, however, not all the financial aspects have been addressed yet.
Am Power initially planned to have the first part of the evaporator ready by July 2018, but September/October seems to be a more feasible date.
The start-up of the process equipped with the evaporator is foreseen around November 2018 and based on the first results it will be decided how to proceed with the necessary improvements.

Products and market

Currently, the digestate treated with the membrane system is transformed in biosolids, NK-concentrate and water. The NK-concentrate is used as fertilizer in greenhouses owned by AM Power or spread on grasslands. Biosolids are exported to France where P demand is high. Product characteristics are listed in Table 4.

Table 4. Composition of the recovered products (target values).

	Ammonium sulphate	Biosolids
Dry matter (%)	3.19	90
Organic matter (%)	1.67	43
N-total (g/kg)	3	27
P_2O_5-total (g/kg)	0.5	77
K_2O-total (g/kg)	2.8	12

Economic benefits

The economic advantages of reusing recovered products are:

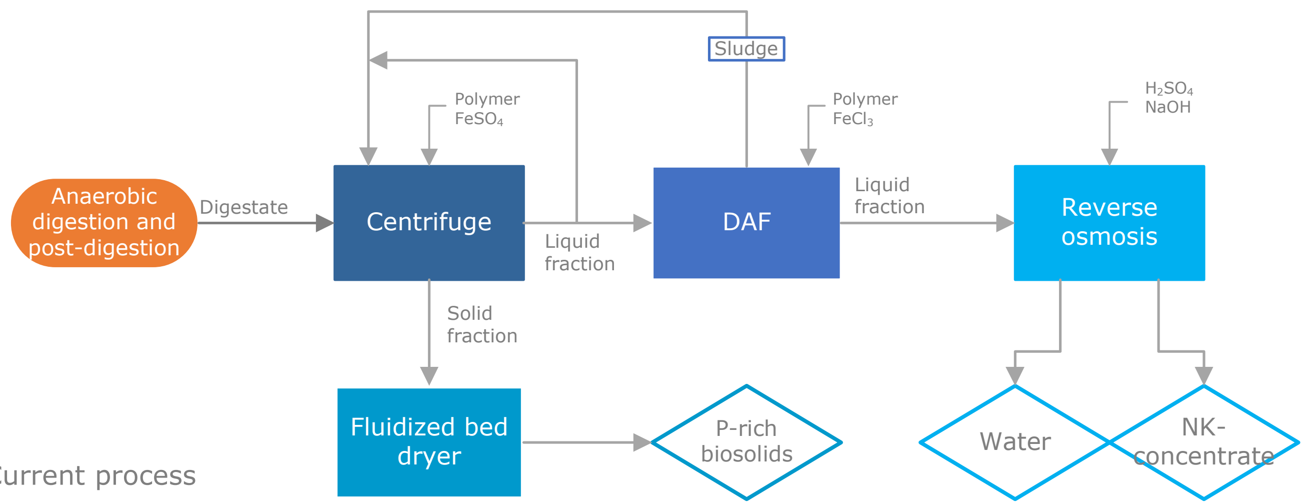
- By improving RO efficiency, AM Power estimated that approximately 160 m³ of water per day will become available as dischargeable water (after polishing) or used on site. This amount of water does not have to be transported and treated, and
- By replacing DAF, the costs for additives will be drastically reduced.

