



Cover Delivery Report

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<https://systemicproject.eu/>

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Construction, monitoring, and demonstration activities at the demonstration plants (year 3)



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Preface

SYSTEMIC is funded under the H2020 framework programme of the European Commission (project number 730400). The five demonstration plants form the heart of the SYSTEMIC project and are locations where innovative nutrient recovery and reuse (NRR) processing techniques are being implemented, monitored and evaluated on their technical, economic and environmental performance. The five demonstration plants received EU funding to cover part of their investment costs, to collect monitoring data and to organise dissemination activities. This document gives an update of the status of the construction, monitoring and demonstration activities at the five full scale demonstration plants within the SYSTEMIC project. It also provides an outlook to the activities planned for the next year.

Results obtained from the monitoring of the demonstration plants are extensively reported in deliverable 1.4 *'Third annual updated report on mass and energy balances, product composition and quality and overall technical performance of the demonstration plants'* and deliverable 1.12 *'Document on product characteristics, lab results and field trials'*.

Summary

The H2020 project SYSTEMIC aims to showcase circular solutions for processing of manure, bio-waste and sewage sludge at five large scale anaerobic digestion (AD) plants. These demonstration plants vary with respect to the type of feedstock that is processed and operate in different regions and hence under different market conditions. The plants demonstrate the effective combination of energy production through AD in combination with novel nutrient recovery and reuse (NRR) technologies at TRL 7 for the production of fertilizers.

This document gives an overview of the construction, monitoring and demonstration activities of the five SYSTEMIC demonstration plants in the third year of the project. The SYSTEMIC project started in May 2017 and one of the first tasks was to set up the demonstration plants. Benas was already fully equipped before the start of the project whereas others had to start with the basic design and engineering of the NRR installations. By the end of the third project year, all demonstration plants except the plant of RIKA Biofuels had completed the installation of the NRR installations and are now fully operational as envisaged.

Groot Zevert Vergisting (GZV) took the RePeat installation, which is innovative technology to recover phosphorous (P) and a low-P Organic Soil Improver (low-P OSI) from the solid fraction of digestate (SF), into use in spring 2020. Delays in the realisation occurred because no similar installation yet exists and because of uncertainties about the required specifications of the precipitation and settling tank. This seriously elongated the testing and engineering phase. Delays also occurred during purchasing of the installation components. In 2018, GZV commissioned the GENIUS installation (November 2018) which has since then produced a concentrate with a high nitrogen and potassium content (NK concentrate), clean water and SF. Together with WUR and Nijhuis Industries, both installations have been monitored continuously and samples have been taken every two to four weeks when there were no production issues. In the last year of the project, GZV will focus on optimisation of the RePeat technology and marketing of the end products.

AM-Power demonstrates a novel approach to reduce the volume of their liquid fraction of digestate (LF) and increase its nutrient concentration through a combination of evaporation and reverse osmosis (RO). Installation of the evaporators was completed by December 2019, though several technical adjustments had to be made afterwards in order to get it working. The delays in the construction of the evaporator at AM-Power were due to difficulties in acquiring a bank loan to cover their own investments in the evaporator. The major goal of AM-Power for the coming year is to produce permeate water that complies with Flemish discharging limits. To do so, the new RO unit and ion exchanger (IEX) will be finalized. Moreover, the dry SF and the evaporator concentrate will be blended to create an organic NPK fertilizer.

Acqua&Sole invested in a new advanced ammonia (NH₃) scrubber in order to increase the amount of ammonia that is recovered in the form of an ammonium sulphate fertilizer from their digestate. Acqua&Sole faced several delays due to slow authorization for the construction and, most importantly, due to difficulties in purchasing the required pipes of nickel-iron-chromium alloy 825 for the NRR installation. This alloy has an exceptionally high resistance against corrosion but is sparsely available. Acqua&Sole completed the construction of the scrubber at the end of 2019 and its process conditions are currently fine-tuned. In the last year of the project, Acqua&Sole will evaluate the performance and improvements of the scrubber on its ammonia recovery and on the quality of the produced ammonium sulphate solution.

Benas showcases an innovative nitrogen stripping technique (FiberPlus) in which ammonia is recovered as ammonium sulphate using gypsum as a source of sulphate. This installation was already in use prior to the start of the SYSTEMIC project and has been monitored by GNS and Ghent University since then. The FiberPlus installation also enables the production of organic fibres with a low ammonia content. In the last year of the project GNS will focus on marketing of the fibres as raw material for fibreboard.

RIKA Biofuels had planned to host a demonstration plant in cooperation with a chicken farm in the UK called Oaklands Farm Eggs in Shrewsbury (England). After a year, they had to switch to another location

because Oaklands Farm Eggs had withdrawn after the UK introduced a lower level of subsidy on biogas. RIKA Biofuels found an alternative farm called Fridays, in Kent (England) and has started construction at their site in 2019. The AD plant and its digestate processing installations will however not be completed before the end of 2020. Therefore it was decided that Fridays could no longer part of the SYSTEMIC project as a demonstration plant. In consultation with the project officer of the European Commission, the AD plant of Waterleau New Energy was appointed as demonstration plant replacing Fridays.

Waterleau New Energy, located in Ypres (Belgium), has already implemented novel NRR technologies at their AD plant including a dryer to produce solid organic fertilizer and an evaporator and RO unit to produce ammonia water and NPK concentrate. The AD plant is a good example of a company that managed to turn their digestate into products with a positive market value. Their organo-mineral NPK fertilizer slurry is sold in France and their ammonia water is sold to a waste incineration plant, which uses it in their DeNO_x system treating exhaust gases. At the start of the fourth year of the SYSTEMIC project, Waterleau New Energy will replace Fridays as a demonstration plant. The plant will be monitored on a regular basis and its case will be included in the upcoming SYSTEMIC deliverables.

Throughout the course of the project, the monitoring of the demonstration plants was harmonised. Mass and energy balances are now available for all demonstration plants, except Waterleau New Energy, and are presented in a similar format. From 2020 onwards, the monitoring campaigns have been extended with analysis of residues of herbicides, pesticides and pharmaceuticals. All demonstration plants have been very active in terms of demonstration activities. This is evident from the long lists of dissemination activities including site visits and open days. Each demonstration plant delivered a plant video which has been shared via the SYSTEMIC website. Plant videos were produced and shared via social media and the project website.

1 Groot Zevert Vergisting

This chapter describes the status and planning of construction of the Nutrient Recovery and Reuse (NRR) installations of the demonstration plant Groot Zevert Vergisting (GZV). The monitoring of these installations and the most important demonstration activities that have been performed by GZV are also explained.

1.1 Status and planning of construction

The anaerobic digestion (AD) plant of GZV is located in Beltrum, The Netherlands, in a region with intensive husbandry and a surplus of manure in terms of what can be regionally applied on agricultural land. GZV produces biogas by co-digestion of pig manure and agro-industrial residues. At the start of the SYSTEMIC project, GZV still exported the liquid digestate to Germany over distances of about 250 km. Since the start of the project, GZV has implemented two Nutrient Recovery and Reuse (NRR) technologies: (i) the RePeat installation for phosphorous (P) recovery from the solid fraction of digestate (SF) and (ii) the GENIUS installation for production of NK concentrate from the liquid fraction of digestate (LF). GZV now processes digestate into biobased fertilizers, a low-P organic soil improver (low-P OSI) and clean water which can be discharged to surface water. These innovations have led to a reduction in transport distances, since most of the products can be applied on agricultural lands in the region or can be used as secondary raw material in the fertilizer industry.

