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Construction, monitoring, and demonstration activities at the demonstration plants (year 4)

SYSTEMIC

Circular solutions for biowaste

2021

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Preface

This study was carried out as part of the European demonstration project SYSTEMIC funded by the H2020 programme (project number 730400). At the heart of the SYSTEMIC project are five large-scale biogas plants at which innovative nutrient recovery and reuse (NRR) processing technologies were implemented and which were monitored by the SYSTEMIC project team on their overall 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 on the status of the construction, monitoring and demonstration activities for the five large-scale demonstration plants within the SYSTEMIC project.

Results obtained from the monitoring of the demonstration plants are extensively reported in deliverable 1.5 *'Fourth annual updated report on mass and energy balances, product composition and quality and overall technical performance of the demonstration plants'* and deliverable 1.13 *'Document on product characteristics, lab results and field trials (Year 4)'*.

We would like to acknowledge and thank the plant owners and staff of Acqua & Sole (Italy), Am-Power and Waterleau NewEnergy (Belgium), BENAS and Gesellschaft für Nachhaltige Stoffnutzung (GNS, Germany), Groot Zevert Vergisting (the Netherlands) for delivering information about the status on construction, monitoring and demonstration activities for their demonstration plants.

The authors.

Summary

The H2020 project SYSTEMIC aims to showcase circular solutions for the processing of manure, biowaste and sewage sludge at five large-scale anaerobic digestion (AD) plants. These demonstration plants differ with respect to the type of feedstock which is processed, they 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 technology readiness level (TRL) 7, for the production of biobased fertilisers.

Groot Zevert Vergisting (GZV) implemented the RePeat system, an innovative process to separate the solid fraction (SF) of digestate into a phosphorous (P) fertiliser and a low-P organic soil improver, in spring 2020. Delays in the construction and commissioning occurred because no similar installation yet exists and because of uncertainties about the required specifications of the precipitation tank and settling tank. This seriously elongated the engineering and testing phases. Delays also occurred in the purchasing and delivery of the installation components. In 2018, GZV commissioned the GENIUS system (November 2018) which produces a concentrate with a high total nitrogen (TN) and total potassium (TK) content (referred to as reverse osmosis (RO) concentrate), purified water and SF of digestate. Together with Wageningen Environmental Research (WENR) and Nijhuis Industries, both systems have been monitored continuously and samples have been taken every two to four weeks, when there were no production issues. In the future, after project end, GZV is planning to focus on optimisation of the RePeat process and marketing of the end-products.

Am-Power (AmP) demonstrates a novel approach to reduce the volume of their liquid fraction (LF) of digestate and increase its nutrient concentration through evaporation followed by polishing of the condensed water by RO to remove volatile impurities. Installation of the evaporators was completed in December 2019, though several technical adjustments had to be made afterwards in order to get it working. After completion of the evaporators, AmP commissioned the RO unit in December 2020. The delays in the construction of the evaporator at AmP were due to difficulties in acquiring a bank loan to cover their own investments in the evaporator. At the start of the SYSTEMIC project envisaged treatment process, AmP was not able to produce a permeate water that complies with Flemish discharge limits. To overcome this issue, an acidification step prior to the evaporator was installed to retain most of the ammoniacal nitrogen in the form of ammonium (NH_4^+) in the evaporator concentrate. This lowered the TN concentration in the condensed water and thereby also in the RO permeate. The operation of the RO with the new setup, unfortunately, resulted in continuous fouling of the RO membranes and AmP is currently adjusting the overall process flow to circumvent this issue. As envisaged, the dried SF of digestate and the evaporator concentrate will be blended to create an organic NPK-rich fertiliser. At the time of writing, the mixing of these two products has not been tried out yet.

Acqua & Sole (A&S) invested in a new advanced ammonia (NH_3) scrubber to replace their existing scrubber in order to increase the amount of NH_3 that is recovered in the form of an ammonium sulphate (AS) solution from their digestate. A&S faced several delays due to slow authorisation for the construction and, most importantly, due to difficulties in purchasing the required pipes of nickel-iron-chromium alloy 825, a high performance material which allows to reach higher process temperature and that it is also more acid resistant. A&S completed the construction of the scrubber at the end of 2019 and the administrative technical testing was completed on the 3rd of March 2020. In addition, with the previous adsorption unit, biogas was used as stripping agent, while with the newly installed N-scrubber, biogas has been replaced by air. After leaving the stripping column connected to the second digester (AD2), the stripping agent is then passed through acid traps to recover NH_3. This is achieved by adsorption with a sulphuric acid 50% solution. The system does not require the addition of any chemical for pH control and the recovered product is a ~36% AS solution containing about 7.2% of NH_4-N. N-depleted digestate is recirculated back to the first digester (AD1). Therefore, N-stripping allows:

- a controlled High Solids Anaerobic Digestion (HSAD) process without NH_3 inhibition
- to produce a high quality mineral fertiliser (characteristics of AS are reported in deliverable D1.5).

A more detailed description of the ammonia extraction unit can be found in deliverable D1.5.

BENAS showcases an innovative N-stripping technique (FiberPlus) in which NH_3 is recovered as AS solution 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 NH_3 content. Different monitoring periods were carried out, with and without the production of biogas fibres. Since 2020, GNS started focusing on marketing of the fibres as raw material and has installed a paper making machine and a fibre moulding machine for producing fibre products like mulch mats, plant pots and paper rolls from the fibres. At time of writing, BENAS and GNS are actively looking for possible clients for the products.

Initially RIKA Biofuels had planned to host a demonstration plant. As the AD plant and its digestate processing installations were not completed before the end of 2020, it was decided to appoint **Waterleau NewEnergy (WNE)** as a demonstration plant instead. WNE, located in Ypres (Belgium), has already implemented novel NRR technologies at their AD plant including a dryer, to produce a solid organic fertiliser, and an evaporator and RO unit, to produce condensed ammonia water (AW) and evaporator concentrate. WNE is a good example of a company that managed to convert its digestate into products with a positive market value. Their organo-mineral evaporator concentrate fertiliser is sold in France and their AW is sold to a waste incineration plant, which uses it in its $DeNO_x$ system to remove NO_x from the exhaust gases.

Throughout the course of the project, the monitoring of the demonstration plants was harmonised. Mass and energy balances are now available for all plants, and are reported in deliverable 1.5 *'Fourth annual updated report on mass and energy balances, product composition and quality and overall technical performance of the demonstration plants'*. From 2020 onwards, the monitoring campaigns have been extended with analysis of residues of herbicides, pesticides and pharmaceuticals (reported in D1.13 '*Document on product characteristics, lab results and field trials (Year 4)'*). All demonstration plants have been very active in terms of demonstration activities until the COVID-19 pandemic outbreak as shown by the long lists of dissemination activities including site visits and open days. Each demonstration plant produced a plant video which has been shared via the SYSTEMIC website and via social media.

