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 treatment capacity of 180 kiloton (kt) feedstock year, spread over four digesters and one post-digester.

Table 1. Technical information of the biogas plant.

Characteristics	
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 and investing in the recovery of nutrients. A long time ago AM-Power already envisaged the importance and benefits of moving towards a circular economy. The disposal of digestate is an important cost for biogas plants. On top of this, the agro-food industry in Flanders realizes that their waste streams are valuable and thus demand to be paid by biogas plants to retrieve waste.

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

Competition between biogas plants makes it difficult to get the turnover break even. AM-Power believes that nutrient recovery can be a way to balance this again. AM-Power produces about 160 kt of digestate per year and strives to process this in a cost effective, efficient and relatively simple way, without losing the nutrients. Their technological solution for the recovery of nutrients into valuable fertilisers is currently implemented and currently optimized.

Feedstocks

In 2019, the co-digestion plant treated 161 kt of feedstock, out of which more than 69% was organic biological waste (industrial food waste and source segregated food waste). Co-substrates mainly include animal manure and glycerine (Table 2). Organic biological waste and animal manure are processed in separate digestion lines.

Table 2. Origin of AM-Power's digester feedstock (2019).

Type	Mass
Organic biological waste	111 kt
Manure	17 kt
Glycerine and fat-rich substrates	9.1 kt
Other feedstock	24 kt
Total	**161 kt**

Anaerobic digestion

- Organic waste is collected and homogenized in a mixing unit to a substance with a dry matter (DM) content of approximately 20%.
- Homogenized feedstock is hydrolysed in a separate unit (with a retention time of 3 days) and fed to a thermophilic digester.
- Retention time is around 50–60 days in digesters and 10 days in the post-digester.

Horizon 2020

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Biogas production

In 2019, the biogas produced (including digesters and post-digester) was around 17 Mm^3 (Table 3). The biogas is converted by a Combined Heat and Power (CHP) installation into electrical and thermal energy. The calculated amounts of heat and electricity produced in 2019 are respectively 32,486 MWh_{th} and 29,102 MWh_e.

Table 3. Yearly biogas production and average composition before purification (2019).

Component	
CH_4 (%)	55
CO_2 (%)	45
Total biogas production (Nm^3)	17 Mio
Biogas per tonne of feedstock (m^3 t^{-1})	105

Nutrient Recovery Technology

The previous process worked as follows:

- Digestate was diluted with liquid fraction of digestate (LF) and sent to two decanter centrifuges for solid/liquid separation. Coagulation and flocculation were favoured by the addition of polymer and iron sulphate. Dilution with recirculated LF was necessary for a better efficiency of the reverse osmosis (RO) step. Each of the two centrifuges requires about 146 kW of electrical energy.
- The phosphorus (P) rich solid fraction of digestate (SF), with a DM content of 24%, was dried in a fluidized bed dryer (268 kW of electricity and 3000 kW of heat). Drying of the SF was accomplished by recycling waste heat from the CHP installation. The exhaust gas from the CHP installations (160 °C) is mixed with ambient air to a temperature of 80 °C. Dry biosolids (containing 2% total-P and 90% DM) were exported to France where P demand is high.
- The nitrogen (N) and potassium (K) rich LF was first processed in a dissolved air flotation unit (DAF), which requires 7 kW of electricity. Iron chloride and polymer were added to reduce the DM content of the LF to 1.2–1.6% DM. Next, the RO unit (100-130 kW) required the addition of sulphuric acid to the influent to ensure a good membrane separation. The resulting concentrate, rich in N and K (respectively 0.5% and 0.4%), was used as a fertiliser on local agricultural land. Permeate water was recycled on site.

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

- Raw digestate is mechanically separated in the decanter centrifuge. AM-Power is still investigating the optimal polymer dosage for an efficient evaporation step.
- As in the previous process, the solid fraction (25–30% DM) will be dried up to 80–90% DM, while the liquid fraction (3.5–4.5% DM) will be sent to the vacuum evaporator.
- In the evaporator, the vapour will contain ammonia (NH_3) that is condensed as ammonia water and subsequently pumped to the RO unit (57 kW). Part of the concentrate that remains after evaporation, which has a DM content of 13%, is blended with the dried biosolids into and organic NPK fertiliser and applied on agricultural land. Compared to the DAF unit, each of the 2 evaporators unit is more energy demanding, consuming respectively about 381 kw of electrical energy and 1500 kW of thermal energy.
- The ammonia containing retentate from the RO is recirculated to the evaporator, while the permeate water is discharged to surface water. The recirculated RO retentate will end up in the concentrated digestate, but it can also be used as a separate product.