(i) RePeat installation for processing of the solid fraction of co-digested manure

GZV invested in a full-scale installation to separate the SF, which has a high P content, into a P fertilizer and a low-P OSI. The installation consists of two leaching steps in which the SF is leached with water and sulphuric acid (pH 5.0) to solubilize mineral P (Figure 1.3). After dewatering by means of a screw press, a low-P OSI remains. The liquid fraction with a high P concentration is first treated in a lamella clarifier to remove fine suspended particles and thereafter flows to a precipitation tank where P precipitates due to addition of a base, currently calcium hydroxide. The precipitated calcium phosphate sludge is recovered in a settling tank whereas the remaining liquid is reused within the process. The installation has a maximum treatment capacity of 17 kt of SF per year, which is similar to the amount of SF produced on site from 140 kt of digestate.

The RePeat installation has been fully operational since February 2020. Delays in the construction of RePeat were in part caused by difficulties in engineering of the installation as this is the first full scale P recovery installation of its kind. Therefore, additional pilot and laboratory tests were needed in order to design the precipitation tank. At the same time, employees of GZV and Nijhuis Industries were occupied with constructing, testing and adjusting the GENIUS installation. From a management point of view, the production of a concentrate with a high nitrogen and potassium content (NK concentrate) with the GENIUS installation had the highest priority. This because of contracts that state that this product has to be applied on agricultural lands, in the region. In spring 2019, GZV started purchasing the equipment for the RePeat installation. Purchasing the precipitation tank gave a serious delay. The precipitation tank is conus-shaped and has a volume of about 70 m³. It is equipped with a rotator and aerator as well as sensors and dosing points for chemicals. Delivery time on this large and special tank was longer than expected. The precipitation tank was delivered in September 2019 (Figure 1.1) and installed on-site in October. Thereafter, instalment of piping, cables and electronics started. In February a large part of the wiring and sensors were installed that allow detailed monitoring of the system. From that point onwards, the installation was in use for testing. In March 2020 an extra mixing tank was placed between the first and second screw press as mixing turned out to be insufficient in the tubes between the two. The last software bugs were removed and the installation was able to operate automatically in April.

In 2020, the RePeat installation will be further optimised to reduce the chemical consumption and improve the product quality. Also, tests will be done to compare the performance of different bases, amongst others

(Ca(OH)₂ and Mg(OH)₂), resulting in different types of P fertilizers. Monitoring of the RePeat installation has started in March 2020. GZV is also actively looking into opportunities to increase the market value of their end products. For example by upgrading the low-P OSI to an ingredient for potting soil. Furthermore, GZV has just started a field trial to demonstrate the effectiveness of their low-P OSI to local farmers.



Figure 1.1 Photos of the new RePeat installation at Groot Zevert Vergisting (left; screw presses, right; stainless steel settling tank, stainless steel precipitation tank and a black buffer tank).

GENIUS process for treatment of the liquid fraction of digestate

The GENIUS installation consists of multiple separation units including two (sequential) decanter centrifuges, a hygienization unit for the SF, a dissolved air flotation unit (DAF), a microfiltration (MF) unit, two sequential reverse osmosis (RO) units and an ion exchanger (IEX) (Figure 1.2). Engineering and installation were performed by Nijhuis Industries. The investments in the GENIUS installation are not part of GZV's SYSTEMIC budget, but monitoring of the GENIUS installation and its products is part of the SYSTEMIC project.

The GENIUS installation was constructed in 2018 and commissioned in January 2019 and has been in operation since then. Since commissioning, the installation has undergone several adjustments to improve the process and its products. At first, the decanters operated parallel to each other in two process lines but in May 2019 the decanters were placed sequentially in one process line to improve the removal of fine particles from the liquid fraction. Since July 2019 the sludge of the DAF is added to the influent of the 2nd decanter instead of to the post-digester. This adjustment has been undone in October 2019 and at the time of writing the sludge of the DAF flows to the post-digester. Also in October 2019 the location where the majority of sulphuric acid is added to the RO, was changed from before the first RO to before the second RO. For roughly half a year, until December 2019, all MF sludge was trucked off site. Since December 2019 roughly 40% of the MF sludge is returned to the digester and the remainder is trucked off-site and applied as fertilizer on agricultural land. In January and February 2020 all 60 tubes of the RO unit were given new membranes.

Decanter centrifuges



Microfiltration unit



Reverse osmosis unit



Ion exchanger



Figure 1.2 Photos of the GENIUS installation for the production of solid fraction of digestate, NK concentrate and clean water from digestate.

1.2 Monitoring activities

Monitoring of the AD plant prior to implementation of NRR (reference situation)

In 2018, prior to commissioning of the NRR installations, monitoring of the AD plant started to make mass and energy balances in order to establish the reference situation for GZV.

The monitoring included:

- Monthly analysis of N, P and K concentrations in the digestate
- Collection of data on the use of chemicals at the AD plant including additives used for biogas desulphurisation
- Biogas and electricity production
- Consumption of electricity and heat for the major installations including the AD plant, desulphurisation unit and the hygienization unit

Monitoring of the RePeat installation

The following aspects are included in the standard monitoring programme of the RePeat installation:

- Sampling of the ingoing, internal and outgoing flows (Figure 1.3) occurs every two to four weeks if the installation is running without problems. Sampling locations have been chosen as such that a mass balance can be made for each process step. Samples are sent to a commercial lab and analysed on:
 - Dry matter (DM) and organic matter (OM) content
 - N, NH₄, P, K and S content
 - Ca, Mg, Fe, Zn and Cu content
 - pH
 - Density
- Measurement of the in and outgoing and internal flows. In total, eight flow meters are placed upstream and downstream of the individual process steps and return flows that are shown in Figure 1.3. A weighing belt measures the weight of the ingoing SF. Weight of the end products, the calcium phosphate and low-P OSI, are manually recorded respectively per big bag and truck that leaves the plant.
- Electricity consumption of the RePeat installation is automatically measured in three power groups. These three groups consist of:
 - Group 1: conveyer belt for solid fraction of digestate, pumps and mixer for addition of process water and the mixer of the first acidification tank.
 - Group 2: screw presses, pumps before screw presses, mixer in between screw presses, dosing pumps for sulphuric acid and the pump for the sludge of the lamella clarifier
 - Group 3: pumps for the phosphate reactor and settling tank, mixers of the phosphate reactor and base storage tank, base dosing pump and the aeration of the phosphate reactor.
- Chemical consumption rate, for sulphuric acid and base, is tracked automatically.

Next to the standard monitoring programme the following parameters are monitored less frequently:

- Heavy metals (lead, cadmium, chromium, nickel, arsenic and mercury)
- End products are analysed on residues of organic micropollutants (herbicides, pesticides and pharmaceuticals) three times per year.

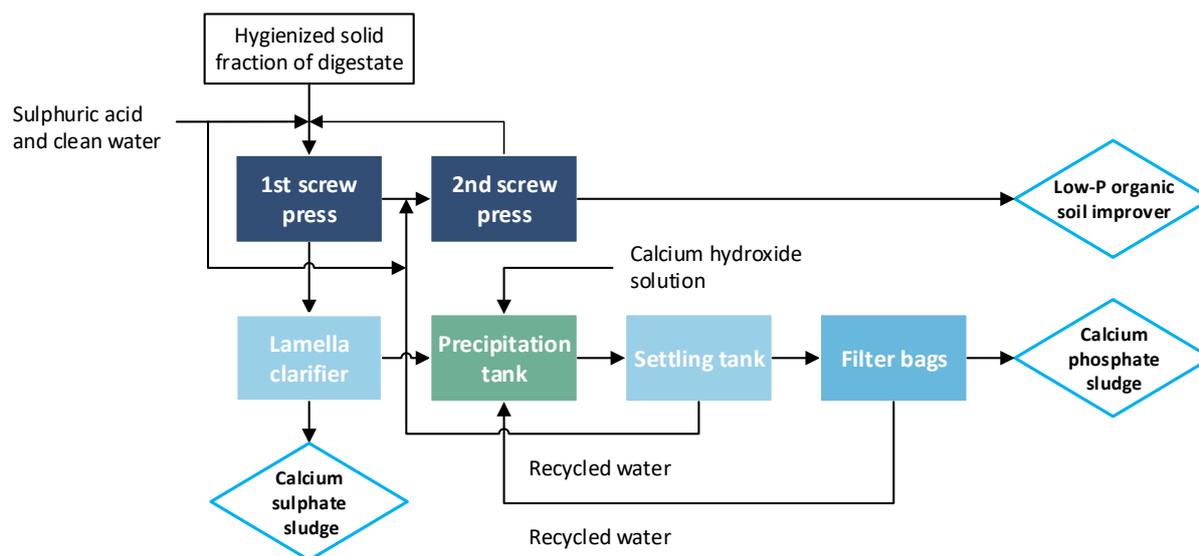


Figure 1.3 Process flow diagram of the RePeat installation at the demonstration plant Groot Zevert Vergisting including locations of chemical addition and the major return flows (as configured in May 2020).