List of abbreviations

A&S: Acqua & Sole
AD: Anaerobic digestion
AmP: Am-Power
AS: Ammonium sulphate solution
AW: Condensed ammonia water
CC: Calcium carbonate
CHP: Combined heat and power
COD: Chemical oxygen demand
DAF: Dissolved air flotation
DM: Dry matter
EC: Electrical conductivity
FW: Fresh weight
GZV: Groot Zevert Vergisting
IX: Ion exchanger
LF: Liquid fraction
NRR: Nutrient recovery and reuse
OM: Organic matter
PLC: Programmable logic controller
RO: Reverse osmosis
SF: Solid fraction
TOC: Total organic carbon
WENR: Wageningen Environmental Research
WNE: Waterleau NewEnergy

List of definitions

Term	Definition
Digestate	Solid material remaining after the anaerobic digestion of a biodegradable feedstock.
Liquid fraction (LF) of digestate	LF of digestate after separation of digestate by a decanter centrifuge or screw press.
Solid fraction (SF) of digestate	SF of digestate after separation of digestate by a decanter centrifuge or screw press.
Reverse osmosis (RO) concentrate	Concentrate remaining after removal of water from a liquid stream (e.g. LF of digestate or condensed water) by RO.
Permeate water	Permeate after reverse osmosis, which needs further purification by means of ionic exchange prior to discharge to surface water.
Purified water	Water recovered from digestate by means of RO and IO (ionic exchange), purified to be used as process water or to be discharged to surface water.
Low phosphorus (P) soil improver	Solid fraction of the digestate after flushing with water and sulphuric acid to remove most of the P.
Precipitated phosphate salts	Precipitated phosphate salts, obtained by precipitation of phosphate (PO_4) with calcium, and which are recovered as a sludge.
Dried SF of digestate	SF of digestate after a thermal drying process.
Evaporator concentrate	LF of digestate, after evaporation of water and volatile components including ammonia.
Ammonium sulphate (AS) solution	Solution of AS obtained after ammonia stripping followed by recovery of gaseous ammonia in sulphuric acid (Acqua&Sole) or with gypsum (FibrePlus at BENAS).
Condensed ammonia water	Condensate after evaporation of LF of digestate with a high content of ammonium, and treated by RO to reduce the water content.
Condensed water	Condensate after evaporation of LF of digestate which contains water and volatile compounds including ammonia, bicarbonate and volatile organic acids.
Low nitrogen (N) organic fibres	SF of digestate obtained by a screw press from digestate after N stripping-scrubbing in the FibrePlus system and used for production of fibre.
Organic fibres	GZV: Organic fibres with a low total nitrogen (TN) and total phosphorus (TP) content, recovered from digestate by means of a screw press after two or three washing steps to remove TP, salts and fine particles. BENAS: SF obtained by a screw press from digestate after N stripping-scrubbing in the FibrePlus system and used for production of fibre.
Calcium carbonate sludge	Precipitate of calcium and carbonate produced as a side product of the FibrePlus N stripping unit at BENAS by the reaction of striped gas containing ammonia and carbon dioxide with gypsum ($CaSO_4$) leading to the formation of ammonium sulphate and calcium carbonate precipitate.
Micro-filtration (MF) concentrate	Concentrate after treatment of LF of digestate by means of microfiltration (MF concentrate).

1 Introduction

The current European policy strongly focuses on the transition from a linear economy towards a circular economy. Main goal is 'an economic sustainable growth by increasing the value of products, materials and raw materials as long as possible in the economy'. The three main strategies are (a) reduce waste to a minimum, (b) promote re-use and recycling of materials and products and (c) create value: from waste to valuable raw material. The European Commission proposes a large package of measures to set product requirements regarding repairability, sustainability and recyclability with the main goal to prevent waste production. One of these measures is the recycling of waste materials and by-products as fertilising product.

Within the Horizon 2020 project SYSTEMIC (Grant Agreement no. 730400) innovative nutrient recovery and reuse (NRR) technologies are implemented at five large-scale biogas plants (hereinafter referred to as demonstration plants) with the aim to create more value out of biowaste (manure, sewage sludge as well as food, feed and agricultural waste) by producing biogas as substitute for natural gas and by recovering nutrients as substitute for synthetic mineral fertilisers. The overall objective of the SYSTEMIC project is to reach a break-through in reuse of nutrients recovered from biowaste in the agricultural production cycle. The project focuses on demonstration of circular economy solutions for biowaste management by an effective combination of AD and innovative NRR technologies at five full-scale demonstration plants. SYSTEMIC aims to validate the technical and economic viability of the presented integrated approach at the demonstration plants. It also focuses on transfer of practical information and business development to other (biogas) outreach locations in order to demonstrate business opportunities elsewhere in Europe, and to strengthen the position of the European biogas sector by offering them innovative NRR technologies.

In order to ensure market uptake of the biobased fertilisers produced within the project, the operational performance of NRR technologies as well as the fertiliser quality must be stable over time and overall quality. The main aim of this report is to give an overview of the construction, monitoring and demonstration activities of the five SYSTEMIC demonstration plants over the course of the four years of the SYSTEMIC project. The report addresses the obstacles encountered by the demonstration plants with the implementation of their existing or novel NRR technologies and the strategies they applied to optimise those technologies. Details are given on the monitoring methodology used for each AD plant, including sampling rounds, product characterisation via chemical analysis and data collection for specific aspects, such as chemicals and energy consumption.

The SYSTEMIC project started in May 2017 and one of the first tasks was to set up the demonstration plants. BENAS and WNE were already fully equipped before the start of the project, whereas other plants had to start with the basic design and engineering of the NRR technologies. By the end of the fourth project year, all demonstration plants have completed the installation of the NRR technologies and are fully operational as envisaged. Optimisation will for some plants still continue after the project. For example, AmP is trying to find a solution for the periodic fouling of the RO membranes.

2 Groot Zevert Vergisting

2.1 Status and planning of construction

The 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 exported the raw digestate to Germany over distances of about 250 km. Since the start of the project, GZV has implemented two NRR technologies: (i) the GENIUS system for processing of digestate into an SF of digestate, RO concentrate, microfiltration (MF) concentrate and purified water, and (ii) the RePeat (**Re**covery of **P** to **eat**) system to further process the SF into a low-P soil improver and precipitated P salts. This enables GZV to process digestate into fertilisers that meet criteria of farmers at the regional and national market. SF of digestate and precipitated P salts, both high in total-P (respectively 8.9 ± 0.80 and 9.3 ± 1.4 g kg^{-1}), are exported to regions with a demand for P fertilising products. RO concentrate, which contains >90% of TN in mineral form, is used within the region to replace synthetic N fertiliser. MF concentrate with a low TP content of 0.42 ± 0.052 g kg^{-1} is mixed with SF of the second decanter centrifuge which contains 4.6 ± 0.58 g TP kg^{-1}. The mixture is used on arable land within the Netherlands. The low-P organic soil improver, which contains 1.1 ± 0.25 g TP kg^{-1} is used on arable land in the region of the plant and has potential to be used as alternative for peat in certain products in the near future. The produced purified water is discharged. Overall, the investment in NRR has led to a reduction in volumes of digestate to be transported over long distances.

(i) GENIUS system for processing of the liquid fraction of digestate

The GENIUS system consists of multiple separation units including two (sequential) decanter centrifuges, a MF unit, two sequential RO units and ion exchangers (IX) (Figure 2-1). Engineering and installation were done by Nijhuis Industries. The investments in the GENIUS system are not part of GZV's SYSTEMIC budget, but monitoring of the system and its products is part of the SYSTEMIC project.

