Factsheet
SYSTEMIC demonstration plant

Am-Power (Pittem, Belgium)

A short introduction to Am-Power

Am-Power (Figure 1) is located in the western part of Flanders (Belgium), a region with a surplus of animal manure and a high market demand for synthetic fertiliser. This SYSTEMIC demonstration plant is the largest biogas plant in Belgium: it has a processing capacity of 180 kilotonne (kt) feedstock per year, spread over four digesters and one post-digester.

Table 1. Technical information of the biogas plant.

Characteristic	
Year of construction	2011
Maximum power output	7.5 MW_e
Digester volume	20 000 m^3
Digestion type	Thermophilic digestion

Drivers for nutrient recycling

Am-Power has a history of experimenting with and investing in nutrient recovery innovations. Several years ago, Am-Power already envisaged the importance and benefits of moving towards a circular economy because disposal of the digestate is an important part of the costs for biowaste processing plants. On top of this, the agro food industry in Flanders realises that their waste streams are valuable and thus demand a gate fee to biogas plants for intake of their biowaste.

Figure 1. Aerial photo of the demonstration plant Am-Power.

Competition between biogas plants makes it difficult to achieve a cash flow above the breakeven point. Am-Power believes that nutrient recovery can be a way to achieve this. Am-Power produces about 160 kt of digestate per year and strives to process it in a cost effective, efficient and relatively simple way, without losing the nutrients. The plant has developed and implemented a process for the recovery of nutrients in the form of valuable fertilisers which is currently being optimised.

Feedstock

In 2020, the co-digestion plant processed 153 kt feedstock of which more than 52% was organic biological waste (industrial food waste and source-segregated food waste (SSFW)). Co-substrates mainly include animal manure and glycerine (Table 2). Organic biological waste and animal manure are processed in separate digestion lines (digester 1 and 2).

Table 2. Origin of Am-Power's digester feedstock (2020).

Type	**Mass (kt)**
Digester 1 (non-manure)	
Food waste & SSFW	**80**
Food industry sludge	**21**
Glycerine and fatty substrates	**15**
Others	**15**
Digester 2 (manure)	
Manure (slurry)	**19**
Solid fraction of manure	**2.4**
Total	**153**

Anaerobic digestion (AD)

- Organic waste is collected and homogenised in a mixer to a substance with a dry matter (DM) content of approximately 20%.
- Homogenised feedstock is hydrolysed in a separate tank (with a retention time of 3 days) and fed to a thermophilic digester.
- Retention time in the digester is about 50–60 days and about 10 days in the post-digester.

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Biogas production

In 2020, around 15 million m^3 biogas was produced, digesters and post-digester included (Table 3). The biogas is converted by a Combined Heat and Power (CHP) installation into thermal and electrical energy. The calculated amounts of heat and electricity produced in 2020 are respectively 32,166 MWh_{th} and 29,727 MWh_e.

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

Parameter	Amount
CH_4 (% v/v)	57
CO_2 (% v/v)	44
Total biogas production (Nm^3)	15 Mio
Biogas per tonne of feedstock (Nm^3 t^{-1})	95

Nutrient Recovery & Reuse (NRR) process

The previous process worked as follows:

- Digestate was diluted with liquid fraction (LF) of digestate and sent to two decanter centrifuges for solid-liquid separation. Coagulation and flocculation were favoured by the addition of respectively iron sulphate and polymer flocculant. Dilution with recirculated LF of digestate was necessary to achieve a better efficiency of the reverse osmosis (RO) step. Each of the two decanter centrifuges require about 146 kW of electric power.
- The phosphorus (P) rich solid fraction (SF) of digestate, with a DM content of 24%, was dried in a fluidised bed dryer (requiring 268 kW_e and 3000 kW_{th}) with waste heat from the CHP installation. To do so, exhaust gas from the CHP installation (160 °C) is mixed with ambient air to a temperature of 80 °C. The dried SF of digestate (with a total P and DM content of respectively 2% and 90%) were exported to France where there is demand for P.
- The LF of digestate, rich in nitrogen (N) and potassium (K), was first processed in a dissolved air flotation (DAF) unit. Iron chloride and polymer flocculant were added to reduce the DM content of the LF to 1.2–1.6%. The subsequent RO unit required the addition of sulphuric acid to the influent to ensure a good membrane separation. The resulting RO concentrate, rich in N and K (respectively 0.5% and 0.4%), was used as a fertiliser on local agricultural land. RO permeate water was reused on-site.