Sustainability goals

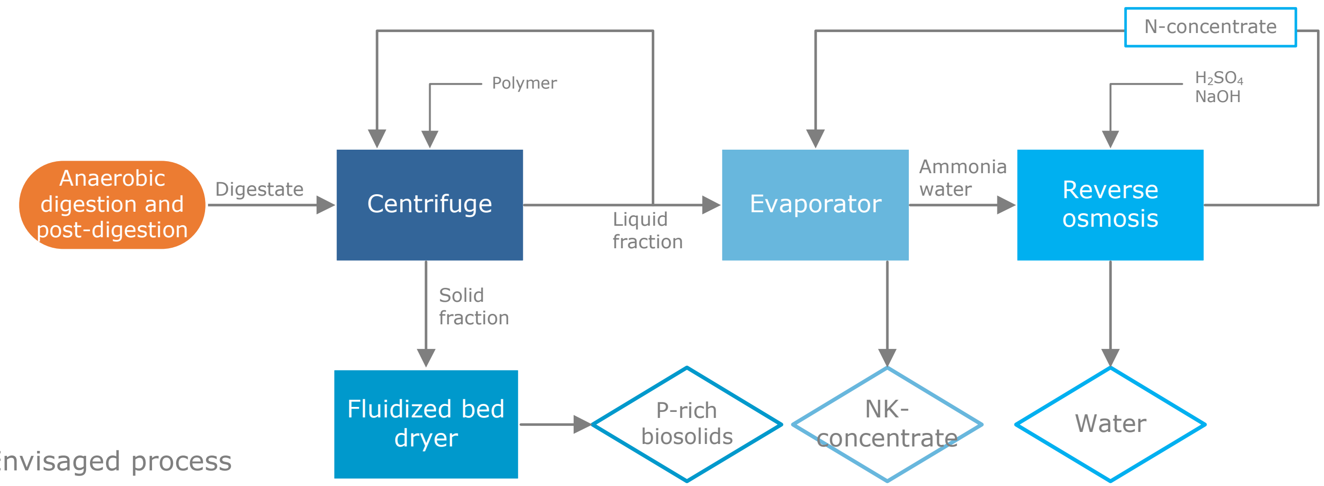
AM Power is committed to reach the following targets:

- Reduce CO_2 emissions related to digestate transport,
- Reduce the use of additives and chemicals,
- Promote water recycling and
- Reduce the distance for fertilizers transport by producing locally bio-based mineral fertilizer.

Annex 2: AM Power Demonstration installation – Pittem (BE)



Current process



Envisaged process

Technical specifications:

Current process

Name	Type	Treatment capacity (m^3/h)	Power consumption (kW)	Heat requirement (kW)
Decanter	Mechanical separation	25	80	-
Fluidized bed dryer	Drying	2800 lH_2O/h	250	2500
DAF	Mechanical separation	20	7	2500
Reverse Osmosis	Membrane filtration	20	130	-

Envisaged process*

Name	Type	Treatment capacity (m^3/h)	Power consumption (kW)	Heat requirement (kW)
Decanter	Mechanical separation	25	80	-
Fluidized bed dryer	Drying	2800 lH_2O/h	250	2500
Evaporator	Evaporation	15	60	2500
Reverse Osmosis	Membrane filtration	20	30	-

*estimated data

Acqua & Sole (Vellezzo Bellini, IT)

A short introduction to Acqua & Sole

Table 1. Technical information of the biogas plant.

Characteristics	
Date of construction	2016
Size (MWe)	1.6
Volume (m^3)	13 500
Digester type	Thermophilic digestion

Acqua & Sole (Neorurale group) is located in Vellezzo Bellini (Northern Italy), in an area dedicated to cereal cultivation, mainly rice. Neorurale has a strong focus on nutrient recycling with special attention to the development of an efficient digestate distribution system (direct injection into the soil). The system is being developed in strict collaboration with local farmers with the aim to maximize fertilization effects and minimize ammonia and odour emissions. In addition to the production of soil improvers (digestate), the demonstration plant generates ammonium sulphate (AmS) from ammonia recovered during the digestion step, which is used as a feedstock for the production of nitrogen fertilizer. For the recovery and reuse of nutrients, Acqua & Sole has an ambition of improving soil fertility without any use of synthetic fertilizer over an area of 5000 hectares (ha), and ensuring the nutrient requirements of the surrounding farms for their annual crop production.

Drivers for nutrient recycling

Excess production of nitrogen (N) and phosphorous (P) has led to environmental issues such as eutrophication of surface waters and nitrate accumulation in groundwaters. Therefore, recycling of disposed waste (e.g. manure, sewage sludge, organic fraction of municipal solid waste and food waste) becomes a great opportunity for the recovery of nutrients. Furthermore, low carbon content in soils is an issue in Italy and the utilization of soil improvers is a valuable tool to tackle this. However, restrictions on N application on agricultural land limit their use, making it necessary to find solutions to lower their N content.

Feedstocks

The co-digestion plant capacity is 120 kt organic substrate per year. In 2017, 72 kt were treated out of which about 85% was sewage sludge and 15% was digestate from anaerobic treatment of source-segregated domestic food waste and liquid fraction of source-segregated food waste (Table 2). The plant can treat manure, expired food, organic wastes, sewage sludge and agri food industry sludge.

Table 2. Origin of Acqua & Sole feedstock (2017).