The GENIUS system was constructed in 2018 and commissioned in January 2019, and has been in operation since then. Since commissioning, it has undergone several adjustments to improve the process and its products. At first, the decanter centrifuges operated parallel to each other in two process lines but in May 2019 the decanter centrifuges were placed sequentially in one process line to produce a liquid fraction (LF) of digestate with less fine particles. Also, a dissolved air flotation (DAF) installation has been part of the GENIUS system. Since July 2019 the sludge of the DAF has been added to the influent of the second decanter centrifuge instead of to the post-digester. Aeration of the DAF has been ceased on purpose since October 2019 and it therefore no longer functions as a DAF unit. Also, in October 2019 the location where the majority of sulphuric acid is added to the RO units, was changed from before the first RO unit to before the second RO unit. Since July 2020 all SF of the second decanter centrifuge, and since April 2021 all concentrate of the MF as well, are trucked off-site and applied as fertilisers on agricultural land. Before, part of it was fed back to the post-digester. In November 2020 the permeate of the third stage of the second RO unit was rerouted. It has since then been fed back to the influent of the second RO unit instead of flowing to the IX.

Decanter centrifuges | *Microfiltration unit*

Reverse osmosis units | *Ion exchangers*

Figure 2-1 Photos of the process units of the GENIUS system at the demonstration plant Groot Zevert Vergisting.

(ii) RePeat system for processing of the solid fraction of digestate

GZV invested in a full-scale installation to separate the SF of digestate, which has a high P content, into precipitated P salts and a low-P organic soil improver. The installation consists of two subsequent leaching steps in which the SF of digestate is leached with water and sulphuric acid at a pH of 5.5 to solubilise mineral P (Figure 2-2). After dewatering by means of a screw press, a low-P soil improver remains. The P-rich liquid 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 P salts, consisting of amongst others calcium phosphate, are currently recovered in the form of a sludge in a settling tank. The effluent of the tank is reused within the process. The installation has a maximum processing capacity of 17 kt of SF of digestate per year, which is equivalent to the amount of SF that would be produced via the GENIUS system from 140 kt of digestate.

The RePeat system has been fully operational since February 2020. Delays in its construction 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 system. From a management point of view, the production of the SF of digestate, RO concentrate and purified water had the highest priority as they have the biggest impact on revenues. There were also serious delays in the delivery of the precipitation- and settling tanks which are both conus-shaped tanks with a volume of about 70 m^3.

In 2020, the RePeat system has been further optimised to reduce the chemical consumption and improve product quality. Amongst others, an optional third leaching step has been implemented, consisting of a mixer and a screw press, this enables washing the soil improver with water to reduce its salt and sulphur content. Also, emissions of hydrogen sulphide (H_2S) gas were encountered, particularly at locations where process streams get into content with air (screw presses, mixers, etc.). Since H_2S is a highly toxic gas, several measures were taken to prevent formation and emissions of H_sS including instalment of extraction channels (suction air is treated via existing air washers and a bio-bed) and ventilators. Also, each tank is now equipped with a blower to continuously add fresh air – and hence oxygen – to the tank, thereby reducing the occurrence of anaerobic conditions which favour H_2S formation. Monitoring of the RePeat system started in March 2020, but as a consequence of the necessary adjustments described above, it was not possible to monitor the RePeat system on a monthly basis as proposed. To compensate for this, the monitoring has been continued in 2021 in order to collect sufficient data to calculate a reliable mass balance.

Marketing of the end-products had a high priority in 2020 and GZV has explored new markets for the low-P soil improver, namely as an alternative for peat in both potting soil and substrate for the growing of mushrooms. In collaboration with partners from industry, the low P-soil improver has been tested in potting experiments and the results are promising (reported in deliverable D1.13). The low-P soil improver has a high water holding capacity which is one of the main prerequisites for application in substrate industry. Its market value as an alternative for peat is estimated at €20–30 per m^3. Furthermore, GZV has started a field trial in collaboration with WENR to demonstrate the impact of low-P soil improver application on carbon sequestration, water retention and nutrient leaching to local farmers and policy makers.

Figure 2-2 Photos of process units of the RePeat system at the demonstration plant GZV (left; screw presses and collection of low-P organic soil improver. Right; stainless steel precipitation tank and settling tank for precipitation and dewatering of precipitated P salts).

2.2 Monitoring activities

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

In 2018, prior to commissioning of the NRR systems, monitoring of the AD plant allowed for calculation of mass and energy balances for the reference situation of GZV. The monitoring included:

- Monthly analysis of TN, TP and TK concentrations in the digestate

- Collection of data on the use of chemicals at the AD plant, including additives used for biogas desulphurisation
- Biogas, electricity and heat production
- Consumption of electricity and heat by the major installations including the AD plant, desulphurisation unit and the hygienisation unit

Monitoring of the RePeat system

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

- Sampling of the ingoing, internal and outgoing flows (Figure 2-3) occurs on a monthly basis unless the system is not running. 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 at least analysed for:
    - Dry matter (DM) and organic matter (OM) content
    - TN, NH_4-N, TP, TK and S content
    - Ca, Mg, Fe, Zn and Cu content
    - pH, electrical conductivity (EC)
- Measurement of the in- and outgoing and internal flows. In total, eight flow meters are placed upstream and downstream of the individual process steps. Weight of the end-products, the precipitated P salts and low-P soil improver, are recorded per truck that leaves the plant.
- Electricity consumption of the RePeat system is automatically measured in the following three power groups:

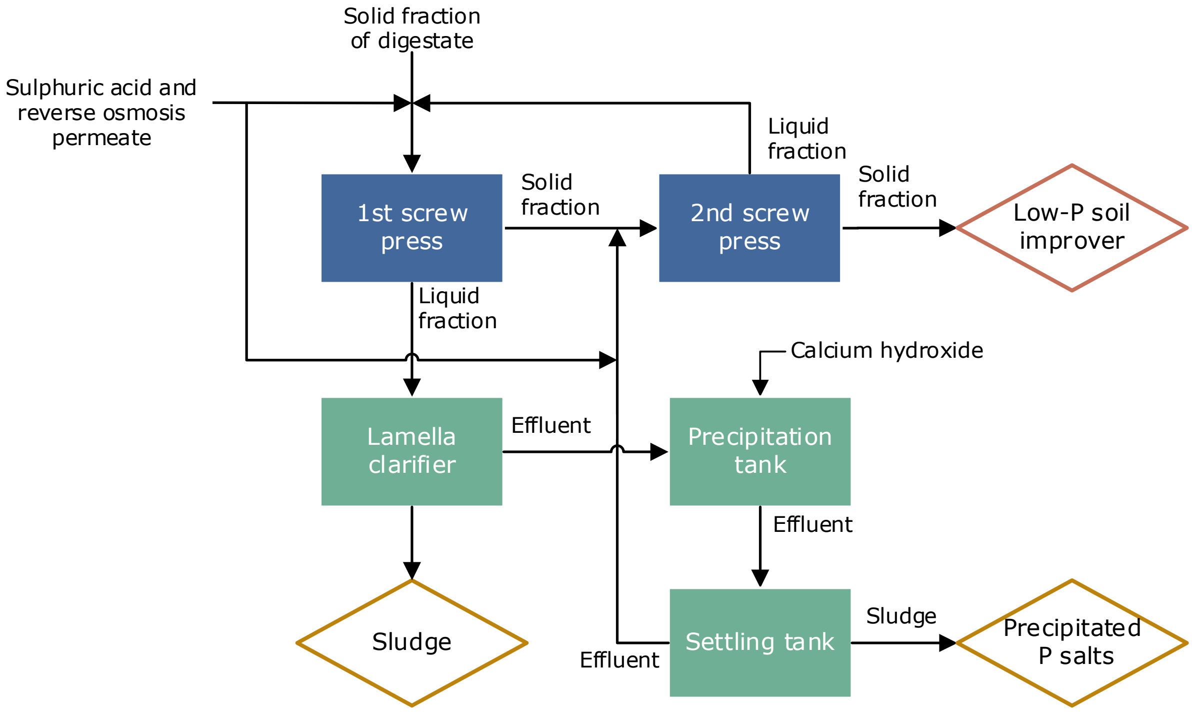
    Group 1: conveyer belt for SF of digestate, pumps and mixer for addition of process water and the mixer of the first acidification tank

    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 and not for all process flows:

- Heavy metals (Pb, Cd, Cr, Ni, As, Hg)
- Density
- End-products are analysed on residues of organic micro pollutants (herbicides, pesticides and pharmaceuticals) (two times in 2020/2021)



Figuur 2-3 Process flow diagram of the RePeat system at the demonstration plant Groot Zevert Vergisting including locations of chemical addition and the major return flows (as configured in October 2021).

