

Acqua&Sole, Vellezzo Bellini (Italy)

A short introduction to Acqua&Sole

The biogas plant of Acqua&Sole (Figure 1) is located in Vellezzo Bellini (Northern Italy), in an area dedicated to cereal cultivation, mainly rice. Acqua&Sole has a focus on nutrient recycling with special attention to the development of a system for digestate application to agricultural lands (direct injection into the soil). This system is developed in collaboration with local farmers.

The aims of the system are to maximize fertilisation and minimize ammonia (NH₃) and odour emissions. In addition to the production of a soil improver (digestate), the demonstration plant produces ammonium sulphate from recovered NH₃ by nitrogen (N) stripping during the anaerobic digestion (AD) step. This ammonium sulphate is used as N fertiliser. For the recovery and reuse of nutrients, Acqua&Sole has an ambition of improving soil fertility without any use of synthetic fertiliser over an area of 5,000 hectares. Also Acqua&Sole wants to deliver the nutrients required for the surrounding farms.

Drivers for nutrient recycling

Degradation of N-rich feedstock leads to the formation of NH₃ which can have an inhibiting effect on anaerobic methanogenic microorganisms when reaching toxic levels are reached. Stripping of N and its subsequent recovery as ammonium sulphate is a great opportunity to prevent inhibition of the anaerobic digestion process. Furthermore, low carbon content in soils is an issue in Italy and the utilization of soil improvers (i.e. digestate) is a valuable tool to tackle this. However, restrictions on N application on agricultural land limit their use of organic materials, making it necessary to find solutions to lower the N content of the produced digestate.

Feedstocks

The co-digestion capacity is 120 kiloton (kt) organic feedstock per year. In 2019, 82 kt feedstock was digested of which about 85% was sewage sludge and 15% was digestate from anaerobic treatment of source-segregated domestic food waste (SSFW), and agro-food waste (Table 2). Liquid fraction of SSFW was not fed to the digester in 2019. The plant can digest manure, expired food, organic wastes, sewage sludge and agro-food industry waste.

Table 1. Technical information of the biogas plant.

Characteristics	
Year of construction	2016
Maximum power output	1.6 (MW _e)
Digester volume	13 500 (m ³)
Digestion type	Thermophilic digestion



Figure 1. Aerial photo of the demonstration plant Acqua&Sole.

Table 2. Origin of Acqua&Sole's digester feedstock (2019).

Type	Origin	Mass
Sewage sludge	Wastewater treatment plants	69.2 kt
Co-substrates	Digestate from anaerobic treatment of source-segregated domestic food waste	5.4 kt
	Agro-food waste	7.2 kt
Total		81.8 kt

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Biogas production

Anaerobic digestion is performed in three consecutive digesters with a volume of 4,500 m³ each. The biogas produced by the plant (Table 3) is converted by a Combined Heat and Power (CHP) installation into electrical energy and heat.

Table 3. Biogas production and average composition before purification in 2019.

Component	
CH ₄ (%)	60 - 65
CO ₂ (%)	33 - 36
H ₂ S ppm	<10 ppm
O ₂ (%)	<1
Total biogas production (Nm ³)	3.3 Mio
Specific CH ₄ production (Nm ³ CH ₄ t ⁻¹ OM)	198



Figure 2. Digester injection application on fields.

Digester characteristics

- Thermophilic digestion ensures a better control of pathogenic and intestinal microorganisms in the digester.
- The high N/NH₄-N ratio of the digester favours long-term fertilisation.
- Uniformity of digester distribution is ensured by the digester injection application system (Figure 2).

Nutrient Recovery and Reuse (NRR) technology

From April 2016 onwards, the plant operates as follows (Figure 3):

- Feedstock (organic waste) is collected in basins located in a closed building to prevent the release of odour. A bio-filter placed on the roof of the building purifies the exhaust air;
- Organic waste is moved to a mixing unit where it is heated and homogenized with biomass coming from the third digester;
- Homogenized and inoculated feedstock is fed to the thermophilic process (minimum retention time of 20 days and temperature of 55 °C) which ensures full hygienization of the incoming sludge;
- The process is equipped with a side-stream N stripping unit, whereby biogas acts as stripping agent, NH₃ is extracted by leading biogas through sulphuric acid (about 50%) resulting in an ammonium sulphate solution;
- Both the digester and the ammonium sulphate solution are stored in steel tanks.