Monitoring of the GENIUS installation

Monitoring of the GENIUS installation started in April 2019. The following aspects are included in the standard monitoring programme of the GENIUS installation:

- Sampling of the ingoing digestate, internal flows and end products occurs every two to four weeks if the installation is running without problems. Samples are sent to a commercial lab and analysed on:
 - DM and OM content
 - N, NH₃, P, K and S content
 - Ca, Mg, Fe, Zn and Cu content
 - pH
 - Density
- Measurement of the in- and outgoing and internal flows. Flow meters are placed upstream and downstream of each of the individual process steps that are shown in Figure 1.4. In case an individual process step consists of separate concatenated process elements, a flow meter is also placed in between those elements. This is, amongst others, the case for the RO unit which consists of two concatenated RO elements. For streams where flow meters cannot be placed, for example because the stream is no pumpable liquid, the flow is calculated from the known flows upstream and downstream of it in combination with the measured concentrations. Flow rates are automatically measured and recorded and daily-averaged numbers are sent to Wageningen Environmental Research for data processing. Mass balances for the installation as a whole and its individual process steps are set up by combining the measured flows and concentrations in Microsoft Excel.
- Total consumption of chemicals, amongst others of sulphuric acid, polymeric flocculant, antiscalant and anti-foaming agent, is determined on a half year basis based on procurement.
- Chemical consumption rate is tracked automatically by monitoring the pumping speed in combination with the concentration and, if applicable the dilution ratio before injection into the process.
- Electricity consumption of the AD plant as a whole, including the NRR installations, is monitored on a yearly basis. The electricity consumption for individual process steps is estimated from the machine wattages.
- Natural gas consumption of the infrared hygienization unit is monitored on a monthly basis.

Next to the standard monitoring programme the following parameters are monitored less frequently:

- Heavy metals: lead, cadmium, chromium, nickel, arsenic, cobalt, mercury.
- End products are analysed on residues of organic micropollutants (herbicides, pesticides and pharmaceuticals) three times per year.
- Pathogens

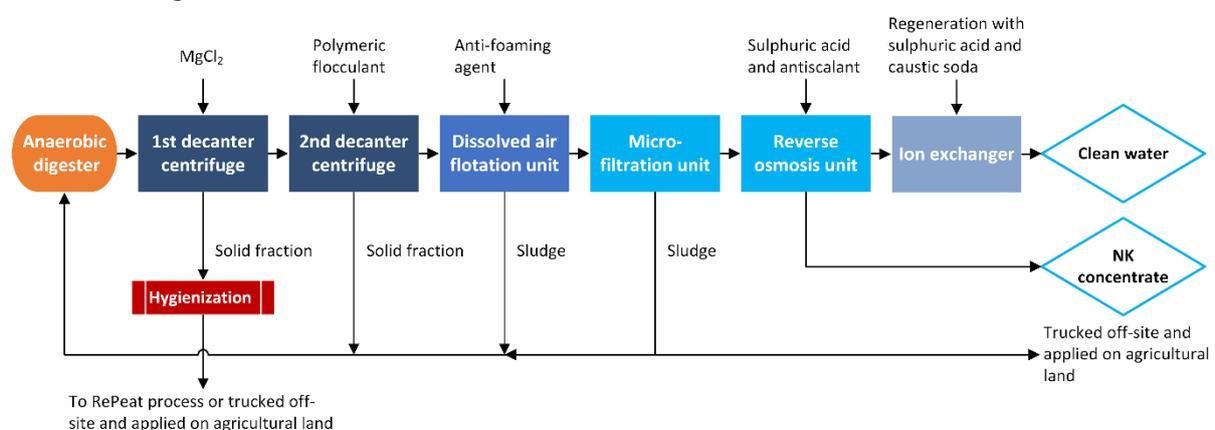


Figure 1.4 Process flow diagram of the GENIUS installation at the demonstration plant Groot Zeverit Vergisting, including locations of chemical addition and the major return flows (as configured in May 2020).

1.3 Demonstration activities

Since the start of the SYSTEMIC project in 2018, there have been over 30 visits to the AD plant of smaller and larger groups. A full list of dissemination activities is available in SYSTEMIC's report on dissemination activities. Underneath, a selection of key events is given.

Key demonstration activities:

- 4 September 2019: The Green Mineral Mining Centre of GZV was officially opened by her majesty Queen Máxima of the Netherlands. About 200 invited visitors attended the official opening ceremony. [Read the news item here \(English\)](#).
- 16 May 2019. Plant visit to GZV organised by VCM and BiogasE as part of Work Package 3 of SYSTEMIC. The 40 visitors were mostly representatives from private companies including AD plants, fertilizer trading companies and engineering companies.
- 11 September 2019. Online release of a [plant movie](#) for the general public (In Dutch).
- Tes 29 May 2019. Online release of a plant movie for farmers and engineers in [Dutch](#) (4,500 views) and [English](#) (350 views).

2 AM-Power

This chapter describes the status and planning of construction of the NRR installations of the demonstration plant AM-Power. The monitoring of these installations and the most important demonstration activities that have been performed by AM-Power are also explained.

2.1 Status and planning of construction

In order to reduce the costs of digestate processing, AM-Power installed a vacuum evaporator as part of the SYSTEMIC project. Previously, the digestate was diluted with the LF and fed to the decanter centrifuge for mechanical separation. There polymeric flocculant and iron sulphate were added to boost coagulation and flocculation. The SF was dried in a fluidized bed drier and the remaining LF was treated by a DAF unit where iron chloride was added. The effluent of the DAF unit was fed to the RO unit. The main bottlenecks of this process were the low treatment capacity (digestate needed to be highly diluted with LF before separation) and the heavy load on the RO units which necessitated much maintenance on the RO membranes. The vacuum evaporator consists of two identical units that are parallelly placed, each with an evaporation capacity of $150 \text{ m}^3 \text{ d}^{-1}$. Also a new RO installation was installed and an IEX will be installed to improve product quality.

In 2017, AM-Power defined all the technical specifications for the vacuum evaporator, after that its financing was arranged. Figure 2.1 shows the process flow diagram of the initially envisaged NRR facility of AM-Power.