Monitoring of the GENIUS system

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

- Sampling of the ingoing digestate, internal flows and end-products is done every one or two months if the installation is running without problems. Samples are sent to a commercial lab and at least analysed for:
    - DM and OM content
    - TN, NH_4-N, TP, TK and S content
    - Ca, Mg, Fe, Zn and Cu content
    - pH, EC
- 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 2-4. In case an individual process step consists of separate cascaded process units, a flow meter is also placed in between those units. This is, amongst others, the case for the RO installation which consists of two sequential RO units.
- For process streams where flow meters cannot be placed, for example because the stream is not a pumpable liquid, the flow was calculated from the known flows and concentrations upstream and downstream of it. Flow rates are automatically measured and recorded, and daily averaged values were sent to WENR for data processing. Mass balances for the system as a whole and its individual process steps were calculated with the measured flows and concentrations in MS Excel.
- Total consumption of chemicals, amongst others of magnesium chloride solution, sulphuric acid, polymer flocculant solution and anti-scalant were determined on a half year basis based on procurement.
- Chemical consumption rate was tracked automatically by monitoring of the pumping speed in combination with the used concentration and, if applicable the dilution ratio before injection into the process.
- Electricity consumption of the AD plant, including the NRR systems, was monitored on a yearly basis. The electricity consumption over 24 hours was measured for clusters of process units in 2021.

Next to the standard monitoring programme the following parameters are monitored less frequently and not for all process flows:

- Heavy metals: Pb, Cd, Cr, Ni, As, Co,
- Density, sodium and total organic carbon (TOC)
- End-products are analysed on residues of herbicides, pesticides and pharmaceuticals (two times)

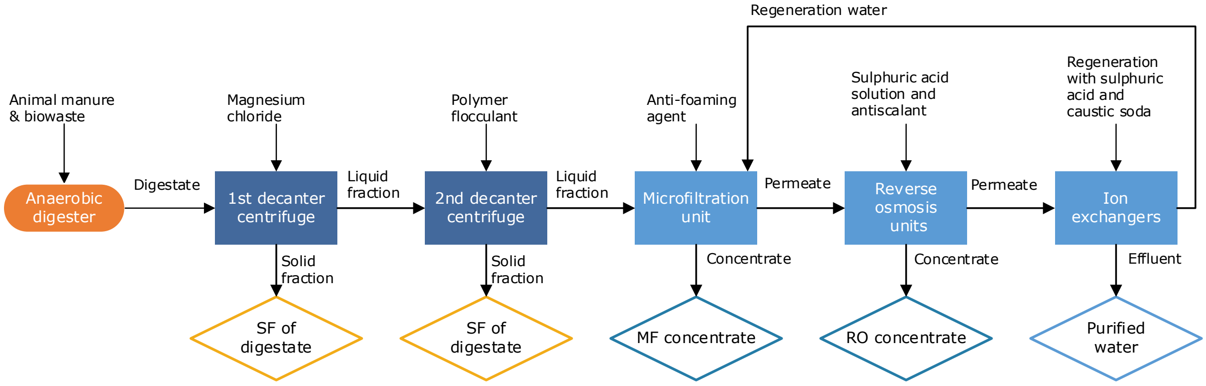


Figure 2-4 Process flow diagram of the GENIUS system at the demonstration plant Groot Zevert Vergisting, including locations of chemical addition and the major return flows (as configured in October 2021).

2.3 Demonstration activities

Since the start of the SYSTEMIC project in 2017, there have been over 30 visits of smaller and larger groups to the AD plant. A full list of dissemination activities is available in SYSTEMIC's report on dissemination activities. Underneath, the most important ones are given.

Key demonstration activities for the demonstration plant of GZV:

- October 2021: Living lab meeting with a visit to GZV organised by VCM as part of the SYSTEMIC project. About 30 visitors – mostly representatives from AD plants (Outreach locations) – joined the meeting and site visit.

- 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 companies including AD plants, fertiliser trading companies and engineering companies.

- SYSTEMIC H2020 movie – all demonstration plants: https://www.youtube.com/watch?v=CEux_Ic1gTo

- SYSTEMIC demoplant movie: www.systemicproject.eu

3 Am-Power

3.1 Status and planning of construction

In order to reduce the costs of digestate processing, AmP installed a vacuum evaporator as part of the SYSTEMIC project. Previously, the digestate was diluted with the LF of digestate and fed to the decanter centrifuges for mechanical separation. There, iron sulphate and polymer flocculant were added to improve coagulation and flocculation. The SF of digestate was dried in a fluidised bed dryer and the remaining LF was treated by a DAF unit after addition of iron chloride. 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 diluted with LF before separation) and the heavy load on the RO units which necessitated much maintenance of the RO membranes. The vacuum evaporator consists of two identical units that are placed in parallel, each with an evaporation capacity of 150 m^3 d^{-1}. Also, a new RO installation has been installed and its optimal configuration is still under investigation.

In 2017, AmP defined all the technical specifications for the vacuum evaporator after its financing was arranged. Figure 3-1 shows the process flow diagram of the initially envisaged NRR facility of AmP.

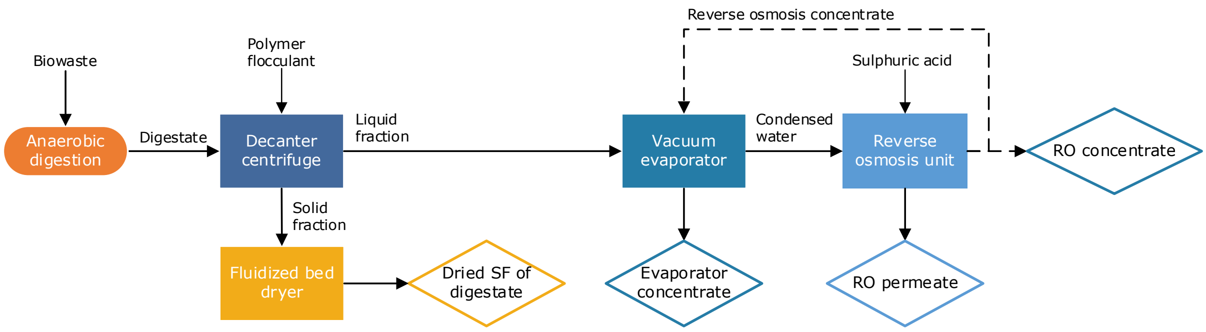


Figure 3-1 Process flow diagram of the initially envisaged NRR facility of the demonstration plant Am-Power.