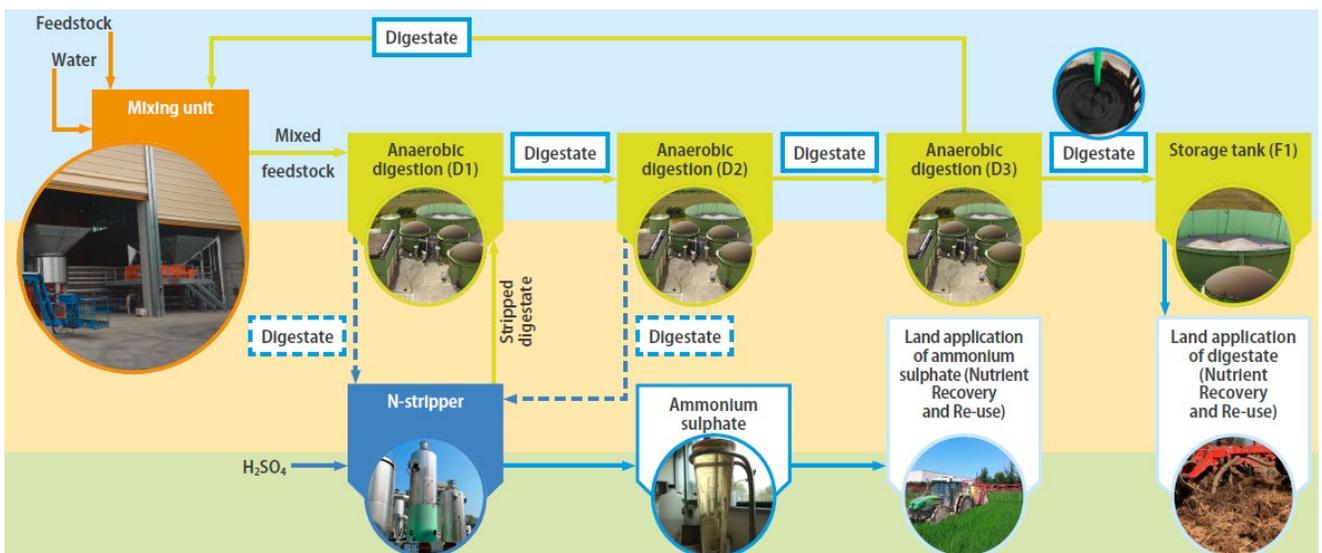


Figure 3. Flow diagram of the nutrient recovery and reuse facility at Acqua&Sole.

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Status of construction

The construction of a novel N absorber was completed by the end of 2019. The start-up of the new absorption unit was coordinated by switching off the existing unit and took place in January 2020 (this transitional period had to be as short as possible in order to avoid NH₃ inhibition in the digester). Currently, Acqua&Sole is fine-tuning the operational conditions, and up to now 27% of NH₃ removal is achieved. This is 35% higher than with the previous absorber unit which could remove about 20% of NH₃.

Products and market

The annual maximum capacity of the co-digestion plant is about 120 kt of organic waste, which will be mixed with water and transformed into at maximum 192 kt of digestate. Product characteristics are given in Table 4.

Acqua&Sole estimated that the use of digestate could replace the following amount of synthetic fertilisers per year: 1550 t N, 1160 t P₂O₅ and 170 t K₂O.

Table 4. Composition of the recovered products at Acqua&Sole (average data January 2018 – October 2019, n=17).

	Digestate	Ammonium sulphate
Dry matter (g kg ⁻¹)	102	354
Organic matter (g kg ⁻¹)	62	<1.6 (TOC)
N-total (g kg ⁻¹)	8.0	73
P-total (g kg ⁻¹)	3.0	0.010
K-total (g kg ⁻¹)	0.65	0.010

Economic benefits

Acqua&Sole calculated that the replacement of conventional fertiliser with digestate over a surface area of 5,000 hectares generated savings of about 2.3 million € per year (Table 5), but Acqua&Sole does not have direct savings from chemical fertiliser replacement. The implementation of the N absorber will further reduce the N content in the digestate, and as such allows a higher amount of digestate to be distributed on fields.

This will allow distribution of a higher amount of digestate per hectare with benefits in terms of transport and disposal costs. On top of that, lowering the NH₃ content in the digester will optimize the digestion process, by avoiding toxicity effects on methanogenic microorganisms and it increases the ammonium sulphate solution production.