Type	Origin	Mass
Sewage sludge	Wastewater treatment plants	62 kt
Co-products	Digestate from anaerobic treatment of source-segregated domestic food waste	6 kt
	Liquid fraction of source-segregated food waste	4 kt
Total		72 kt

Horizon 2020

Acqua & Sole (Vellezzo Bellini, IT)

Biogas production

AD is performed in 3 consecutive digester of 4500 m^3 each. The biogas produced by the plant (including digesters and storage tank) is converted by a CHP engine into electrical and thermal energy. In 2017, about 30% of the electricity produced was consumed by the plant and the remaining 70% was sent to the national grid.

Table 3. Biogas production and average composition before purification in 2017.

Component	
CH_4	55-60 %
CO_2	33-37 %
H_2S	<50 ppm
O_2	1%
Total CH_4 production	~ 2300 kNm^3 CH_4
Specific CH_4 production	~ 245 lCH_4/kgVS fed

Digestate characteristics

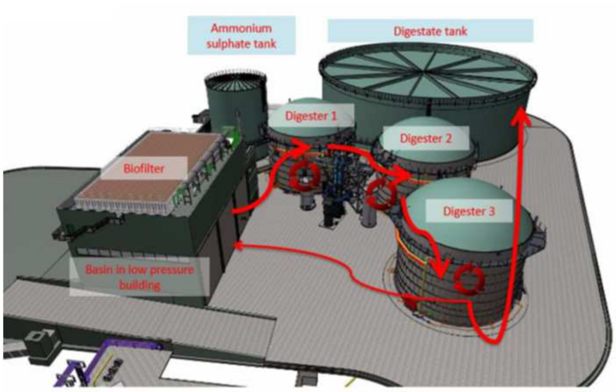
- Thermophilic digestion ensures a better control of pathogenic and intestinal microorganisms in the digestate.
- Lower N content in digestate favours a long-term fertilization effect of digestate (higher ratio organic N/NH_4-N in digestate).
- Uniformity of digestate distribution is ensured by precision agriculture system, following conservation agriculture criteria.

Nutrient Recovery and Reuse (NRR) technology

From April 2016, the plant operates as follow:

- Organic waste is collected in basins located in a closed building to prevent the release of odour. A bio-filter placed on the roof of the building purifies the exhausted air.
- Substrates are moved to a mixing unit where they are heated and homogenized with biomass coming from the third digester.
- Homogenized and inoculated feedstock is fed to the thermophilic process (minimum retention time of 20 days and temperature of 55°C) which ensures full sanitation of the incoming sludge and better agronomic properties of the digestate.
- The process is equipped with an ammonia stripping unit, whereby biogas acts as stripping agent. Ammonia is extracted from biogas by adding acid (H_2SO_4) resulting in inorganic ammonium sulphate (AmS) production.
- Both digestate and AmS are stored in steel tank facilities.

Results from material balances, performed in the first quarter of 2018, indicated that the side-stream ammonia stripper recovered 22% of the NH_4-N contained in the digestate.



SYSTEMIC
Circular solutions for biowaste

Acqua & Sole (Vellezzo Bellini, IT)

Status of construction

Acqua & Sole will implement and demonstrate a novel N recovery absorber which enables higher N recovery from digestate. The investment for the N absorber amounts to 0.4 M€**.**
The designing phase has started on April 26th 2018 and will last until the end of May 2018. The contract with suppliers will be finalized in the first week of June, followed by purchase of materials. Construction works will start in October and are planned to be concluded by December 2018. The equipment will be finally installed and tested between December 2018 and January 2019.

Products and market

The co-digestion plant capacity is 120 kt of waste, which will be transformed into 4 kt of AmS and maximum 192 kton of organic fertilizer (digestate). Product characteristics are listed in Table 4.

Acqua & Sole estimated that the use of digestate could replace the following maximum amount of synthetic fertilizers: 1550 t/y of N, 1160 t/y of P_2O_5 and 170 t/y of K_2O.

Table 4. Composition of the recovered products at Avqua&Sole (based on average data since October 2017).