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 2019 and installed in June 2019. Pictures of both units are shown in Figure 3-2. The start-up of the vacuum evaporator and the initial tests with water as the liquid to be treated, were successful. Further tests were then conducted with treatment of LF instead, the results were encouraging. After evaporation, the DM content of the treated LF was 22%. In the tests an increase in DM content of the outgoing LF up to 4–5 times compared to the ingoing digestate was achieved. In September 2019, AmP investigated the optimal polymer flocculant dosage for the performance of the vacuum evaporator. Tested dosages ranged between 0 and 50 l per m^3 of digestate. K-RÉVERT, the supplier of the vacuum evaporator, finalised some technical aspects and implemented the software for the remote control of the vacuum evaporator.

Further tests performed until December 2019 with the initial configuration resulted in a very high pH of the produced condensed water. To decrease the pH of the condensed water, a high dosage of sulphuric acid on the RO units was required due to the presence of dissolved NH_3. Moreover, the TN content of the RO permeate (108 ± 52 mg L^{-1}) did not comply with the Flemish discharging limits (15 mg L^{-1}). Therefore, AmP decided to add an acidification step prior to the vacuum evaporator to reduce the evaporation of NH_3 in the vacuum evaporator. This resulted in an N-rich evaporator concentrate which AmP plans to mix with the dried SF of digestate into an organic NPK fertiliser.

Figure 3-2 Photos of the vacuum evaporator (a) and reverse osmosis unit (b) of the demonstration plant Am-Power.

The vacuum evaporator has been operational since January 2020 and the acidification unit prior to the evaporator has been completed in September 2020. AmP, together with K-RÉVERT, is still examining the possibilities to maximise the efficiency of the vacuum evaporator. The currently used aluminium brushes for cleaning of the heating plates will be replaced by ones made of stainless steel. The RO unit has been placed and its sensors, software of the programmable logic controller (PLC) and the cabling of its pumps have been completed. Only the pumping system and the recirculation loops of the RO still need to be improved after the end of the SYSTEMIC project to reduce the membrane fouling that AmP is experiencing. The installation of an IX as a final polishing step was initially envisaged by the demonstration plant. However, AmP will try to first improve the performance of the RO and consider the implementation of an IX only if the quality of the RO permeate will not meet Flemish discharge limits. The process flow diagram of the final NRR facility of AmP is depicted in Figure 3-3.

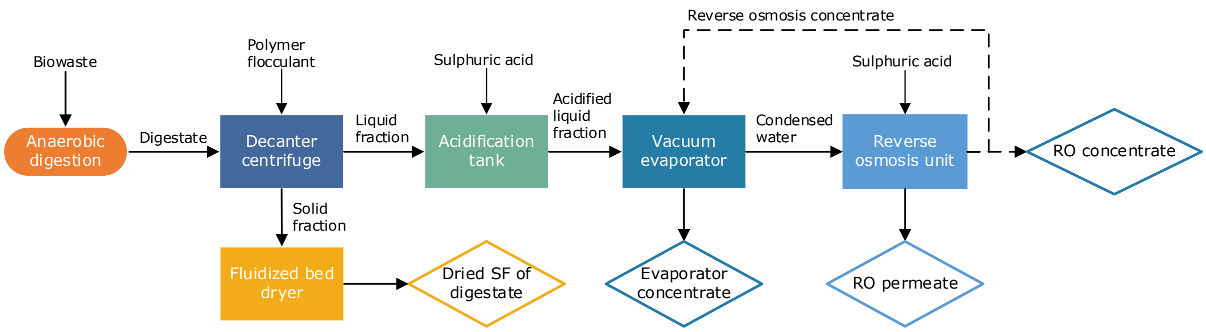


Figure 3-3 Process flow diagram of the final NRR facility of the demonstration plant AM-Power (2021).

3.2 Monitoring activities

In the years 2017 and 2018 monitoring activities were carried out by collecting data directly from AmP. The information provided by the demonstration plant included the chemical characterisation of intermediate and final end-products, the yearly production of digestate and biogas, the biogas composition and the yearly energy production. No information on process flows was available regarding the actual production flows, and the mass balances extrapolated from the calculation of flow streams were not reliable. AmP installed flow meters so that Ghent University could monitor the NRR installation inclusive of the newly installed vacuum evaporator system. A short sampling campaign was conducted by Ghent University, which included the sampling of intermediate process flows and final end-products generated at AmP during the period September–October 2018. A thorough characterisation of intermediate process flows and final products is available for this period. However, no flow meters 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 for:

- DM, OM, TOC,
- pH, EC
- TN, NH_4-N, TP, TK, S, Ca, Mg, Na
- Cu, Zn, Al, Fe, Co, Cd, Cr, Mn, Ni, Pb

By the end of 2019, flow meters placed on the ingoing and outgoing streams of the individual process steps were operational. Flow meters were installed at the following sampling locations:

- Decanter centrifuge: at the ingoing digestate, at the place where polymer flocculant solution is added and at the outgoing LF.
- Vacuum evaporator: at the ingoing LF of digestate, the ingoing water for rinsing of the evaporator and at the outgoing condensed water.
- RO unit: at the ingoing condensed water, outgoing RO permeate and outgoing RO concentrate.

Moreover, the amount of polymer flocculant solution added to the decanter centrifuge and the amount anti-foaming agent dosed to the decanter centrifuges and to the vacuum evaporators were tracked on a monthly basis. The implementation of flow meters at the RO unit was essential for calculation of a reliable mass balance since it is not possible to calculate the outgoing flows of the RO unit based on the DM content of the condensed water. Nevertheless, the RO unit has not worked continuously and long enough yet to be reliably monitored.

A new sampling campaign of the NRR plant was started by Ghent University in January 2020. This included monitoring the mass balance, consumption of additives and assessment of product quality. However, AmP campaign was temporarily stopped at the end of February due to measures to mitigate the global coronavirus outbreak. The monitoring campaign of the NRR installation resumed in October 2020 when the acidification unit was installed and operational. Ten sampling rounds were performed until April 2021. During the campaign, all units (decanter centrifuge, dryer, acidification unit, vacuum evaporator) were monitored with the exception of the RO step. The feeding of condensed water to the RO resulted in quick fouling of the membranes and the unit operated continuously for approximately 2 weeks. As reported above, AmP is currently investigating different recirculation strategies to overcome this issue.

3.3 Demonstration activities

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 for the demonstration plant of AmP:

- In 2017/2018 three plant visits to AmP 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 AmP 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.

- AmP demonstration plant video: English and Dutch version

4 Acqua & Sole

4.1 Status and planning of construction

The N-rich feedstock which is processed at A&S may lead to inhibiting levels of NH_3 in the digester and ultimately failure of the digestion process. N-stripping allows NH_3 levels to be maintained below inhibiting concentrations and to simultaneously recover N in the form of the mineral N fertiliser AS solution. A&S 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 4-1). 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 NH_3 recovered.