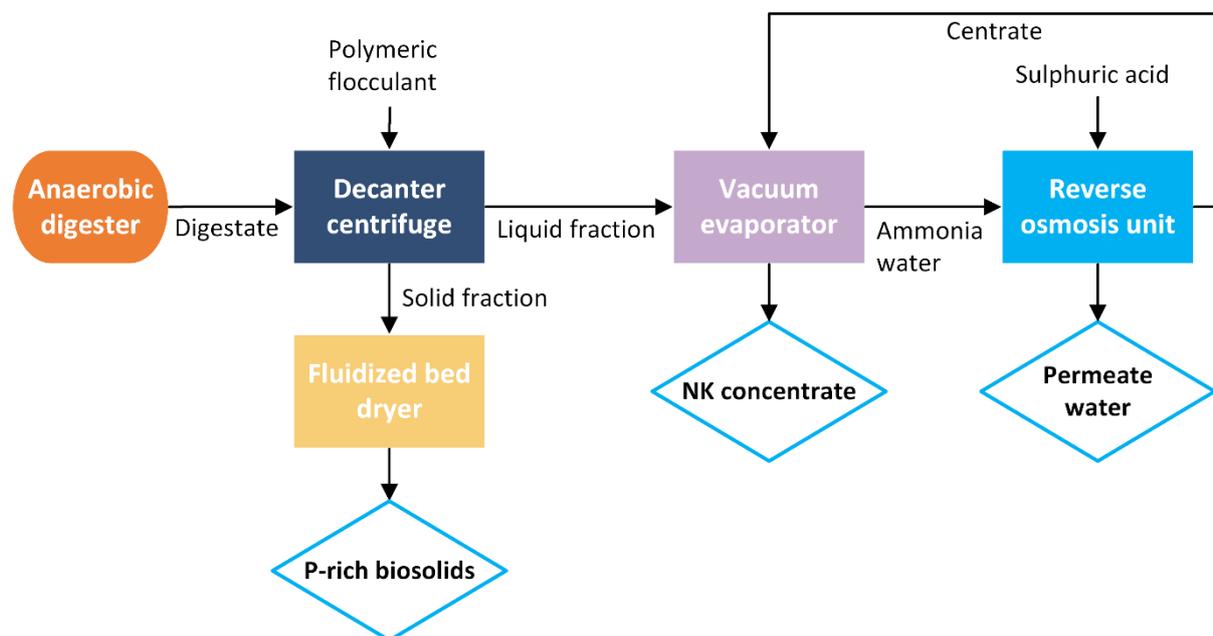


Figure 2.1 Process flow diagram of the initially envisaged NRR facility of the demonstration plant AM-Power.

The first of the two vacuum evaporator units was delivered in January 2019 and connected to the decanter centrifuge in April 2019. The second vacuum evaporator unit was delivered in April and installed in June 2019. Pictures of both units are shown in Figure 2.2. The start-up of the vacuum evaporator and the initial tests with water as the liquid to be treated, were successful. Further tests were conducted with the LF as the liquid to be treated and the results were encouraging. After evaporation, the DM content of the treated LF was 22%. The tests with the vacuum evaporator showed a total increase in DM content of the LF up to 4–5 times compared to the ingoing digestate. In September 2019, AM-Power investigated the optimal polymer dosage for the performance of the vacuum evaporator. K-revert, the supplier of the evaporator, finalized some technical aspects and implemented the software for the remote control of the evaporator.

Further tests performed until December 2019 with the initial configuration resulted in a very high pH of the evaporator distillate. This required a high dosage of sulphuric acid on the RO units (Figure 2.3). Moreover, the total nitrogen (TN) content of the RO permeate ($108 \pm 52 \text{ mg L}^{-1}$) did not comply with the Flemish discharging limits (15 mg L^{-1}). Therefore AM-Power decided to add an acidification step prior to the evaporator to reduce the evaporation of ammonium in the evaporator. This furthermore resulted in an N-rich evaporator concentrate which can be mixed with dried biosolids into an organic NPK fertilizer. Although not part of the SYSTEMIC project, as a polishing step for the RO permeate, an IEX has been installed that has not yet been commissioned (Figure 2.4). This will result in water that adheres to the Flemish discharging limits.



Figure 2.2 The vacuum evaporator installed at the demonstration plant AM-Power (2019).



Figure 2.3 The new reverse osmosis unit installed at the demonstration plant AM-Power (2020).



Figure 2.4 The new ion exchanger installed at the demonstration plant AM-Power (2020).

The vacuum evaporator has been operational since January 2020 and K-Revert currently examines the possibilities to maximize its efficiency. The acidification installation prior to the evaporator has been completed as well. The RO unit has been placed and sensors, control software of the PLC and cabling of the pumps are expected to be completed by June 2020. No commissioning date for the IEX has been determined yet. The process flow diagram of the final NNR facility of AM-Power is depicted in Figure 2.5.

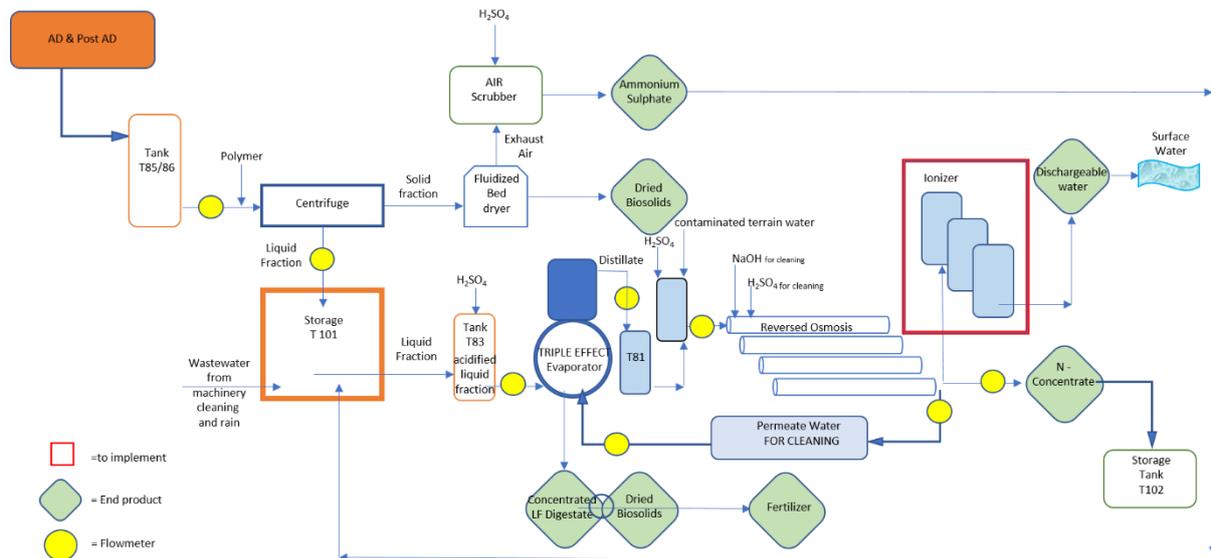


Figure 2.5 Process flow diagram of the final NNR facility of the demonstration plant AM-Power.

2.2 Monitoring activities

Since the start of the SYSTEMC project, the mass of the digester feedstock, biogas production and electricity generation and consumption have been monitored. Conversely, for digestate and all final products generated, only estimations are available (Table 2.1).

Table 2.1 Production of biogas, methane (CH_4) as constituent of that biogas, digestate and final products of the demonstration plant AM-Power for the years 2017–2019.

Component	Unit	2017	2018	2019
Total biogas production	MNm ³	18	14	17
Specific biogas production	Nm ³ t ⁻¹ digester feed	108	103	111
Total CH ₄ production*	MNm ³	9.9	7.6	9.2
Specific CH ₄ production*	Nm ³ CH ₄ t ⁻¹ organic matter	216	206	223
Digestate	t	170 590	134 420	161 280
Mineral concentrate	t	≈ 65 000	≈ 65 000	≈ 65 000
Permeate water	t	≈ 55 000	≈ 55 000	≈ 60 000
Dry biosolids	t	7 868	4 492	≈ 4 000

*calculated

In the years 2017 and 2018 monitoring activities were carried out by collecting data directly from AM-Power. The information provided by the demonstration plant included the chemical characterization of intermediate and final products, the yearly production of digestate and biogas, the biogas composition and the yearly energy production. No information on process flows was available regarding flows production, and the mass balance extrapolated from the calculation of flow streams were not reliable. AM-Power installed flow meters such that Ghent University could monitor the NNR installation from September 2018 onwards.