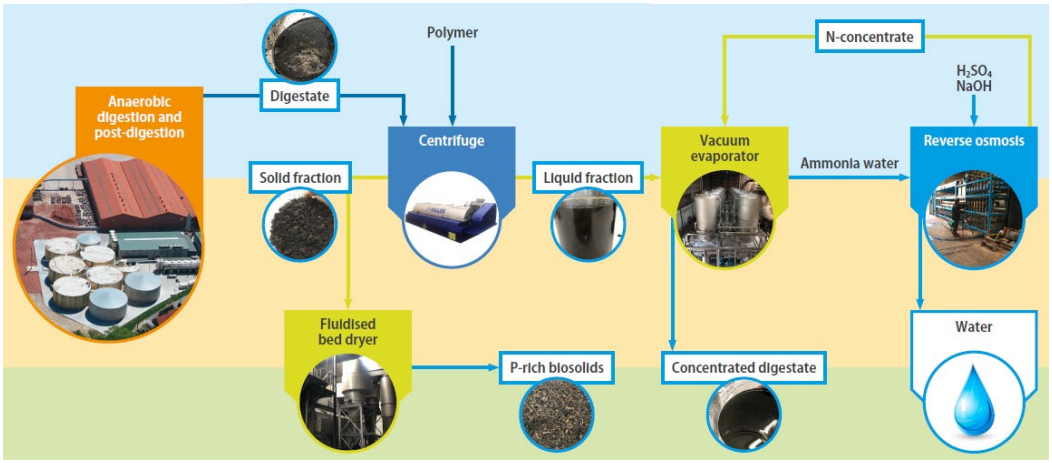

Figure 2. Overview of AM-Power's current process scheme.

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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 evaporator lines have been installed and are in operation (Figure 3). Since the total N content in the permeate water (108 mg L^{-1}) did not comply with Flemish discharging limits (15 mg L^{-1}), AM-Power decided to introduce an acidification step prior the evaporator to lower the amount of ammonia that evaporates, thereby increasing the amount of N in the concentrate that remains after evaporation.

Figure 3. Overview of the evaporator.

Currently, AM-Power is investigating the optimal polymer dosage required for the best performance of the evaporator. The evaporator manufacturer is finalizing some technical aspects of the unit and implements the software for the remote control of the system. The investment of the evaporator and adaptation of the process amounted approximately to 2 M€.

Products and market

- The digestate treated with the DAF and membrane system was processed into P-rich biosolids and mineral concentrate. The mineral concentrate was applied on agricultural land in the region, whereas P-rich biosolids were exported to France.
- With the novel system, AM-Power will blend part of the concentrate that remains after vaporization and P-rich biosolids with a ratio 1:1 into an NPK fertiliser to be exported to nutrient depleted regions. Product characteristics are given in Table 4.

Table 4. Composition of the recovered products at AM-Power.

		Previous process (DAF + RO)		Current process (evaporator + RO)	
	Digestate	NK concentrate	P-rich biosolids	Concentrate remaining after vaporization	P-rich biosolids
pH	8.6	7.6	7.5	9.6	9
Dry Matter (g kg^{-1})	62	24	912	114	840
Organic Matter (g kg^{-1})	31	18	523	n.a.	n.a.
N-total (g kg^{-1})	5.3	3.5	31	4.3	17
NH_4-N (g kg^{-1})	3.0	3.5	0.88	n.a.	n.a.
P-total (g kg^{-1})	1.3	0.02	19	1.8	17
K-total (g kg^{-1})	3.0	3.3	11	8.9	11

Economic benefits

The economic advantages of reusing recovered products are:

- By improving RO efficiency, AM-Power estimated that 160 m^3 of water per day will become available as dischargeable water (after polishing by an ion exchanger) or used on site. This amount of water does not have to be transported. About 36 m^3 per day of water can be additionally removed by drying the solid fraction digestate.
- Replacement of the DAF by the vacuum evaporator cuts costs for chemical additives.

Sustainability goals

AM-Power is committed to reach the following targets:

- Reduce CO_2 emissions related to digestate transport.
- Reduce the use of polymer usage and eliminate the use of iron salts.
- Increase the production of clean water.