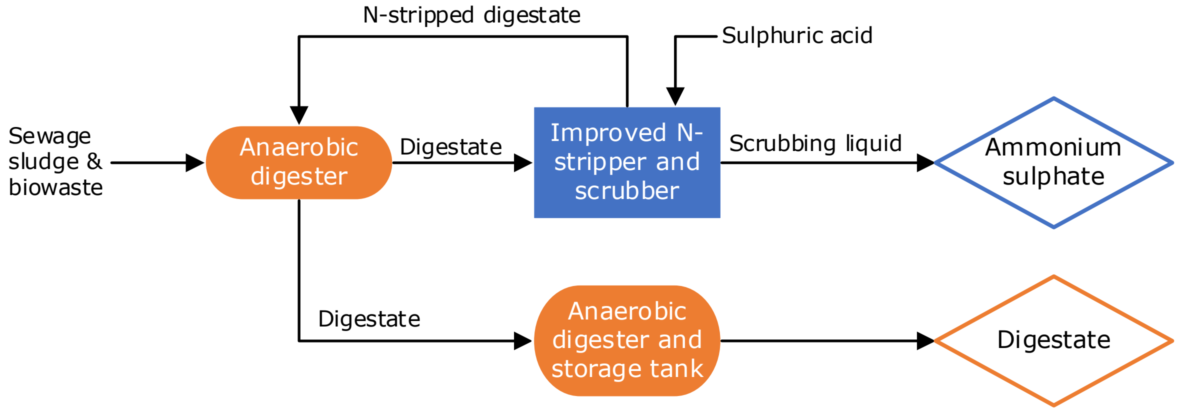


Figure 4-1 Process flow diagram of the final NRR facility of the demonstration plant Acqua & Sole.

The implementation phases of the N-absorber are summarized as follows. The contracts with suppliers were finalised 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 finalised between December 2018 and January 2019. However, the authorisation 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 AS pipes was delayed for six weeks by the purchasing company. The construction of the N-absorber (Figure 4-2) was completed by the end of 2019 and the administrative technical testing was completed on the 3rd of March 2020. In the first half of 2020, A&S optimised the operational conditions, reaching 35% NH_3 recovery efficiency, while with the previous adsorption unit just about 20% was reached. For about one month between November and December 2020, the NH_3 extraction unit did not work due to a failure of the thin film evaporator (TFE) and also for this reason AS solution production resulted to be lower compared to previous year.

Figure 4-2 N absorber installed at the demonstration plant Acqua & Sole (2020).

4.2 Monitoring activities

A&S AD plant normally operates 365 days a year. However, in 2018 monitoring was conducted for seven consecutive months (from January to July) because from August to September the plant was not operational due to a legislative block. The activity gradually restarted in October 2018 and was again fully operational by January 2019. In 2019 and 2020, a thorough characterisation of the produced digestate and AS solution was performed. In particular, during 2019 the monitoring was expanded to ten consecutive months (from January to October), and in the last period of SYSTEMIC, the monitoring was expanded to six consecutive months (from October 2020 to March 2021). The aim was to compare the performance of N-stripping systems and the quality of AS solution produced with the old and the new absorber. Samples of digestate and AS solution were sent and analysed by an accredited laboratory and/or University of Milan. Parameters analysed are summarised in Table 4-1.

Table 4-1 Overview of parameters analysed on digestate and ammonium sulphate solution produced at demonstration plant Acqua & Sole.

Digestate (2019-2021)	
Parameters	Frequency of analyses
DM, OM, pH, EC, TOC, macro-, micro-nutrients, heavy metals, THC (C10-C40)	Monthly
Organic pollutants, Pathogens, Phytotoxicity	Bimonthly
Weed seeds, glass and plastic particles	Determined on six samples
Residues of pharmaceuticals	Determined on six samples
Residues of pharmaceuticals, herbicides and pesticides	Determined on three samples
Ammonium sulphate solution (2019-2021)	
Parameters	Frequency of analyses
pH, DM, TOC, TN, NH_4-N, TP, TK, S, As, Cd, Ca, Cr, Fe, P, Mg, Mn, Hg, Ni, Pb, K, Cu, Zn, Al, Co, Na	Quarterly
Residues of pharmaceuticals, herbicides and pesticides	Determined on two samples
Pathogens	Determined on six samples

The following aspects were also included in the monitoring programme of A&S biogas installation:

- Measurement of the in- and outgoing and intermediate flows. The flows were automatically recorded and monthly-averaged numbers are sent to Ghent University for further data processing
- Consumption rates of sulphuric acid were collected on a monthly basis
- Electrical and thermal energy production and consumption of the plant as a whole were monitored on a monthly basis

4.3 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 organised an open day at their AD plant. Moreover:

- In 2018 a total of 15 visits to the plant were organised. Visits organised for specific groups, such as farmers or public institutions, included on average 10 to 20 people; while events organised in collaborations with schools reached groups of 80 students
- In 2019 a total of 20 visits to the plant were organised
- In 2020 a total of 7 visits to the plant were organised (Covid-19 emergency prevented the organisation of more events)
- SYSTEMIC demoplant movie for Aqua&Sole: www.systemicproject.eu

5 BENAS

5.1 Status and planning of construction

BENAS operates an innovative N-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 Fertilisation Regulation (DüMV) for agricultural land. Figure 5-1 shows the process flow diagram of the NRR facility of BENAS. Removal of NH_4-N by the stripper reduces the risk of NH_3 inhibition when poultry manure is used as feedstock. It also simultaneously recovers N in the form of an AS solution, a biobased mineral N fertiliser. Furthermore, organic fibres and a soil improver, the SF of digestate, can be produced.

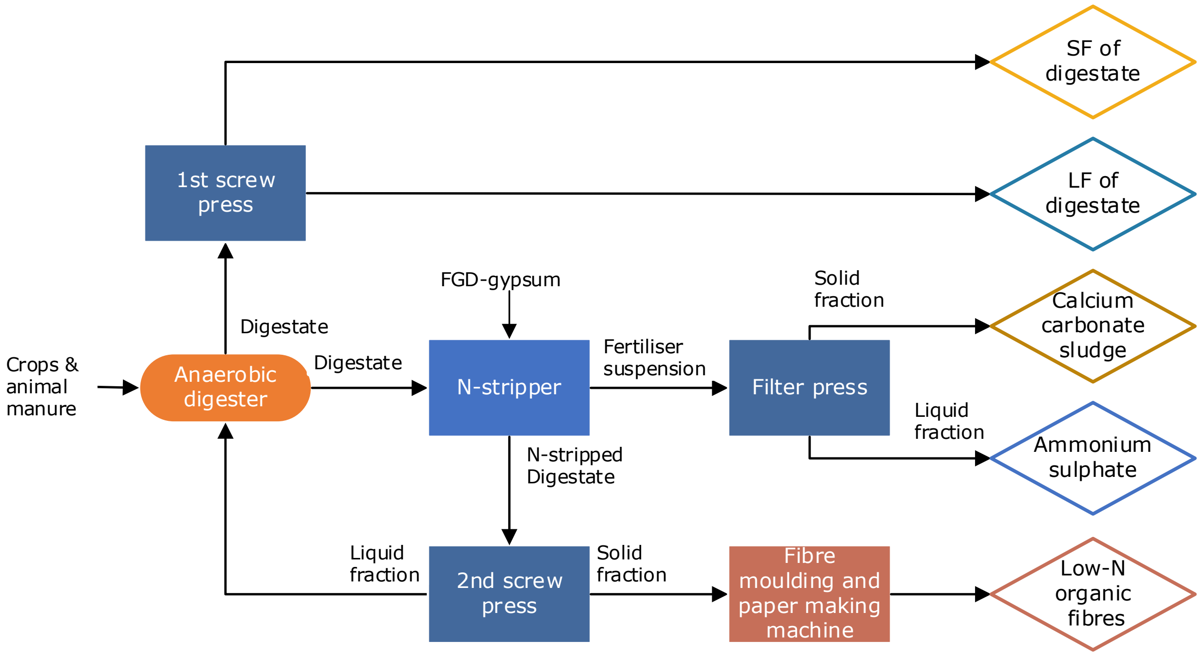


Figure 5-1 Process flow diagram of the final NRR facility of the demonstration plant BENAS.