A short sampling campaign was conducted by Ghent University, which included the sampling of intermediate process flows and final products generated at AM-Power during the period September–October 2018. A thorough characterization of intermediate process flows and final products is available for this period. However no flowmeters were operational during this period and monitoring was interrupted due to the construction of the vacuum evaporator. Therefore, mass balances for this period are not optimal. The samples taken were analysed by Ghent University on:

- DM, OM and total organic carbon (TOC)
- pH, electrical conductivity (EC)
- TN, NH₄, P, K, S, Ca, Mg, Na
- Cu, Zn, Al, Fe, Co, Cd, Cr, Mn, Ni, Pb
- Residues of pharmaceuticals, herbicides and pesticides (twice per year)

By the end of 2019, flow meters were operational to monitor ingoing and outgoing streams of the different process steps. A new sampling campaign of the NNR plant was started by Ghent University in January 2020. This included monitoring the mass balance, consumption of additives and assessment of product quality. However, AM-Power was temporarily stopped at the end of February. After restarting the monitoring was interrupted due to measures to mitigate the global coronavirus outbreak.

Flow meters are installed at the following sampling locations:

- Decanter centrifuge: at the ingoing digestate, the place where polymers are added and the outgoing liquid fraction
- Vacuum evaporator: at the ingoing liquid fraction of digestate, the ingoing tap water for rinsing of the evaporator and at the outgoing condensate
- RO unit: at the ingoing distillate, outgoing permeate water and outgoing N concentrate

The implementation of flow meters at the RO unit is essential for a reliable mass balance since it is not possible to calculate flows based on the DM content of the evaporator condensate.

Detailed mass balances and an assessment of the product quality are included in deliverable 1.4 ("*Third annual updated report on mass and energy balances, product composition and quality and overall technical performance of the demonstration plants*") and deliverable 1.12 ("*Document on product characteristics, lab results and field trials*").

2.3 Demonstration activities

In 2017/2018 three plant visits to AM-Power were held, two for the Outreach Locations Atria and Biogas Bree and one for the associated plant ENSY AB.

As part of a SYSTEMIC workshop, a guided visit to AM-Power was organised on the 18th of September 2019 with around 45 visitors. A second visit was held on 27 September 2019 under the guidance of Stefania Rocca (H2020 SYSTEMIC advisor) and Erik Meers (H2020 SYSTEMIC WP1 leader) with a delegation of EC representatives.

3 Acqua&Sole

This chapter describes the status and planning of construction of the NRR installations of the demonstration plant Acqua&Sole. The monitoring of these installations and the most important demonstration activities that have been performed by Acqua&Sole are also explained.

3.1 Status and planning of construction

The N-rich digester feedstock which is processed at Acqua&Sole may lead to inhibiting levels of ammonia in the digester and ultimately failure of the digestion process. N stripping allows ammonia levels to be maintained below inhibiting concentrations and to simultaneously recover ammonia in the form of the mineral N fertilizer ammonium sulphate. Acqua&Sole joined the SYSTEMIC project with the goal of demonstrating a novel N recovery absorber which enables, in combination with the stripper, higher N recovery from digestate (Figure 3.1). This is possible thanks to the construction material used, the nickel-iron-chromium alloy 825, which allows a higher process temperature and is more acid resistant than regularly used iron alloys. Moreover, the novel absorber design enables a higher gas flow rate, which will in turn increase the amount of ammonia recovered.

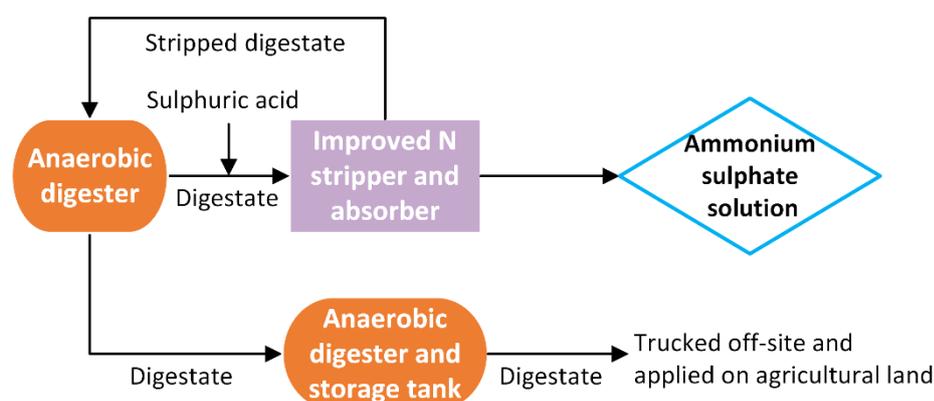


Figure 3.1 Process flow diagram of the final NRR facility of the demonstration plant Acqua&Sole.

The implementation phases of the N absorber are summarized as follows. The design phase of the N absorber started in April 2018 and was completed in May 2018. The contracts with suppliers were finalized in the first week of June 2018, followed by the purchase of materials. Initially, construction works were scheduled between October and December 2018 and installation and testing of the equipment were supposed to be finalized between December 2018 and January 2019. However, the authorization for the construction of the new absorber was only obtained from the Province of Pavia in April 2019. This caused a delay in the construction works. The start-up of the plant was rescheduled for the end of 2019, but the delivery of recirculation pipes (made of alloy 825) for the ammonium sulphate pipes was delayed by six weeks by the purchasing company. The construction of the N absorber (Figure 3.2) was completed by the end of 2019 and the administrative technical testing was completed on the 3rd of March 2020. Currently, Acqua&Sole optimizes the operational conditions, and so far 27% of ammonia removal is achieved. This is a 35% higher removal than with the previous absorber, which could remove about 20% of ammonia, but not yet as high as anticipated. The N removal rate of the new absorber will be optimised in the coming months.



Figure 3.2 Photo of the N absorber installed at the demonstration plant *Acqua&Sole* (2020).

3.2 Monitoring activities

Since 2017, mass of feedstock input, biogas and methane production, power generation and consumption are tracked. Similarly, digestate and ammonium sulphate production are closely monitored (Table 3.1). Since 2018, the performance of the AD plant and NNR unit, together with the characterization of both digestate and ammonium sulphate, are tracked on monthly bases.

Table 3.1 Production of biogas, methane (CH_4) as constituent of that biogas, digestate and ammonium sulphate of the demonstration plant *Acqua&Sole* for the years 2017–2019

Component	Unit	2017	2018	2019
Total biogas production	MNm ³	4	2.3	3.3
Specific biogas production	Nm ³ t ⁻¹ digester feed	56	52	40
Total CH ₄ production	MNm ³	2.3	1.4	2.1
Specific CH ₄ production	Nm ³ CH ₄ t ⁻¹ organic matter	202	203	198
Digestate	t	91 245	59 570	112 322
Ammonium sulphate	t	722	637	571,2

Acqua&Sole normally operates seven months per year, from January until July. In 2018, monitoring was therefore conducted for these seven months. In August and September 2018 the plant was not operational due to a legislative block. It however restarted in October and was again fully operational by January 2019. In 2019, the monitoring was expanded to ten consecutive months instead of seven. Since 2019, the University of Milan has performed a thorough chemical characterization of the produced digestate and ammonium sulphate.