Monitoring data (total mass and nutrient mass balances)

Total mass (Figure 4) and nutrient mass (Figure 5) balances were calculated for the demonstration plant over the period of one month (February 2020). The aim was to evaluate the overall performance of the plant and the separation efficiencies of each process unit.

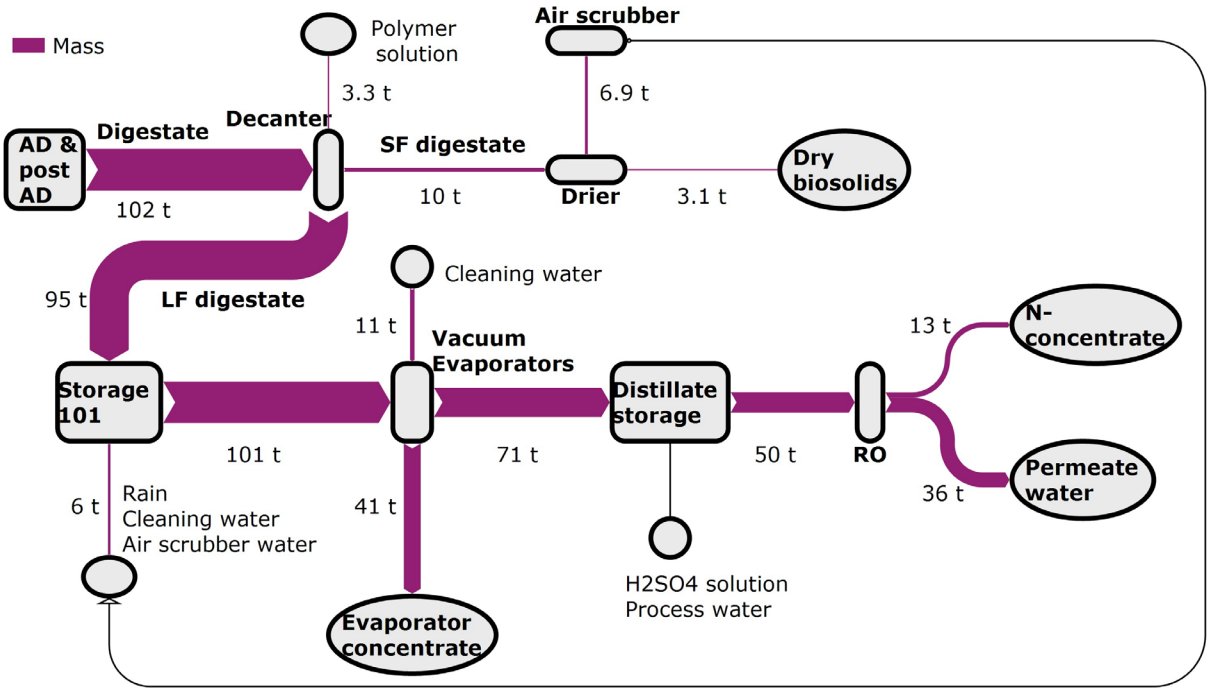

Figure 4. Total mass flows at the demonstration plant AM-Power. Values are expressed in tonnes per day (t d^{-1}).