Table 5. Saved economic costs.

Conventional fertiliser	Cost € t ⁻¹ *	Quantity t y ⁻¹	Total (€)
Urea 46% N	344	3 370	1 159 280
triple superphosphate 46% P ₂ O ₅	369	2 520	929 880
Potash 60% K ₂ O	669	280	187 320
Total Saved Cost			2 276 480

* Source: CCIAA Modena, Average 2017

Sustainability goals

Acqua&Sole is committed to reach the following targets:

- Close nutrient cycles through the use of fertilisers produced from sewage sludge and biowaste.
- Showcase that fertilisers from sewage sludge and biowaste are agronomically effective and environmentally friendly.
- Increase soil quality due to the use of digestate rather than chemical fertiliser, thereby contributing to sequestration of carbon in soil.
- Reduce NH₃, NO₃ and N₂O emissions during digestate application.
- Eliminate unpleasant odour to improve public acceptance.

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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 a period of 280 days, from January 2019 to October 2019. The aim was to evaluate the overall performance of the plant, including the recovery efficiencies of the N stripper. In the N stripper, 8.7% of total nitrogen (TN) fed to the system was collected as ammonium sulphate solution (which has an $\text{NH}_4\text{-N}$ content of 73 g kg^{-1}).

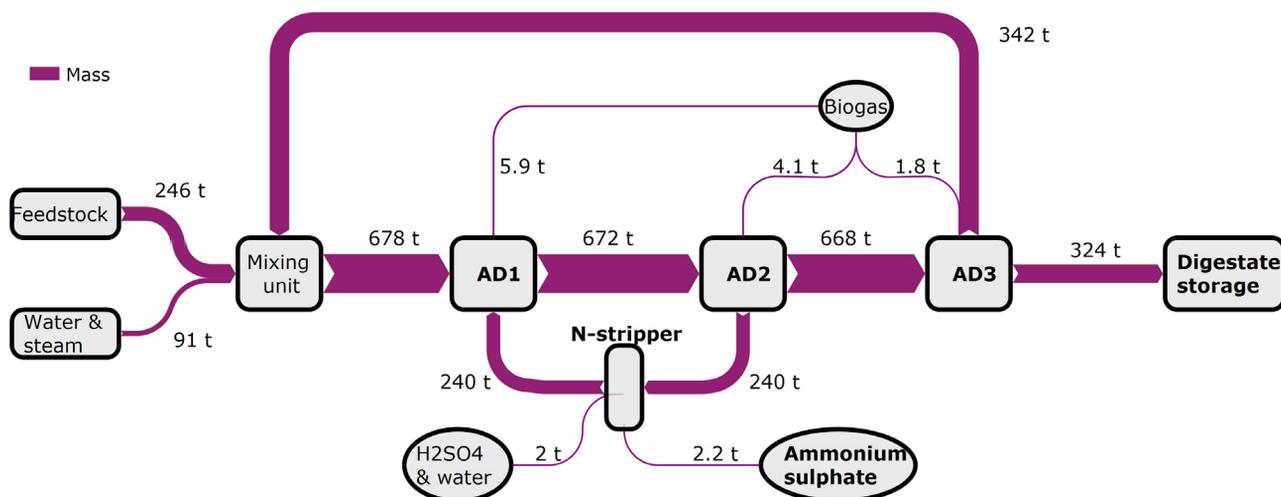


Figure 4. Total mass flows at the demonstration plant Acqua&Sole. Values are expressed in tonnes per day (t d^{-1}).