The following is included in the monitoring programme of the NNR facility of Acqua&Sole:

- Monthly sampling of the produced digestate and ammonium sulphate. Samples are sent to a commercial lab and/or to University of Milan and analysed on:
 - DM, OM, TOC
 - pH, EC
 - TN, NH₄-N, P, K, S, Ca, Mg, Na
 - Cu, Zn, Al, Fe, Co, Cd, Cr, Hg, Mn, Ni, As, Pb, Se, Mo
 - Pathogens, weed seeds, glass and plastic particles,
 - Residues of pharmaceuticals, herbicides and pesticides (twice per year)
- Measurement of the in- and outgoing and intermediate flows. The flows are automatically recorded and monthly-averaged numbers are send to Ghent University for further data processing

- Consumption rates of sulphuric acid are collected on a monthly basis
- Electrical and thermal energy production and consumption of the plant as a whole are monitored on a monthly basis

3.3 Demonstration activities

In the first year of the SYSTEMIC project the demonstration plant of Acqua&Sole was visited by SYSTEMIC consortium members (including employees of other demonstration plants), as part of the general assembly held in Milan (Italy) in May 2018.

As every year, Acqua&Sole organized an open day at their AD plant. Moreover:

- in 2018 a total of 15 visits to the plant were organized. Visits organized for specific groups, such as farmers or public institutions, included on average 10 to 20 people; while events organized in collaborations with schools reached groups of 80 students
- in 2019 a total of 20 visits to the plant were organized.

4 Benas

This chapter describes the status and planning of construction of the NRR installations of the demonstration plant Benas. The monitoring of these installations and the most important demonstration activities that have been performed by Benas are also explained.

4.1 Status and planning of construction

Benas operates an innovative stripper developed by GNS (Gesellschaft für Nachhaltige Stoffnutzung), the FiberPlus stripper, to recover N from the produced digestate. This is done to meet the N application limits imposed by the German Fertilization Regulation (DüV) for agricultural land. Figure 4.1 shows the process flow diagram of the NRR facility of Benas. Removal of ammonium by the stripper reduces the risk of ammonium inhibition when poultry manure is used as feedstock. It also simultaneously recovers N in the form of an ammonium sulphate solution, a biobased mineral N fertilizer. Furthermore organic fibres and a soil improver, the press cake, can be produced.

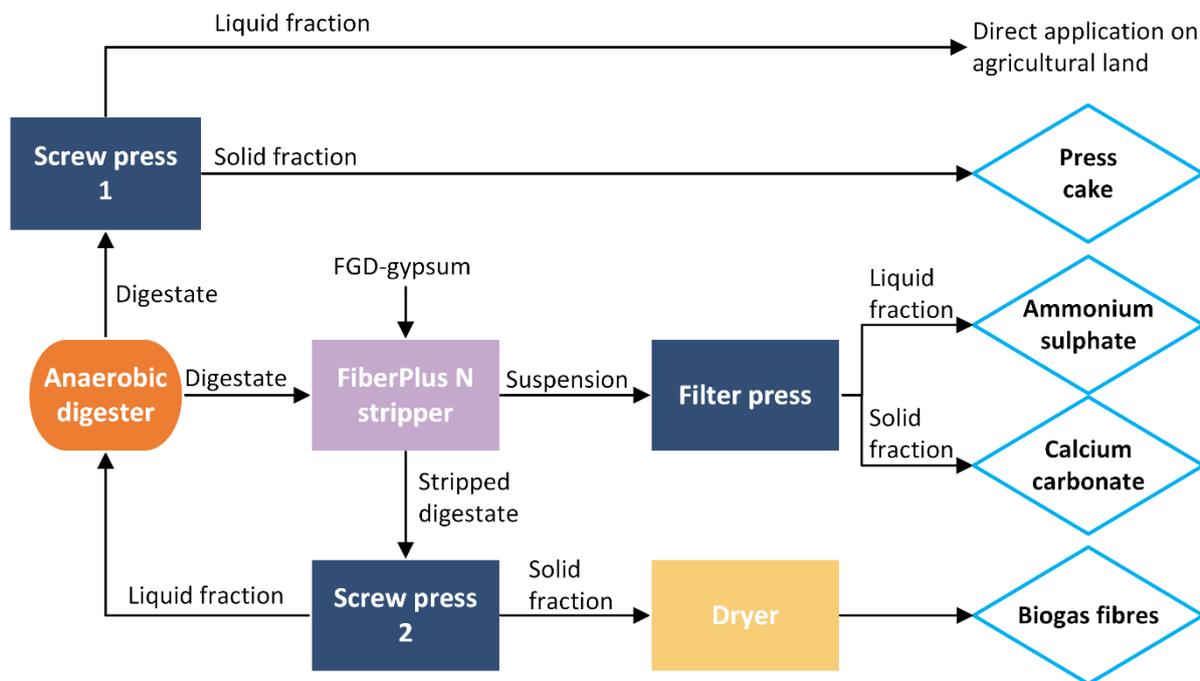


Figure 4.1 Process flow diagram of the final NRR facility of the demonstration plant Benas.

An ammonia stripper has been continuously operational since October 2016 and the produced dried fibres have been tested in large scale trials in the fibre industry. Nonetheless, the automatic operation of the fibre separation and washing unit with two screw presses can still be improved to a more cost effective fibre production. At the time of writing, the installations for fibre production are operational though fulltime production of fibres will only start once Benas has found a customer for them. Benas plans to produce 6 kt of dry fibres in 2020.

To make the energy production of the AD plant more flexible, in 2018 Benas started constructing an additional biogas reservoir with a volume of 12,000 m³ and a biogas storage capacity of 8,870 m³. In 2019, construction of the reservoir was completed. Also two additional 3 MW combined heat and power (CHP) installations with a conversion efficiency to electrical energy of over 44% were installed. Next to that, all digesters were given new roofs (Figure 4.2). Most of the construction work was already completed in 2018 and the AD plant has been operational with these additions from January 2019 onwards. Since January 2019 the AD plant has operated with flexible power generation. For power grid

stabilization, the AD plant is sometimes disconnected from the grid for a few hours by the grid owner, externally controlled. During this period, the produced biogas is stored in the reservoirs and no power and heat are produced. Since the FiberPlus system relies on waste heat from the CHP installations, the FiberPlus system turns into a "sleep mode" during these shutdown phases. The AD plant and its NRR installations operate successfully in a fluctuating grid stabilizing mode. This was demonstrated during the monitoring campaign performed by Ghent University between January and April 2019 (results reported in deliverable 1.4). Additionally, in 2019 new screw presses which achieve improved separation efficiencies were installed.



Figure 4.2 Aerial photo of the demonstration plant *Benas* (2019).

4.2 Monitoring activities

Since 2017, mass of the digester feedstock, production of biogas and methane (CH₄) as constituent of that biogas, electrical energy generation and electrical energy consumption have been monitored in collaboration with GNS. Similarly, the production of digestate and its products (solid and liquid fractions of digestate, ammonium sulphate, calcium carbonate and biogas fibres) are closely monitored (Table 4.1). Since 2018, the performance of the AD plant and its NRR installations and the composition of the digestate and its products are tracked for several months per year.

Table 4.1 Production of biogas, methane (CH₄) as constituent of that biogas, digestate and final products of the demonstration plant *Benas* for the years 2017–2019.

Component	Unit	2017	2018	2019
Total biogas production	MNm ³	20	16.9	20.4
Specific biogas production	Nm ³ t ⁻¹ digester feed	194	221	222
Total CH ₄ production	MNm ³	10.6	9	11
Specific CH ₄ production	Nm ³ CH ₄ t ⁻¹ organic matter		333	325
Digestate	t	74 886	61 200	65 542
Liquid fraction of digestate	t	57 286	51 316	49 167
Solid fraction of digestate	t	17 600	9 921	16 375
Ammonium sulphate	t	3 696	2 011	3 545
Calcium carbonate	t	1 088	592	1 287
Biogas fibres	t	<1 000	<1 000	< 1 000

The composition of products was analysed in 2017 over one month, August, and in 2018 over three months. However, in these monitoring periods not all products and internal flows were analysed on all desired parameters. A draft mass balance was made based on the in 2017 measured concentrations in the ingoing and outgoing flows of each process unit.