	Digestate	Ammonium Sulphate
Dry matter (%)	10.5	
Organic carbon (% DM)	31.2	
N-total (g/kg DM)	77.0	~7,2% on wet weight
P_2O_5-total (g/kg DM)	57.6	-
K_2O-total (g/kg DM)	8.3	-

Economic benefits

Acqua & Sole calculated that the replacement of conventional fertilizer with digestate over a surface area of 5000 ha would generate a maximum saved economic cost of about 2.3 million €/y (Table 5). The implementation of N absorber will reduce the N content in digestate, and as such not limit the digestate spreading on fields. This will allow distribution of a higher amount of digestate per hectare with benefits in terms of transport and disposal costs.
On top of that, lowering ammonia content in the digester will optimize the digestion process, avoiding toxicity effects on methanogen microorganisms and increasing AmS production.

Table 5. Saved economic costs.

Conventional fertilizer	Cost €/t *	Quantity t/y	Total (€)
Urea 46% N	344	3 370	1 159 280
triple superphosphate 46% P_2O_5	369	2 520	929 880
Potash 60% K_2O	669	280	187 320
Total Saved Cost			**2 276 480**

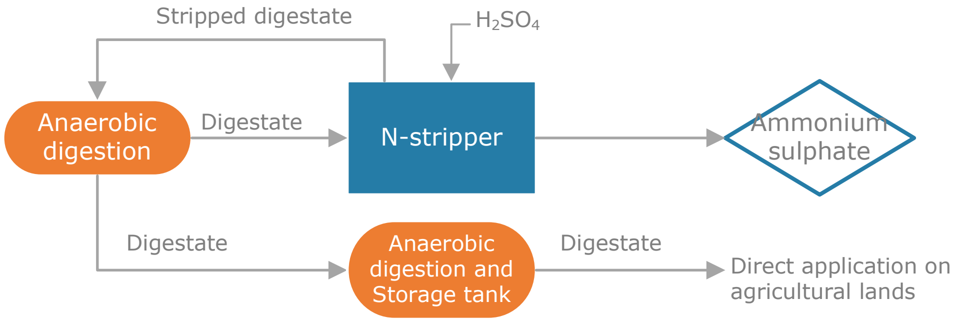
** Source: CCIAA Modena, Average 2017*

Sustainability goals

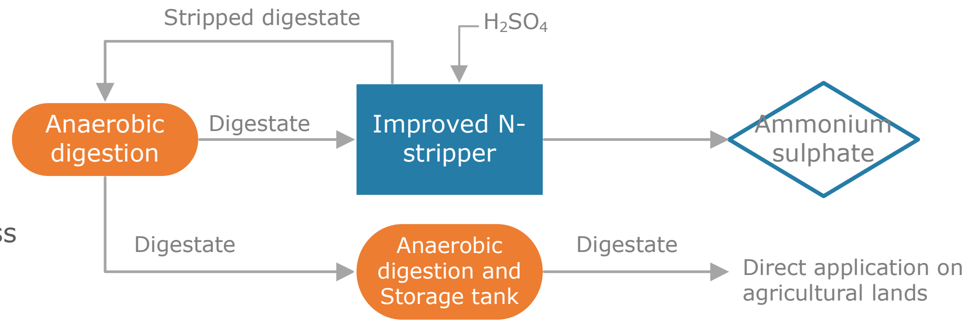
Acqua & Sole is committed to reach the following targets:
- Increase soil quality and contribute to sequestration of carbon in soil,
- Decrease greenhouse gas emissions,
- Reduce ammonia, nitrate and nitrous oxide emissions,
- Eliminate unpleasant odour to improve public acceptance and
- Promote nutrient recycling and this circular economy model in the region as an effective solution for waste management.

Annex 3: Acqua & Sole Demonstration installation – Vellezzo Bellini (IT)

Current process



Envisaged process



Technical specifications:

Current process

Name	Type	Power consumption (kW)	Heat requirement (kWth)	Ammonia removal (%)
N-Stripper + N-absorber	Stripping	45	220	21

Envisaged process*

Name	Type	Power consumption (kW)	Heat requirement (kWth)	Ammonia removal (%)
N-Stripper + N-absorber	Stripping	45	300	30

*estimated data

RIKA Biofuels (Fridays, UK)

A short introduction to RIKA Biofuels

Rika Biofuels (UK) develops large scale anaerobic digestion (AD) projects in Europe and is specialized in manure treatment from intensive livestock production.
Rika Biofuels, partnered with DVO (supplier of the digester), has initiated the construction of the AD plant of Fridays in the United Kingdom. Fridays will be operated with 100% poultry manure and a treatment capacity of 50 kton per year.