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 m^3 and a biogas storage capacity of 8,870 m^3. In 2019, construction of the reservoir was completed. Also, two additional 3 MW CHP installations with a conversion efficiency to electrical energy of over 44% were installed. Next to that, all digesters were given new roofs (Figure 5-2). 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 stabilisation, 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 stabilising mode. Additionally, in 2019 new screw presses were installed with aim to achieve improved separation efficiencies.

Even after adopting the fluctuating grid stabilising 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 m^3 of biogas combusted)
- Higher N recovery and AS solution fertiliser production
- Less unprocessed digestate and more SF of digestate per amount of digestate produced

Figure 5-2 Aerial photo of the demonstration plant BENAS (2019).

The N-stripper unit 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 has been recently improved (2020) to a more cost effective fibre production. At the time of writing, the installations for fibre production (fibre moulding machine and a paper making machine) are operational though fulltime production of fibres will only start once BENAS has found a customer for them. BENAS is currently able to ensure the production of products like mulch mats, plant pots and paper rolls from the fibres themselves. Product development and first customer acquisition took place in 2020.

During the course of 2020, the NRR installation of BENAS was connected to the fibre molding machine and the paper making machine. This required several construction works and, as a result, the N-stripping unit was operating only part of the time. This is the reason why the production of both AS solution and CC sludge was reduced in 2020, compared to previous years. In spring 2021, more than 3 000 mulch mats were produced for the first time with the fibre moulding machine and used as protection against weeds in German and French wine-growing regions instead use of Glyphosate. BENAS plans to produce 6 kt of dry fibres in future (https://www.magaverde.de/).

5.2 Monitoring activities

The composition of products was analysed in 2017 during the month of August, and in 2018 over three months. However, in these monitoring periods not all products and internal flows were analysed for all desired parameters. A draft mass balance was made based on the measured concentrations from 2017 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 CC 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.

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. 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. Nevertheless, in July 2021 BENAS has started the production of dried products, in order to collect valuable information on the mass and nutrient balances in the fibre production steps. Samples were shipped to an external laboratory for physico-chemical characterisation and results were sent to Ghent University for further data processing.

The following aspects were included in the monitoring programmes of BENAS biogas installation:

- Sampling of the produced digestate, all internal flows and the final products. Samples were sent to Ghent University and analysed for:
    - DM, OM, TOC
    - pH, EC
    - TN, NH_4-N, TP, TK, S, Ca, Mg, Na
    - Cu, Zn, Al, Fe, Co, Cd, Cr, Mn, Ni, Pb
    - Pathogens (in ammonium sulphate solution and calcium carbonate)
    - Residues of pharmaceuticals, herbicides and pesticides (twice per year)
- Measurement of the in- and outgoing and internal flows. The flow rates were automatically recorded and monthly-averaged numbers were sent to Ghent University for further data processing
- Consumption rates of gypsum were collected on a monthly basis
- Electrical and thermal energy production and consumption of the plant as a whole were monitored on a monthly basis

Detailed mass balances and product quality assessment are included in deliverable 1.5 (*"Fourth annual updated report on mass and energy balances, product composition and quality and overall technical performance of the demonstration plants"*) and deliverable 1.13 (*"Document on product characteristics, lab results and field trials (year 4)"*).

5.3 Demonstration activities

Since the start of the SYSTEMIC project, there have been over 45 demonstration activities for various target audiences. A full list of dissemination activities is available in the report on dissemination activities. The main activities have been:

- Movie of the BENAS plant
- Open day at the BENAS plant, 13 July 2019
- Participation in Living lab Online-Webinars 2021
- publications in German professional environmental and 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

6 Waterleau NewEnergy

6.1 Status and planning of construction

Since the start of the SYSTEMIC project, the AD plant of Waterleau NewEnergy (WNE) in Ypres (Belgium) has been involved in the project as an Outreach Location (Figure 6-1). From June 2020 onwards, WNE's plant became one of SYSTEMIC's demonstration plants, replacing the demonstration plant Fridays in Kent (UK).

Figure 6-1 Aerial photo of the demonstration plant Waterleau NewEnergy (2019).

Since the AD plant was bought in 2013 by Waterleau environmental engineering, it has implemented and improved NRR technologies of the plant. Their digestate processing thereby turned into a positive business case due to the value of the end-products made from recovered nutrients. The plant demonstrates the production of condensed AW, evaporator concentrate, dried SF of digestate and permeate/purified water (Figure 6-2). Part of the RO permeate is reused to make the polymer flocculant solution, the remainder is discharged as purified water. Half of the final condensed AW is mixed with the evaporator concentrate and the other half is used as reductant in the DeNOx system for treatment of the exhaust gases of a Belgian waste incineration plant. Part of the evaporator concentrate is mixed with the dried SF of digestate, but the majority is exported as organo-mineral fertiliser which contains approximately 11 kg TN, 2.1 kg TP and 22 kg TK per tonne. The dried SF of digestate is composted in Flanders (Belgium) and the resulting compost is exported to France.

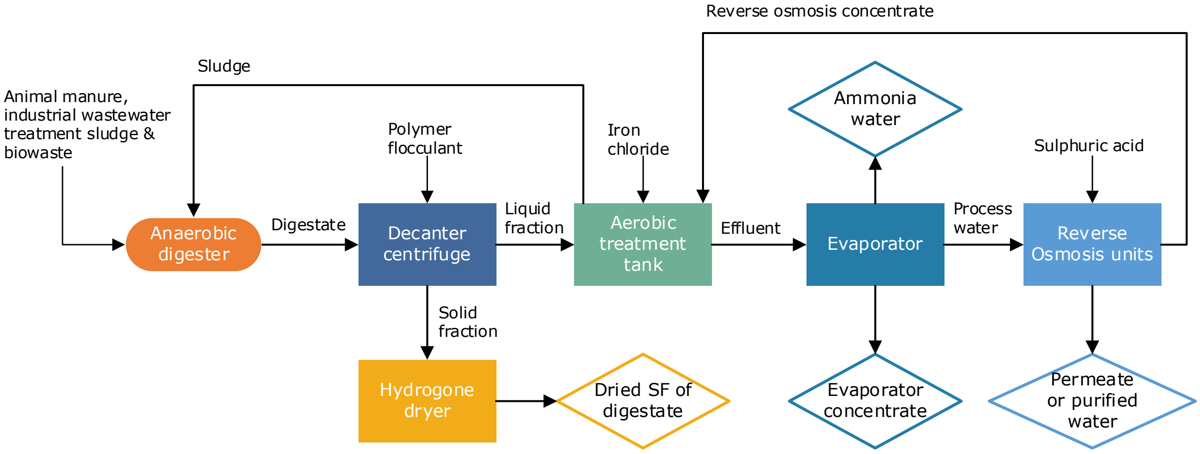


Figure 6-2 Process flow diagram of the final NRR facility of the demonstration plant Waterleau NewEnergy.

The pig manure fed to the anaerobic digester has a higher N content than the sewage sludge and biowaste, and thus contributes to a higher N content of the digestate. The pig manure therefore contributes strongly to the mass and N content of the produced condensed AW and evaporator concentrate. Disposal costs for the condensed AW and evaporator concentrate currently account for a large part of the total costs of the plant. This is due to the costs for transport of the condensed AW to the waste incineration plant and due to transport of the evaporator concentrate to the Netherlands.