The adjusted process includes a continuous vacuum evaporator prior to the RO unit, thereby increasing the recovery of nutrients from digestate (Figure 2).

- The decanter centrifuge, with addition of polymer flocculant to improve separation, separates the digestate in an SF and an LF of digestate.
- As in the previous process, the SF of digestate (25–30% DM) is dried up to 80–90% DM.
- The LF of digestate (3.5–4.5% DM) flows into an acidification tank where addition of sulphuric acid lowers the pH to 6.5–7 to prevent ammonia losses in the subsequent evaporation step. Compared to the previous NRR system, the amount of polymer flocculant needed decreased from 63 to 38 tonnes per year.
- The vapour produced by the vacuum evaporator, containing <0.1% mineral N, is condensed to form condensed water. Currently, the condensed water is reused to a.o. dilute the digester feedstock, make the polymer flocculant solution or clean the evaporator plates. In the future, the RO unit (57 kW_e) will process it into dischargeable purified water.
- The evaporator concentrate, which has a DM content >10%, will be blended with the dried SF of digestate into an organic NPK fertiliser and applied on agricultural land. Each of the two evaporator units require about 381 kW_e and 1500 kW_{th}, which is a lot more than the DAF unit did require.

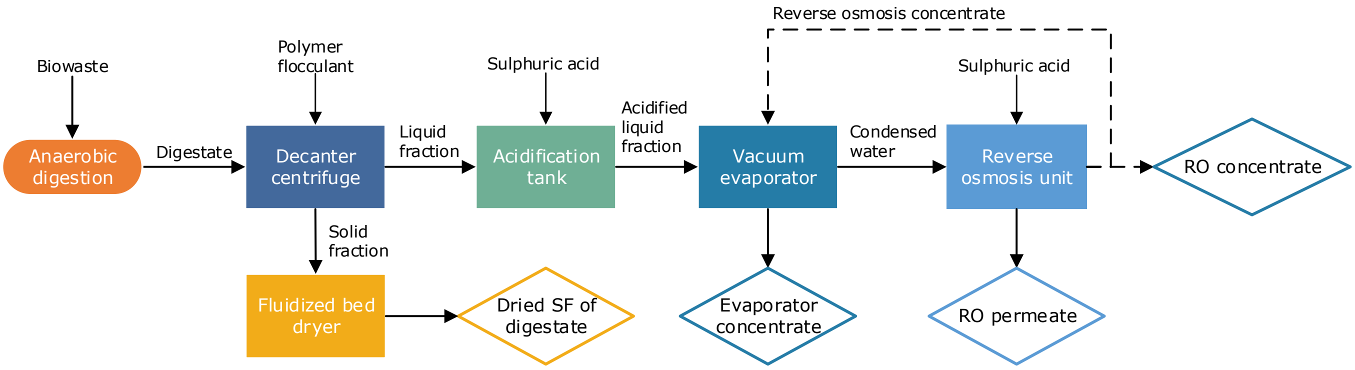

Figure 2. Simplified process flow diagram of Am-Power's current nutrient recovery and reuse system.

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Status of construction

The vacuum evaporator consists of two identical units, each with an evaporation capacity of 150 m^3 d^{-1}. Both units have been installed and are operational (Figure 3). Since the total N content of the permeate water (108 mg L^{-1}) did not comply with Flemish discharge limits (15 mg L^{-1}), Am-Power has installed an acidification step prior to the evaporator to reduce lower the amount of ammonia that evaporates. This results in a higher total N content of the evaporator concentrate. The investment costs for the evaporator and adaptation costs of the process amounted to € 2 million in total.

Figure 3. Photo of the vacuum evaporator.

The new RO unit however suffers from continuous membrane fouling, Am-Power is currently adjusting several process steps to overcome this issue.