Table 1. Technical information of the biogas plant.

Characteristics	
Date of construction	2019
Size (MWe)	1.8
Volume (m^3)	14 000
Digester type	Mesophilic digestion

Drivers for Nutrient Recycling

To date, poultry manure is often incinerated because of the high organic matter content and low water content. The energy production during incineration is high, however, it causes valuable nitrogen and carbon loss as N_2 and CO_2 in addition to greenhouse gas (GHG) emissions.
Rika Biofuels wants to generate value from manure via AD and provide solutions to farmers whose manure is a liability to their business rather than an asset. The company realized that nutrient recovery (nitrogen separation) could improve the efficiency of the AD by reducing the requirement for water to dilute high nitrogen containing feedstocks (e.g. poultry manure). As a consequence, higher biomass yield and a more stable digestion process is achieved.
Fridays will demonstrate that chicken manure can be treated in a sustainable way while recycling nitrogen (N) and phosphorous (P), reducing GHG emissions and reducing manure disposal costs.

Feedstocks

Every year the digestion plant will treat 50 kt of poultry manure (Table 2) diluted with 134 kt of recycled water coming from the nutrient recovery plant.

Table 2. Origin of Fridays feedstock.

Type	Origin	Mass
Manure	Poultry manure	50 kt

Biogas production

The installation will produce around 8 Mm^3/y of biogas (Table 3), of which 450 m^3 of biomethane will be injected to the grid. Furthermore, the installation will produce 550 kW of heat and 500 kW of electricity. The expected biogas composition is reported in Table 2.

Table 3. Yearly biogas production and average composition before purification.

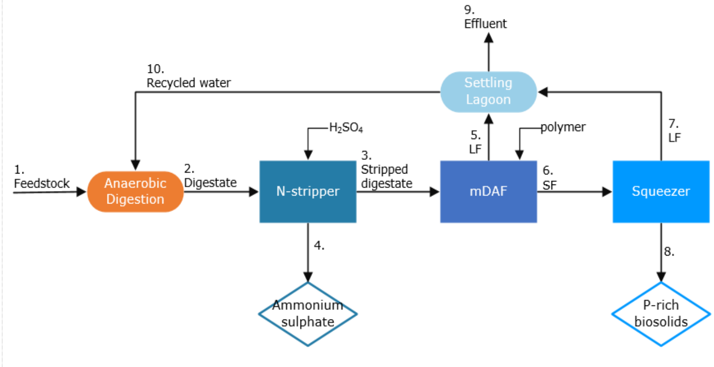
Component	
CH_4 (%)	55
CO_2 (%)	43.8
H_2S (ppm)	500
O_2 (%)	0,7
Total biogas production (Mm^3)	8
Biogas per tonne of feedstock (m^3/t)	125

Rika Biofuels
Integrated Biogas Solutions
Horizon 2020

RIKA Biofuels (Fridays, UK)

Nutrient Recovery and Reuse (NRR) Technologies

The anaerobic digester is a two-step, mesophilic mixed plug-flow system with a retention time around 20 days. The first step takes place in an acidification chamber, while the second occurs in a methanogenic chamber, allowing separation of bacteria for acid and methane formation. The waste flows through a channel as follows: as fresh manure enters one end, digestate is pushed out of the other end, continuously mixed with biogas circulation. The gradual increase of pH in the methanogenic chamber to 8.5 provides optimal conditions for subsequent ammonia stripping.
N is recovered as a valuable ammonium sulphate (AmS) since during the process ammonia is stripped by adding acid (H_2SO_4). Up to 90% of P is recovered from digestate through a modified Dissolved Air Flotation step (mDAF) and subsequent squeezing. The investment for the AD plant and the N stripping system amounts to 12.8 M€.



Status of construction

The reason for the delay in the construction of Oaklands biogas plant is that planning permission was retarded due to the Environmental Agency demands of a detailed design at a very late stage in the planning application. Rika Biofuels completed the design work and successfully attained planning permission for the project. However, in September 2016, government renewable energy policy was changed and any Feed In Tariff (Rika's renewable subsidy) for projects with an output over 500 kW electricity (kWe) has been effectively removed.