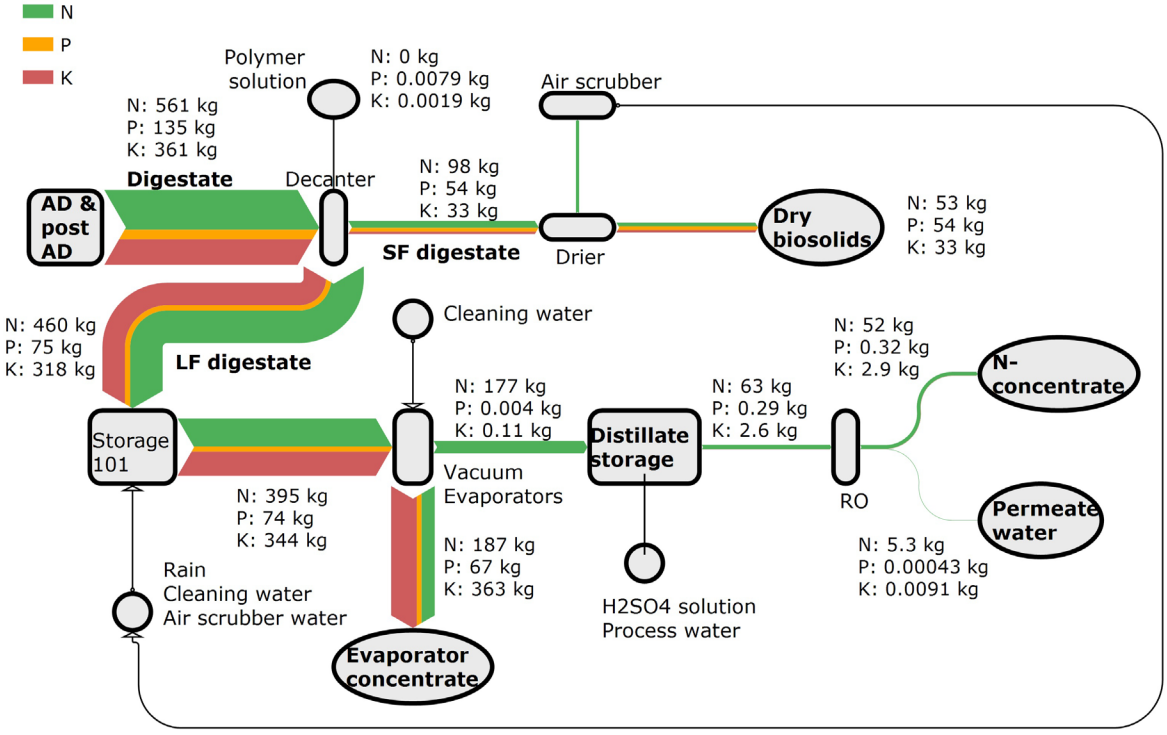

Figure 5. Total nitrogen (N), phosphorus (P) and potassium (K) mass flows at the demonstration plant AM-Power. Values are expressed in kilograms per day (kg d^{-1}).

Monitoring data (energy balance)

In terms of energy production, in 2019 the plant generated 44,177 MWh of thermal energy. The CHP installation also generated 32,295 MWh of electricity, out of which 9% was consumed at AM-Power and the rest was sent to the national grid (Figure 6).

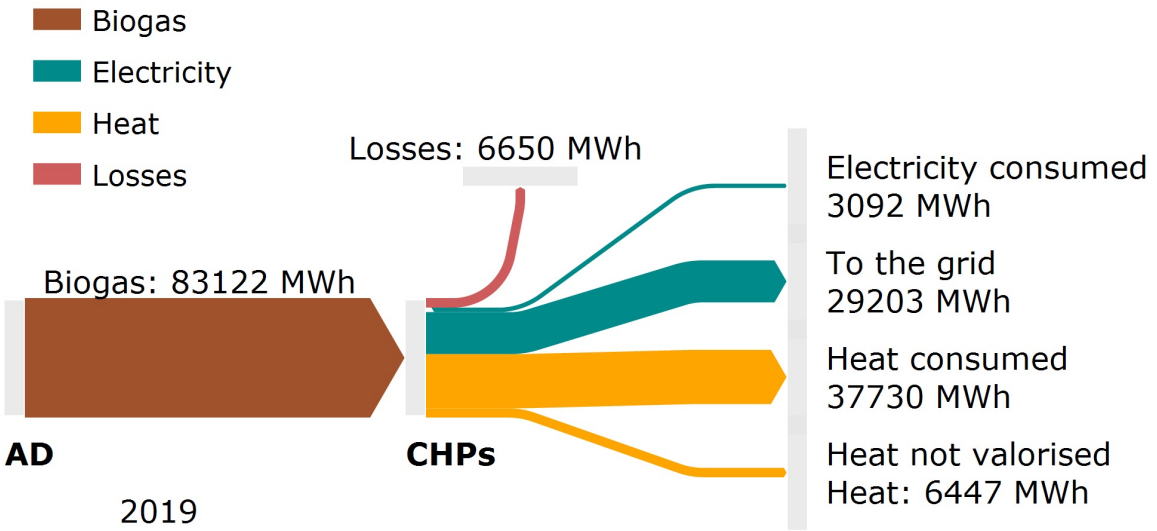

Figure 6. Energy balance of the demonstration plant AM-Power.

Key Performance Indicators (KPI's)

A KPI is a tool to understand how an organization is performing:

KPI_1: EBIT (Earning Before Interest and Tax) margin in % of revenues.
KPI_2: EBITA (Earning Before Tax, Interest And Amortization) margin in % of revenues.
KPI_3: Substrate Financial Productivity → total 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 → costs/revenues generated by digestate per tonne of feedstock.

Table 7. KPI's of AM-Power's demonstration plant.

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