Products and market

- The digestate previously processed with the DAF unit and RO unit resulted in a dried P-rich SF of digestate and an RO concentrate. The RO concentrate was applied on agricultural land in the region, whereas the dried SF of digestate was exported to France.
- With the current process, Am-Power will blend part of the evaporator concentrate and the dried SF of digestate (ratio 1:1) into an NPK fertiliser to be exported to regions with demand for this fertiliser, such as France. Product characteristics are given in Table 4.

Table 4. Composition of the ingoing digestate and produced end products at AM-Power (October 2020 – April 2021).

	Digestate	Liquid fraction of digestate	Evaporator concentrate	Dried solid fraction of digestate
pH	8.1	8.3	6.2	8.1
Dry matter (g kg^{-1})	81	26	115	823
Organic matter (g kg^{-1})	50	14	63	529
Total N (g kg^{-1})	4.9	4.0	7.1	23
NH_4-N (g kg^{-1})	2.3	2.4	3.0	1.3
Total P (g kg^{-1})	1.4	0.21	2.2	19
Total K (g kg^{-1})	3.3	3.1	5.6	14

Economic benefits

The economic advantages of the produced end products are:

- Monitoring of Am-Power suggests that up to 75% of the water in the LF of digestate is removed in the vacuum evaporator and will, after future polishing by an RO unit, become available as dischargeable purified water. An additional 45 m^3 of water per day is removed by drying the SF of digestate. These amounts of water do not have to be transported.
- Replacement of the DAF unit by the vacuum evaporator cuts costs for chemical additives.

Sustainability goals

Am-Power is committed to reaching the following targets:

- Reducing CO_2 emissions related to digestate transport.
- Reducing the addition of polymer flocculant and eliminate the addition of iron salts.
- Increasing the production of permeate water.

This project has received funding from the European Union's H2020 research and innovation programme under the grant agreement No: 730400. SYSTEMIC started 1 June 2017 and ran for 4 years.

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Monitoring data: total mass and nutrient mass flows

Total mass (Figure 4) and nutrient mass (Figure 5) flows were calculated for the NRR system of Am-Power for the period October 2020 – April 2021. This was done to evaluate the overall performance of the plant and the separation efficiencies of the individual process units.