Fortunately, Rika Biofuels has another site under development with Fridays Eggs in Kent which will substitute Oaklands demonstration installation. This project is identical to Oaklands since both rely on DVO technology to process at least 50,000 tonnes per annum of poultry manure. This is a gas to grid project and therefore does not rely on the Feed in Tariff over 500 kWe as Oaklands. The project has planning permission, a grid connection and funding. After a delay of more than a year, the UK Government finally introduced new renewable heat tariffs in May 2018 for which Rika have applied. Subsequently, construction of the Fridays project is due to start in September 2018 with the commissioning targeted to take place in October 2019.

RIKA Biofuels (Fridays, UK)

Products and market

Pathogen reduction by 90-99% of faecal coliforms and streptococcus is ensured by the mixed plug-flow digester. The solids obtained with 20% of dry matter (DM) will be exported to Germany and neighbouring countries. By mixing biosolids with AmS 40% solution, Rika is planning to produce marketable NPK-fertilizers.
Rika Biofuels is also exploring the option of crystallising AmS solution. This can be achieved at a cost of about 60 € per tonne of crystal for which the market is thought to be in excess of 120 € per tonne.

Table 4. Expected composition of the recovered products.

	Ingoing manure	RIKA Recovered products	
		AmS	P-rich biosolids
Dry matter (DM %)	73		27
Organic matter (%)	68% of DM		32% of DM
N-total (%)	4	7.2	0.7
P_2O_5-total (%)	2.6	0.08	3.3
K_2O-total (%)	2	0.08	1.3

Economic benefits

The economic advantages of reusing recovered products are:

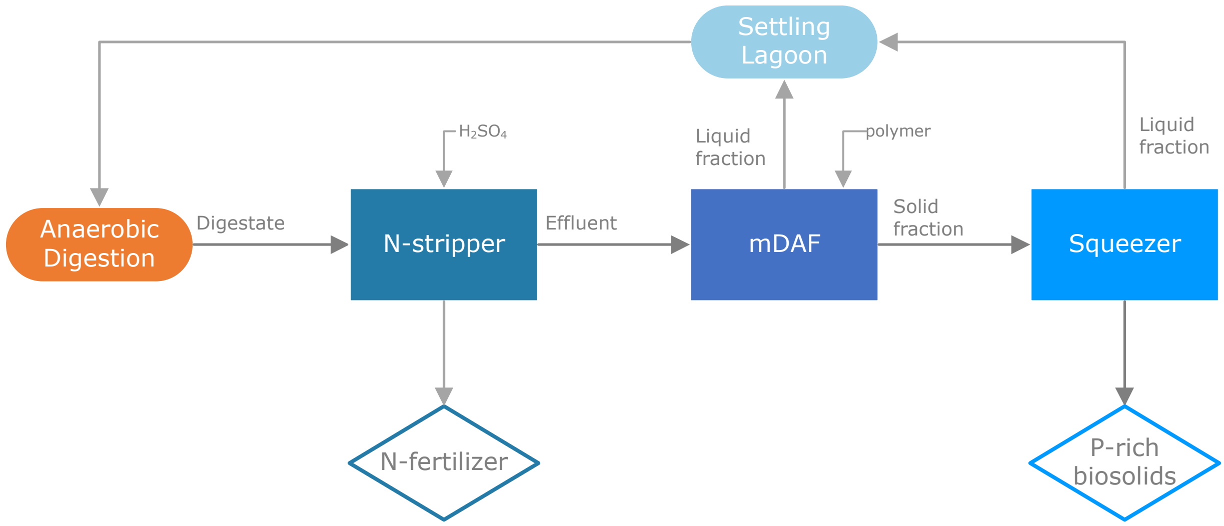
- Cost efficient production of biosolids and mineral organic fertilizers and
- Direct recycling of the final liquid fraction (e.g. feedstock dilution for AD) due to its low nutrient concentration.

Sustainability goals

Rika Biofuels is committed to reach the following targets:

- Improving the sustainability of livestock farming through the production of renewable energy from the mono/digestion of manures and wastes from the agriculture sector and
- Achieving a GHG saving of at least 70% compared to fossil fuel alternative in Rika's facilities for the production of renewable energy.