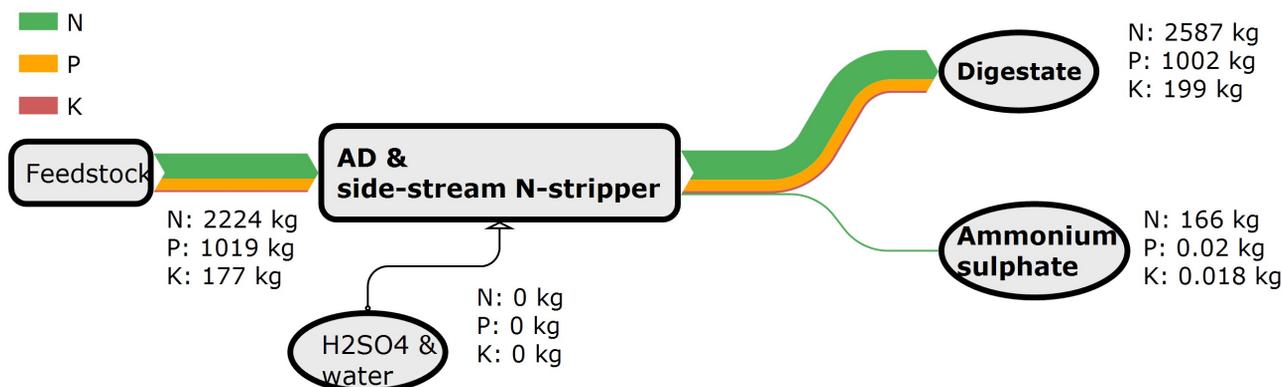


Figure 5. Total nitrogen (N), phosphorus (P) and potassium (K) mass flows at the demonstration plant Acqua&Sole. Values are expressed in kilograms per day (kg d^{-1}).



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Monitoring data (energy balance)

A preliminary energy balance was drafted for the period January–October 2019 and it will be implemented in the near future.

In terms of energy production, the plant generated 4,780 MWh of thermal energy, which was entirely used at the installation. An additional 1,343 MWh of thermal energy were required to fulfil the heating requirements of the plant. The CHP installation also generated 6,632 MWh of electricity, out of which 4.5% was consumed by the N stripper (Figure 6).

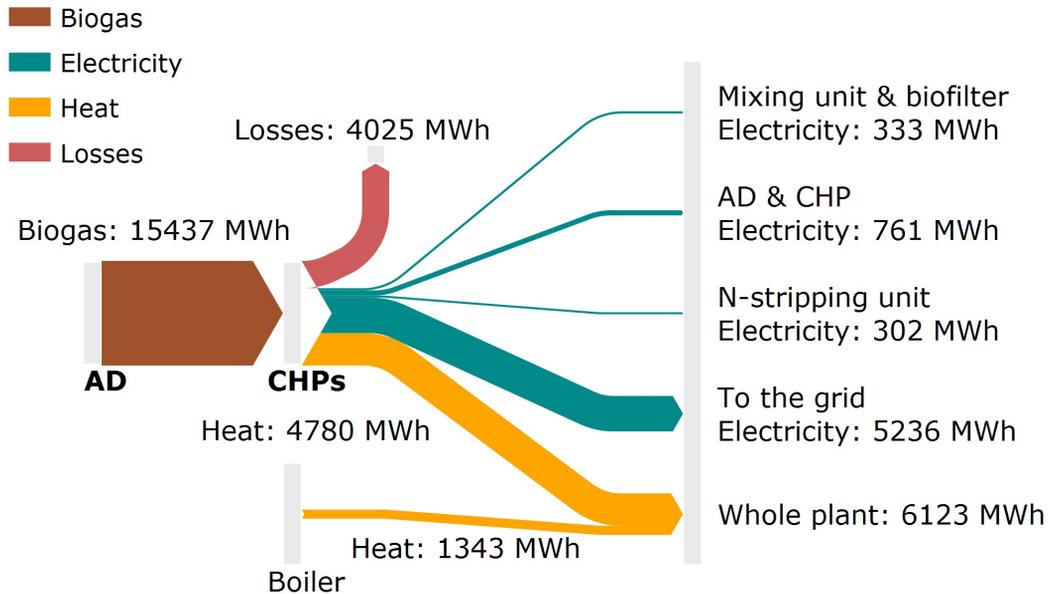


Figure 6. Energy balance at the demonstration plant Acqua&Sole.

Key Performance Indicators (KPI's)

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

KPI₁: EBIT (Earning Before Interest and Tax) margin in % of revenues.

KPI₂: EBITA (Earning Before Tax, Interest And Amortization) margin in % of revenues.

KPI₃: Substrate Financial Productivity → total revenues per tonne of feedstock.

KPI₄: Biogas Financial Productivity → net revenues of biogas (energy / green certificates) per cubic meter of biogas delivered.

KPI₅: Digestate Financial Productivity → costs/revenues generated by digestate per tonne of feedstock.

Table 7. KPIs of Acqua&Sole's demonstration plant.

KPI	
EBITA margin	41% / €
EBIT margin	16% / €
Substrate productivity	57 € / tonne feedstock
Biogas productivity	0.34 € / m ³ biogas
Digestate productivity	-4.6 € / tonne feedstock