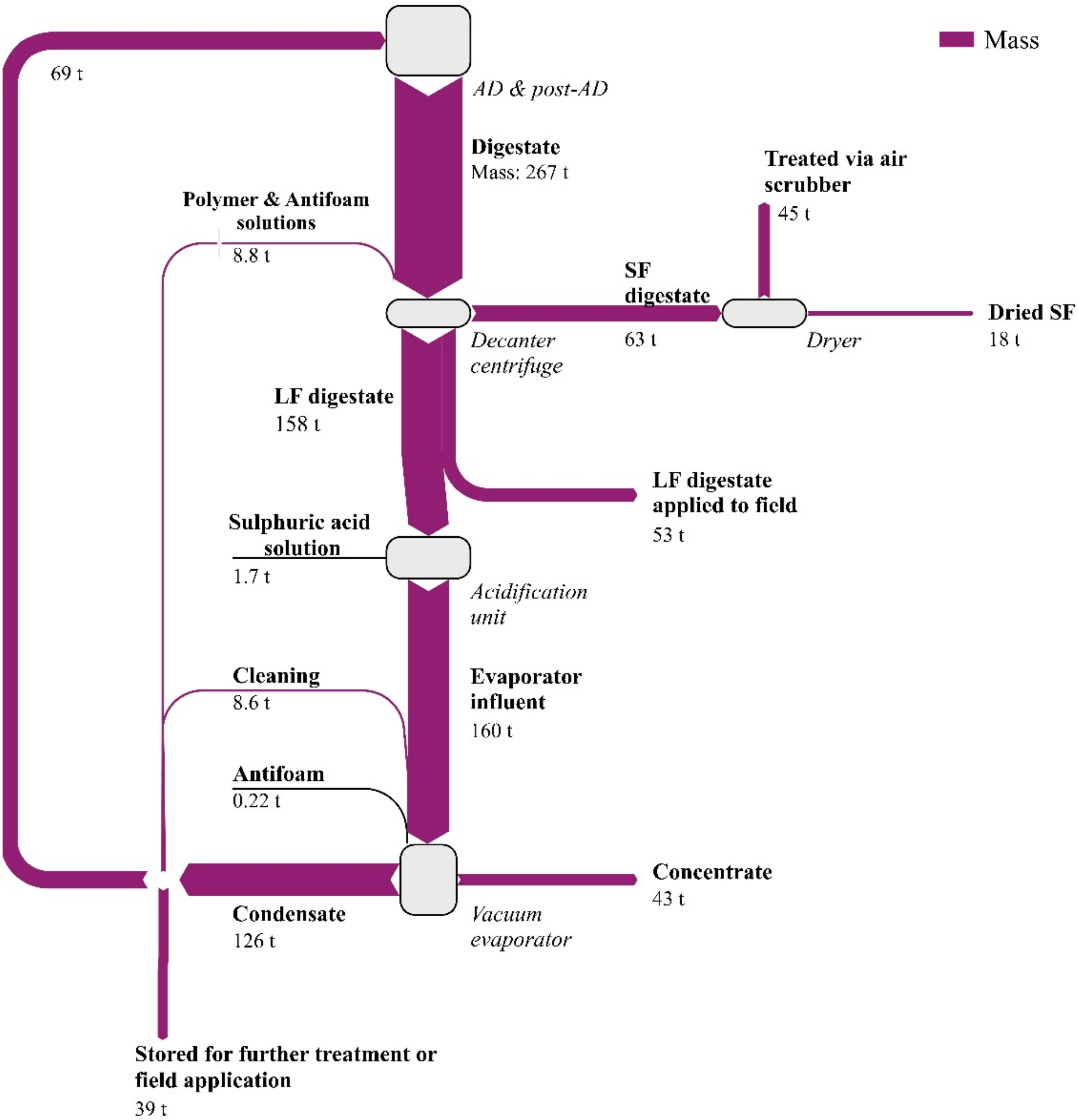

Figure 4. Total mass flows of the nutrient recovery and reuse system at Am-Power in tonnes (t) per day.