Annex 4: Rika Biofuels Demonstration installation – Fridays (UK)



Envisaged process

Technical specifications:

Name	Type	Treatment capacity	Power consumption (kW)	Heat requirement (kW)
N-Stripper	NH_3 stripping	5-7 t AS/h	122	284
mDAF	Mechanical separation	13 m^3/h	4.5	
Squeezer	Mechanical separation		4.5*	

*estimated data

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**

Factsheet
SYSTEMIC Demonstration Plant

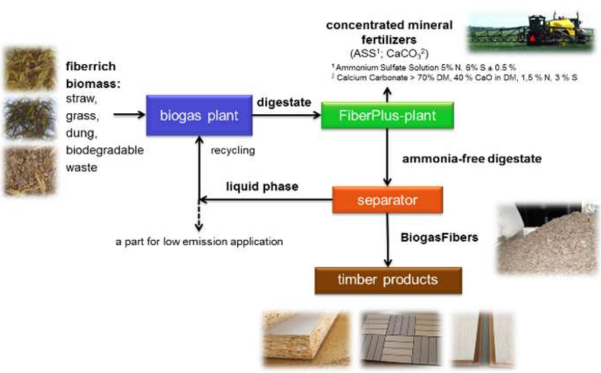
Benas-GNS, Ottersberg (GE)

Biogas production

The biogas produced every year is around 20 Mm³ (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 (Mm³)	20
Biogas per tonne of feedstock (m³/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/m³ 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 m³/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.

Benas-GNS, Ottersberg (GE)

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:

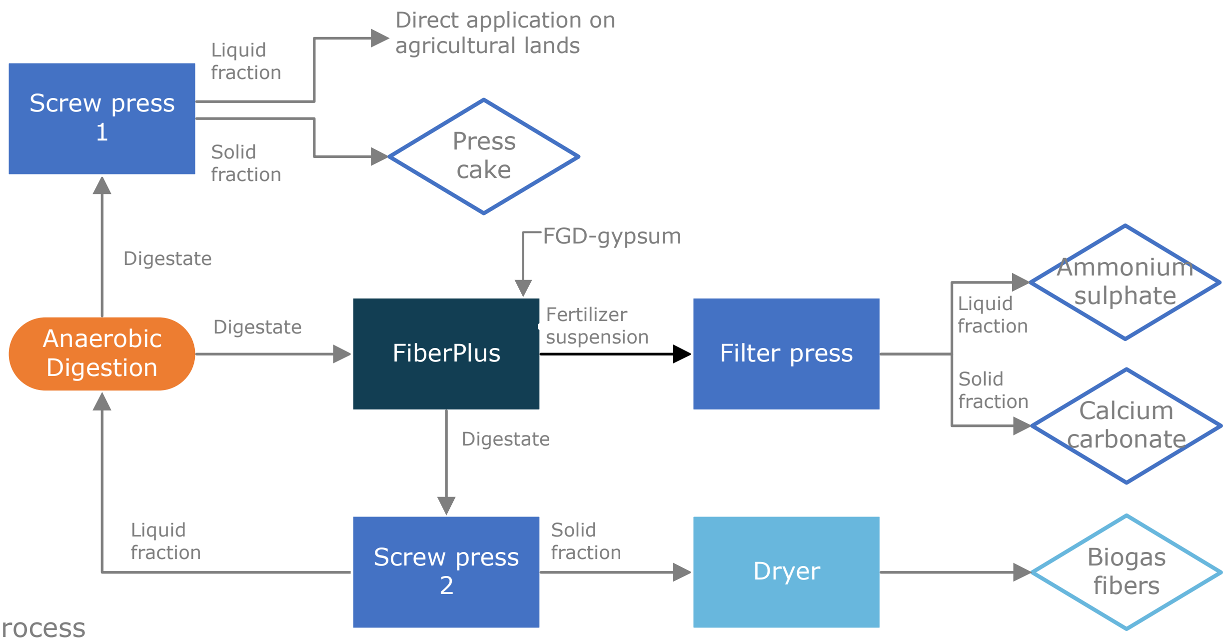
- Digestate recycling after stripping and consequent higher biogas yield,
- Increase of chicken manure as substrate at lower prices (up to 50% of actual incoming N is contained in the dry chicken dung) and
- Efficient heat utilization.