Monitoring activities were expanded in 2019. The automatically measured (one data point each second) and stored data from the control software of the FiberPlus installation was processed by GNS on a monthly basis. Gypsum consumption and calcium carbonate production were calculated by GNS and Ghent University. From January until April 2019, the chemical analysis of the products and internal flows was done by Ghent University.

Even after adopting the fluctuating grid stabilizing mode, the performance of the AD plant has improved in the following ways compared to 2018:

- Higher biogas production
- More biogas available for upgrading to biomethane
- Higher conversion efficiency of biogas energy to electrical energy (more electrical energy and less waste heat generated per m³ of biogas combusted)
- Higher N recovery and ammonium sulphate fertilizer production
- Less unprocessed digestate and more solid fraction of digestate per amount of digestate produced

In 2020, Ghent University conducted one sampling campaign in January and one in February. Chemical analysis of the samples was however, due to the measures to mitigate the global coronavirus outbreak, suspended until the end of May 2020. Since the start of the SYSTEMIC project, the fibre production at the plant has not been operational yet for a sufficiently long time that is required for monitoring. Fibre production is envisaged to start in June 2020.

The following aspects are included in the monitoring programme of Benas biogas installation:

- Sampling of the produced digestate, all internal flows and the final products. Samples are sent to Ghent University and analysed on:
 - DM, OM, TOC
 - pH, EC
 - TN, NH₄-N, P, K, S, Ca, Mg, Na
 - Cu, Zn, Al, Fe, Co, Cd, Cr, Mn, Ni, Pb
 - Pathogens (in ammonium sulphate and calcium carbonate)
 - Residues of pharmaceuticals, herbicides and pesticides (twice per year)
- Measurement of the in- and outgoing and internal flows. The flow rates are automatically recorded and monthly-averaged numbers are sent to Ghent University for further data processing
- Consumption rates of gypsum are collected on a monthly basis
- Electrical and thermal energy production and consumption of the plant as a whole are monitored on a monthly basis

Detailed mass balances and product quality assessment are included in deliverable 1.4 ("*Third annual updated report on mass and energy balances, product composition and quality and overall technical performance of the demonstration plants*") and deliverable 1.12 ("*Document on product characteristics, lab results and field trials*").

4.3 Demonstration activities

Since the start of the SYSTEMIC project, there have been over 32 demonstration activities for various target audiences. A full list of dissemination activities is available in the report on dissemination activities. This can be summarized as follows:

- Participation in six conferences (four presentation and two posters):
 - Biogas conference of the regional group Saxony-Anhalt of the German Biogas Association, October 2017, Halle (Germany)
 - FNR conference "Pflanzenbauliche Verwertung von Gärreststoffen aus Biogasanlagen" (Agricultural use of digestates from biogas plants); German specialist agency for renewable raw materials, www.fnr.de, July 2018, Berlin (Germany)

- Conference "Biogas from Straw" with the European Biogas Association, August 2018, Haiden (Germany)
- DFG (German-French Society) conference with urban partnership Halle/Grenoble, September 2019, Halle (Germany)
- "Biogas19" congress Austria, December 2019, St. Pölten (Austria)
- Abonocare conference "ORGANIC RESIDUES TO ADVANCED NUTRIENT", March 2020, Leipzig (Germany)
- Participation in five workshops with short statements/lectures:
 - Meeting of the Society for Renewable Resources Saxony-Anhalt NAROSSA e.V. (www.narossa-ev.de), August 2017, Magdeburg (Germany)
 - Three workshops "Ländliche Bioökonomie" (Rural bio economy); Institute for Applied Material Flow Management (IfaS), Trier University of Applied Sciences, September 2017 Birkenfeld, September 2018 Unsleben, March 2019 Berlin (Germany)
 - Workshop "Newfert" and "Phorwärts" joint event of two projects; October 2018, Brussels (Belgium)
- Four publications in German professional biogas magazines and series:
 - Proceedings "Gülzower Fachgespräche, Band 57", media library of www.fnr.de; ISBN 978-3-942147-38-5
 - Proceedings "Biogas aus Stroh 2018", www.messen-profair.de; ISBN 978-3-94777-01-3
 - Journal "Energie aus pflanzen" April 2019: "Nährstoff-Rückgewinnung international", ISSN 2194-6744
 - Journal "Umweltmagazin" September 2019 "Nährstoffe aus Gärprodukten", ISSN (Print) 0173-363X
- Eight publication campaigns in online media (newsletters, websites)
- Ten consultation meetings with interested appliers of NRR technologies
- Presentation of the SYSTEMIC project in numerous technical discussions with policy makers and researchers
- Movie of the Benas plant (in German with German and English subtitles) was published on the SYSTEMIC and GNS websites
- Open day at the Benas plant on 13 July 2019 with about 500 participants: the SYSTEMIC project in Germany was symbolized with EU and German flags in the hall. Posters and flyers related to the project were available for visitors in German and English
- An article in the local newspaper "MZ" on 7 June 2019 written by an independent journalist
- Two press releases in German about the General Assembly of the SYSTEMIC project held in Halle (Germany) in June 2019 with information about the project

5 RIKA Biofuels

The fifth demonstration plant was planned to be hosted by RIKA Biofuels as a to be build AD plant on a chicken farm in England. This AD plant would only be fed with poultry litter and would be equipped with a stripper for N to prevent ammonia toxification of the digester. It also would be equipped with processing installations for digestate to produce granular organic fertilizer. The initial site for the plant was a location in proximity of the chicken farm Oaklands Farm Eggs in Shrewsbury (England). The owner of the farm however had to withdraw, after changes in UK's renewable energy policy which seriously affected the business case of the AD plant. A new site was found at a large chicken farm called Fridays, in Kent. Initially it was expected that the AD plant and digestate processing at this farm would be operational by the end of 2019. Though construction started in 2019, it became evident that the plant would not be running in 2019 due to serious delays in the construction of the digester. RIKA Biofuels, at the time of writing, expects to commission the AD plant in October 2020 and the NRR installations in November 2020. There are still major steps in the construction to be taken and the engineering of the plant is performed by other parties, not associated with SYSTEMIC. As this engineering is not part of the SYSTEMIC project, there is a dependency on others. As a consequence, the SYSTEMIC project cannot guarantee that this demonstration plant will be fully operational by the end of this year. Also, regardless of whether the planning will be realised, the SYSTEMIC project will not be able to perform the promised actions in relation to Fridays as a demonstration plant before the end of the project. After discussing the situation with the project officer of the European Commission, the decision was made to eliminate Fridays as a demonstration plant. Also it was decided that the AD plant of Waterleau New Energy in Ypres (Belgium) will replace Fridays as a demonstration plant. The AD plant of Fridays will remain connected to the project as an Outreach Location.

6 Waterleau New Energy

This chapter describes the status and planning of construction of the NRR installations of the demonstration plant Waterleau New Energy (Waterleau). The monitoring of these installations and the most important demonstration activities that have been performed by Waterleau are also explained.

6.1 Status and planning of construction

Since the start of the SYSTEMIC project, the AD plant of Waterleau in Ypres (Belgium) has been involved in the project as an Outreach Location. From June 2020 onwards, Waterleau's plant will however be one of SYSTEMIC's demonstration plants, replacing the demonstration plant of Fridays in Kent (England). The Waterleau plant demonstrates the production of biogas, ammonia water, NPK concentrate, dried organic fertilizer and purified process water from pig manure and co-products. Since the AD plant was bought in 2013 by Waterleau Environmental engineering, it has implemented and improved NRR technologies. Thereby their digestate processing transformed into a positive business case due to the value of its products made up of recovered nutrients. Pig manure and solid fraction of pig manure constitute roughly 45% of the digester feedstock. The added co-products are organic waste streams (grain residues, molasses, glycerine and sewage sludge), and make up the remaining 55%.