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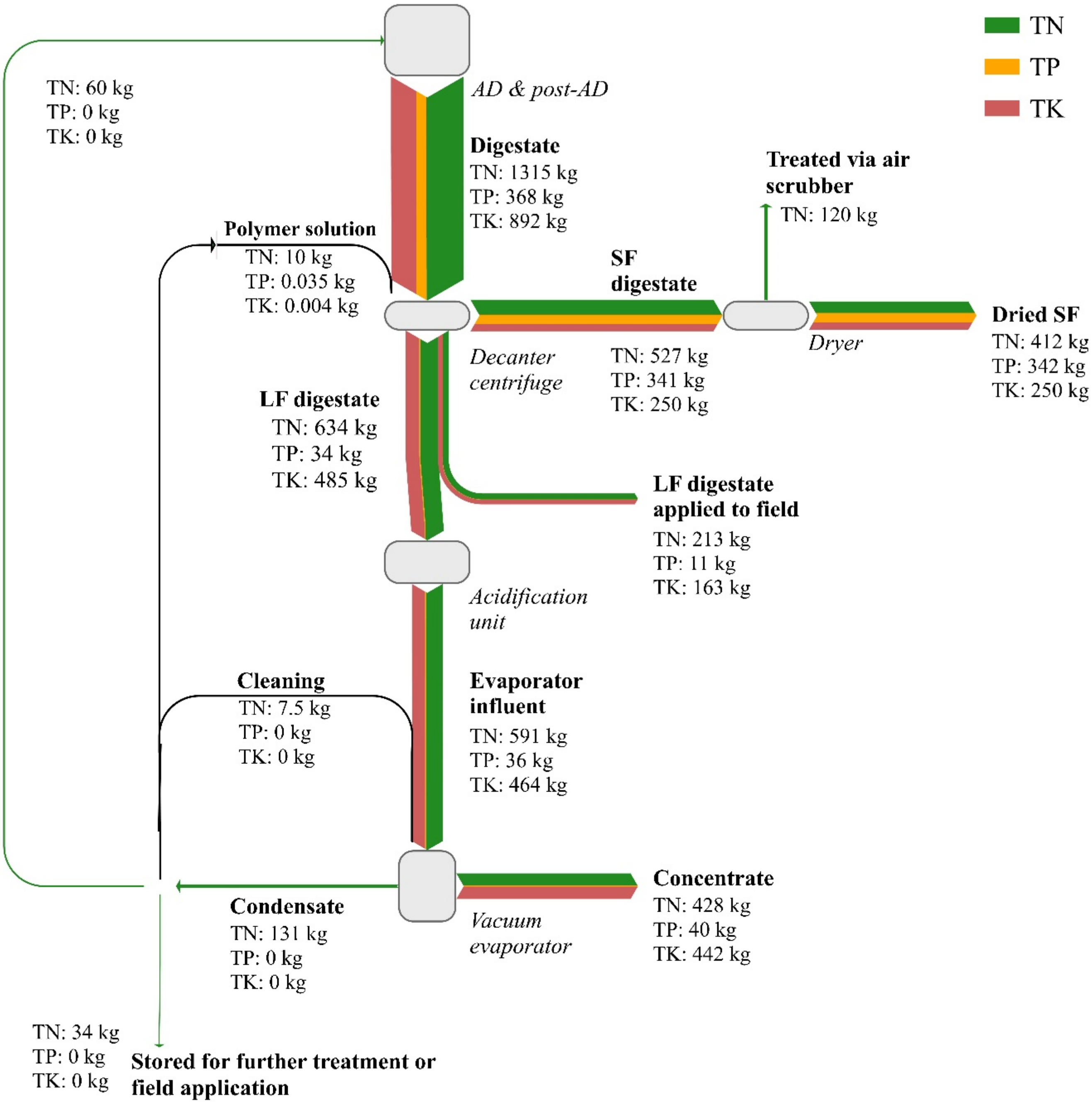

Figure 5. Total nitrogen (TN), total phosphorus (TP) and total potassium (TK) mass flows of the nutrient recovery and reuse system at Am-Power in kilogram (kg) per day.

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Monitoring data: energy balance

In 2020 the plant generated 29,727 MWh of thermal energy. The CHP installation also generated 32,166 MWh of electricity, of which 13% was in total consumed by the AD and NRR system. The remainder was sold via the national grid (Figure 6).

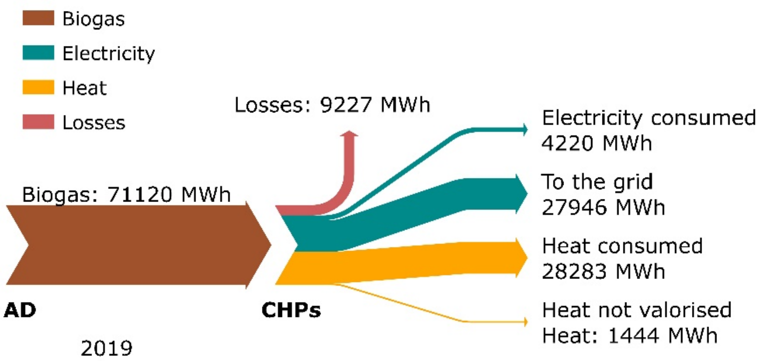

Figure 6. Energy balance of the anaerobic digestion and nutrient recovery and reuse system at Am-Power for the year 2020.

Key Performance Indicators (KPIs)

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

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

Table 7. Economic KPIs of Am-Power's plant.

KPI	
EBIT margin	3%
EBITA margin	25%
Substrate productivity	€44 / tonne feedstock
Biogas productivity	€0.24 / Nm^3 biogas
Digestate productivity	€-7.2 / tonne feedstock

Despite the large scale of the plant, Am-Power deals with high costs for feedstock, which translates into a low substrate financial productivity.
Although the digestate financial productivity is negative, the implementation of the NRR system for processing of the digestate increased the digestate financial productivity from € -17 per tonne of feedstock to €-7.25 per tonne of feedstock.

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