WNE currently investigates means to reduce these costs, amongst others:
- Creating other products as alternative for condensed AW, as it is not a suitable fertiliser because of the high risk of NH_3 emissions during application. Possible alternatives are urea and AS solution.
- Drying of the evaporator concentrate to an even more concentrated fertiliser, as in that case less liquid needs to be transported which lowers the transport costs. The Hydrogone® dryer does not have sufficient capacity to dry the evaporator concentrate.
- The heat available from the CHP's flue gasses (190 °C) that is not being used, could be valorised. Due to the high viscosity and high salt content of the evaporator concentrate, it is technically difficult to dry it to a DM content of 20–30%.

The way in which the anaerobic digester is fed also could be optimised to achieve a higher biogas production and associated higher revenues from biogas. 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 DM content of this mixture as it is added to the digester by pumping. Addition of more energy rich feedstock types, like potato starch waste, would make the DM content of the mixture surpass the pumpable limit. Therefore, WNE 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 was carried out from June 2020 until December 2020 and the following was included in the monitoring of the demonstration plant WNE:
- Sampling of the digestate, all internal process streams and the end-products. Samples were sent to Ghent University and analysed for:
    - DM, OM, TOC
    - pH, EC
    - TN, NH_4-N, TP, TK, S, Ca, Mg, Na
    - Cu, Zn, Al, Fe, Co, Cd, Cr, Mn, Ni, Pb
    - Residues of pharmaceuticals, herbicides and pesticides
- Measurement of the in- and outgoing and internal flows. The flow rates were automatically recorded and monthly-averaged numbers were calculated by Ghent University for further data processing
- Consumption of chemicals was estimated for the whole monitoring period
- Electrical and thermal energy production and consumption of the plant as a whole were estimated on an annual basis by WNE.

6.3 Demonstration activities

Since the start of the SYSTEMIC project the following demonstration activities have been organised by WNE as an outreach location, and later on as a demonstration plant:
- 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 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
- Waterleau NewEnergy demonstration plant video: English version and Dutch version
- A site visit to the WNE plant for all interested Outreach Locations and Associated Plants in the autumn of 2020

7 Conclusions

The five SYSTEMIC demonstration plants operate in different legal, commercial and agricultural contexts, within the European Union. As such, different combinations of AD and NRR technologies are implemented to process different organic substrates such as animal manure, sewage sludge and food waste. The mutual collaboration between demonstration plants and research partners fosters the upscaling of NRR processes, as in the case of GZV and WENR for the development of the RePeat process. Moreover, the quality of recovered mineral and organic fertilisers has been evaluated by their continuous monitoring, in terms of nutrients and contaminants. An important contribution to the practical implementation of NRR technologies and production of NRR products comes from sharing experiences among AD plant owners during the different demonstration activities such as the General Assemblies and webinars.

GZV operates a co-digester fed with animal manure and co-products in an area with intensive livestock farming. GZV aimed to reduce long-distance transport of digestate, and therefore, implemented two NRR technologies to separate digestate into different tailor-made fertilising products, of which some are used within the region or the Netherlands, and purified water. The GENIUS system has been operational since January 2019 and separates digestate into an SF (export), RO and MF concentrate, and purified water. The RO concentrate is used within the proximity of the plant as an alternative for synthetic N fertiliser. The MF concentrate is applied within the Netherlands on arable land whereas only the SF of digestate is exported to Germany. Over the last three years, improvements have been made leading to increased production of purified water (up to 18% of ingoing digestate mass) and reduction of the use of sulphuric acid. Yet, the production of purified water is still low compared to what was envisaged at the start of the project (circa 50% of digestate mass). Engineering and construction of the RePeat system proved to be more difficult than expected and caused serious delays in the monitoring campaign. In 2020, GZV has been active in finding new markets for the low-P organic soil improver, for example as an alternative for peat in potting soil. Since the start of the project, the manure surplus in the Netherlands has decreased and consequently, supply of manure to GZV and gate fees declined as well showing the enormous uncertainties and financial risks that plant owners face when investing in NRR.

Disposal of the digestate which AmP produces competes with manure disposal in Flanders. As such, the demonstration plant is forced to transport digestate and its fractions over long distances to France. AmP implemented two vacuum evaporators in order to reduce the water content of the LF of digestate and thereby reduce transportation costs. The installation, testing and troubleshooting of the evaporators lasted almost one year. Meanwhile the optimal polymer dosage to improve the overall efficiency of the process was investigated. During the first months of operation of the evaporators, AmP realised that the ammoniacal nitrogen content of the condensed water was too high to meet national discharge limits. Consequently, the plant had to implement an acidification step prior to evaporation. This resulted in further adjustments to the overall installation. The novel NRR installation has been operational since January 2020 and the monitoring results show that the vacuum evaporators remove about 77% of the water from the ingoing processed LF of digestate. However, the process is still under optimisation because the RO unit does not work continuously without experiencing severe fouling. Consequently, the condensed water has not yet achieved a sufficient quality for discharge.

Anaerobic digestion of N-rich feedstock can result in high NH_3 levels, which may hinder the overall biogas production. For this reason, A&S implemented its NRR system with an NH_3 adsorption system that could achieve higher process temperatures and higher N removal rates. The implementation of the N-scrubber at A&S was postponed due to delays in the authorisation process and in the furniture of Alloy 825. The scrubber is operational since end of 2019 and is now operating at full regime. Results from the monitoring of the new A&S scrubber indicate that the recovery of higher amount of NH_3 resulted in higher methane content in the biogas produced. This, in turn, reflects in a higher thermal energy production, which allows the plant to decrease the dependency on natural gas, a non-renewable resource. At the same time, AS solution generated with the new adsorber showed comparable quality to the previous AS solution produced.

The NRR at BENAS has been operational since the beginning of SYSTEMIC project. The monitoring campaigns performed so far showed a high stability of AS solution composition. AS solution, CC sludge and biogas fibers generated at BENAS, have been assessed for their chemical composition over the whole duration of the project. BENAS managed to develop a market for paper products and invested in a full-scale installation converting biogas fibres into mulch paper and other useful products. This is a true example of exploration for a niche market and creating high-value products out of the digestate.

Just as AmP, WNE is forced to transport its digestate fractions over long distances to dispose it. Digestate is processed into condensed AW, used locally in a DeNOx system of a waste incineration plant. The long-term monitoring of this product during the SYSTEMIC project shows high variability over time in its mineral N content. This, together with the high pH of the solution (>11), may hinder the reuse of this product as mineral fertiliser. On the other hand, organic products (i.e. dried SF of digestate and evaporator concentrate) are currently successfully used as soil improvers.

The SYSTEMIC demonstration plants have been very active in organising demonstration activities and in sharing their experience with other plants. Each demonstration plant produced a video in which the importance of NRR is highlighted and in which the process installations are shown in a nutshell. Due to the governmental measures for the COVID-19 pandemic less demonstration activities were however organised in 2020/2021 than planned.

Overall, the SYSTEMIC project team learned that large-scale implementation of novel NRR technologies does not go without setbacks and that it takes driven and skilled people to succeed in this. All demonstration plants that have implemented NRR technology during the SYSTEMIC project have experienced a delay in its engineering and/or construction phase. Furthermore, NRR technologies may, after commissioning, not function as expected due e.g., fouling of membranes, lower separation efficiencies than envisaged, or formation of toxic H_2S gasses (RePeat). In terms of product marketing, some true successes were made including the start-up of the paper production at BENAS, the production of a replacement for peat in potting soil at GZV and the production of RO concentrate which is used as an alternative for synthetic N fertiliser (GZV).

SYSTEMIC

Circular solutions for biowaste

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

Consortium

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Horizon 2020