Residence time in the digester, which is heated to 40 °C and is mixed, is 30 days and residence time in the post-digester is 10 days. The produced digestate is hygienized by heating it to 70 °C for one hour and afterwards separated into a solid and liquid fraction by a decanter centrifuge. The solid fraction of digestate is dried in a Hydrogone® dryer which can evaporate 1–1.8 t of water per hour. The evaporated water and the liquid fraction of digestate flow to an aerobic biological water treatment facility for partial lowering of their chemical oxygen demand (COD). The effluent of the water treatment flows to an evaporator where it is heated to 50–60 °C. Thereby the ammonia and water partially evaporate and are largely separated from each other based on volatility in the three consecutive stages of the evaporator. After condensation of these gaseous streams in the condenser this results in three liquids: ammonia water, process water and a concentrate rich in N, P and K (NPK concentrate). The process water can be treated by the RO unit into an ammonia solution, which is mixed with the ammonia water produced in the condenser, and purified process water. The purified process water is reused on site in the different treatment installations. Half of the final ammonia water (10 wt%) is mixed with the NPK concentrate and the other half is used as reductant in the DeNOx system which treats the exhaust gases of a Belgian waste incineration plant.

Small amounts of the NPK concentrate are mixed with the dried solid fraction of digestate, but the majority is exported as organo-mineral NPK fertilizer slurry which contains 9 kg N, 4.5 kg P and 20 kg K per tonne. The dried solid fraction of digestate is composted in Flanders (Belgium) and the resulting compost is exported to France. Figure 6.1 shows the process flow diagram of the final NRR facility of the demonstration plant Waterleau.

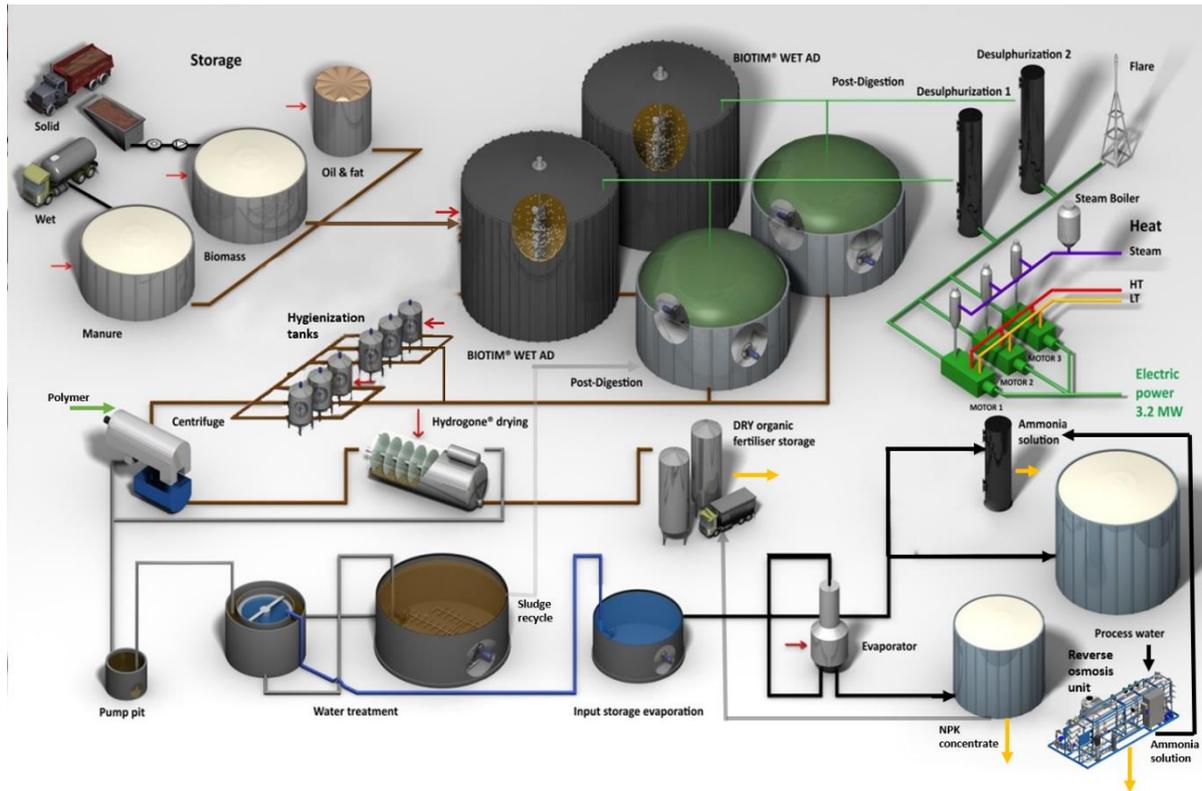


Figure 6.1. Process flow diagram of the final NNR facility of the demonstration plant Waterleau New Energy. Yellow arrows indicate final products, red arrows indicate locations where heat is reused (steam or hot water), HT: high temperature water (95 °C), LT: low temperature water (40 °C).

The pig manure fed to the digester has a higher N content than the organic waste streams, and thus contributes to a higher N concentration of the digestate. The pig manure therefore contributes strongly to the amount and concentration of the ammonia water and NPK concentrate that are produced. The NPK concentrate and ammonia water currently account for a large part of the disposal costs of the AD plant. This is due to the costs for transport of the ammonia water to the waste incineration plant and transport of the NPK concentrate to the Netherlands.

Waterleau currently investigates means to cut these costs, for example:

- Creating other products as alternative for ammonia water, as ammonia water is not a suitable fertilizer because of the high risk of ammonia emissions during application. Possible alternatives are urea and ammonium sulphate
- Drying the NPK concentrate to an even more concentrated fertilizer, as in that case less liquid needs to be transported which lowers the transport costs. The Hydrogone® dryer does not have the capacity to also dry the NPK concentrate. There however is heat available from the CHP's flue gases (190 °C) that is not being used and that could be applied in an alternative dryer for the NPK concentrate. Due to the high viscosity and high salt content of the NPK concentrate, it is technically difficult to dry it to a DM content of 20–30%.

The way in which the digester is fed also could be optimised to achieve a higher biogas production and associated higher biogas revenues. The feedstock is added to the digester as a mixture of pig manure and co-products. The combination of different types of feedstock in this mixture is limited by the mixture's DM content as it is brought into the digester by pumping. Adding more energy rich feedstock types, like potato starch waste, would make the DM content of the mixture surpass the pumpable limit. Therefore, Waterleau wants to adjust the digester's feeding regime to optimise the amount of energy

rich feedstock that is added. A new pump that can handle a higher DM content, or adding the energy rich feedstock types to the digester in a different way than by pumping could also solve this problem.

6.2 Monitoring activities

Monitoring is planned from June 2020 until June 2021. It will include monitoring campaigns on macronutrients, micronutrients and heavy metals. Data on mass flows from flow meters, purchasing and weighing will be provided by Waterleau. Similar as for the other demonstration plants, end products will be analysed on residues of pesticides, herbicides and pharmaceuticals.

6.3 Demonstration activities

Since the start of the SYSTEMIC project the following demonstration activities have been organised by Waterleau as an Outreach Location:

- Pitch presentation at the first SYSTEMIC Living Lab meeting for Outreach Locations that was held on 22 and 23 February 2018
- Two guided tours at their plant twice for other Outreach Locations and consortium members.
- Presentation at the workshop on digestate valorisation across the Belgian language border, during the Belgian biogas week on 27 November 2019
- A planned site visit to their plant for all interested Outreach Locations and Associated Plants in the autumn of 2020



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Horizon 2020

Systemic large-scale eco-innovation to advance circular economy and mineral recovery from organic waste in Europe

Consortium

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