Sustainability goals

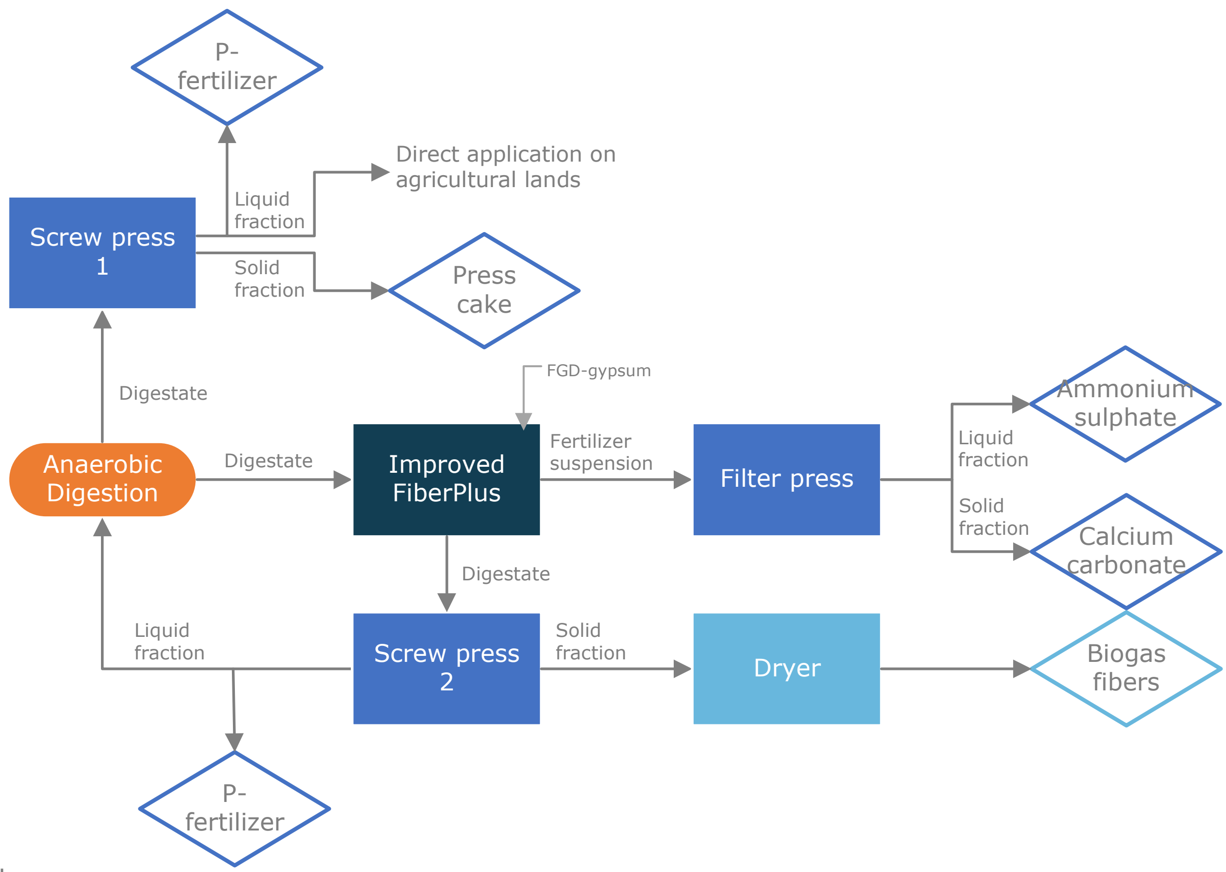
Benas is committed to reach the following targets:

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

Annex 5: Benas-GNS Demonstration installation – Ottersberg (DE)



Current process



Envisaged process

Technical specifications:

Current process

Name	Type	Treatment capacity (t/h)	Power consumption (kW)	Heat requirement (kW)
FiberPlus	Stripping	9.6	37	900
Screw press 1	Mechanical separation	9.4	3	-
Filter press	Mechanical separation	0.6	6	-
Screw press 2*	Mechanical separation	9.1	3	-
Dryer*	Drying	0.5	1	300

*Optional, depending on selling of biogas fibers

Envisaged process*

Name	Type	Treatment capacity (t/h)	Power consumption (kW)	Heat requirement (kW)
FiberPlus	Stripping	9.6	37	900
Screw press 1	Mechanical separation	9.4	3	-
Filter press	Mechanical separation	0.6	6	-
Screw press 2**	Mechanical separation	9.1	3	-
Dryer**	Drying	0.5	1	300

* Phosphorous recovery not included

** Optional, depending on selling of biogas fibers