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ENERGY AND NUTRIENT FACTORY AT AMERSFOORT WWTP IN THE NETHERLANDS

RECOVERY OF ENERGY AND NUTRIENTS FROM WASTE-ACTIVATED SLUDGE AND WASTEWATER

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ABSTRACT

Amersfoort Wastewater Treatment Plant (WWTP) in The Netherlands is owned and operated by Dutch water board Vallei & Veluwe. In 2013, Eliquo Water & Energy was awarded the project to upgrade the existing wastewater and sludge processing facilities and transform them into a regional sludge processing hub that will act as an 'energy and nutrient factory', using innovative technologies and commercial concepts to recover energy and nutrients.

Energy recovery is enhanced by the application of Lysotherm® thermal pressure hydrolysis technology to the anaerobic digestion process. The technology uses available waste heat instead of steam as a driving force for the hydrolysis process. The combination of this technology with the processing of import sludge results in the plant becoming energy-positive.

Phosphorus is recovered by creating a valuable fertiliser product, which will generate non-regulated revenue, combined with a guaranteed long-term off-take agreement through which the product marketing and distribution risks are transferred to the technology provider. It also prevents uncontrolled deposition of struvite occurring, resulting in significant savings in avoided maintenance costs

Keywords: energy recovery, nutrient recovery, enhanced digestion, anaerobic digestion, thermal pressure hydrolysis.

Figure 1. Aerial view of Amersfoort WWTP during the upgrade.

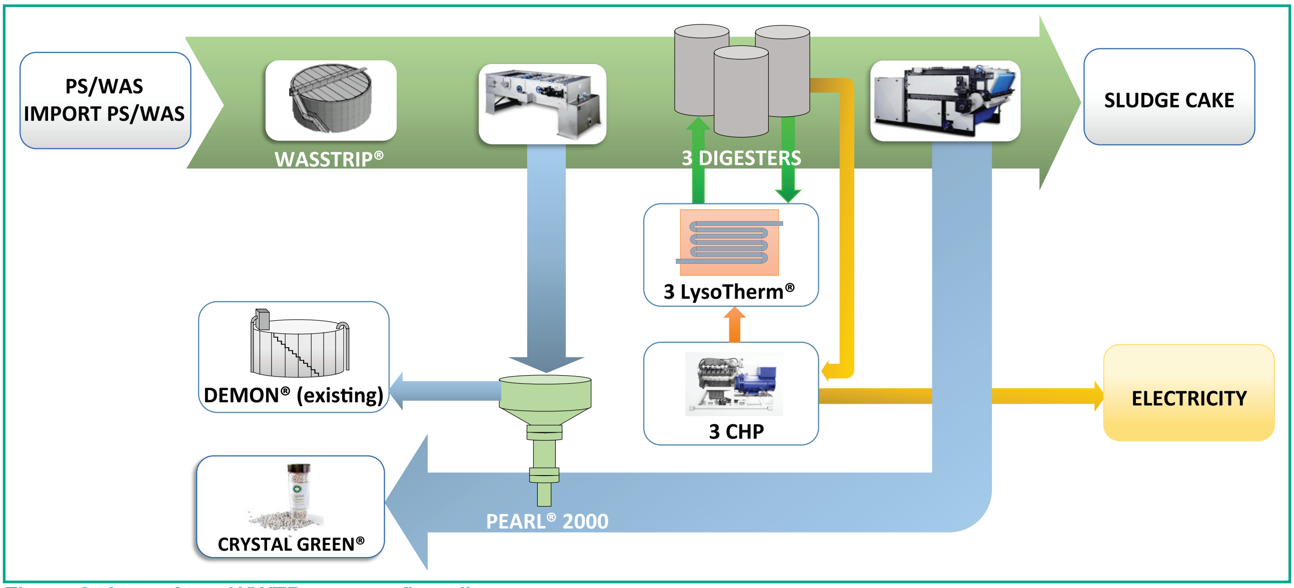


Figure 2. Amersfoort WWTP process flow diagram.

ENERGY AND NUTRIENT FACTORY

The upgraded Amersfoort WWTP will act as a regional sludge-processing hub for a number of WWTPs in the area. In line with an ongoing trend in The Netherlands and Western Europe, the focus was on the recovery of energy and nutrients from waste-activated sludge and wastewater; the plant will be transformed into a so-called 'energy and nutrient factory'.

The wastewater treatment capacity of Amersfoort WWTP is 315,000 PE (population equivalents), with a maximum flow of 8,900 m^3/h. The upgraded sludge processing facilities process a total of 12,000 tonne dry solids per annum. This includes approximately 40% imported sludge from other locations. An aerial view of Amersfoort WWTP is shown in Figure 1.

The project's main objectives were as follows:

1. To create a regional sludge-processing hub while re-using the existing assets;
2. To become energy-positive – i.e. sell electricity back to the grid;
3. To recover phosphorus in a commercially viable way;
4. To reduce overall sludge processing cost;
5. To achieve a payback period on capital investment of less than 10 years.

Eliquo Water & Energy delivered the upgrade by means of a Design & Construct contract together with a one-year operations and maintenance responsibility.

INCREASING DIGESTION CAPACITY AND ENERGY RECOVERY

The processing capacity and biogas production of the three existing anaerobic digesters were increased by the application of the Lysotherm thermal pressure hydrolysis technology.

In thermal pressure hydrolysis, sludge is heated to a temperature of 150–200°C at elevated pressure. Under these conditions the cells of the microorganisms present in activated sludge are broken down into soluble organic materials such as carbohydrates, proteins and lipids. The bioavailability of the sludge content is thus improved, enhancing the performance of anaerobic digestion and methane production.

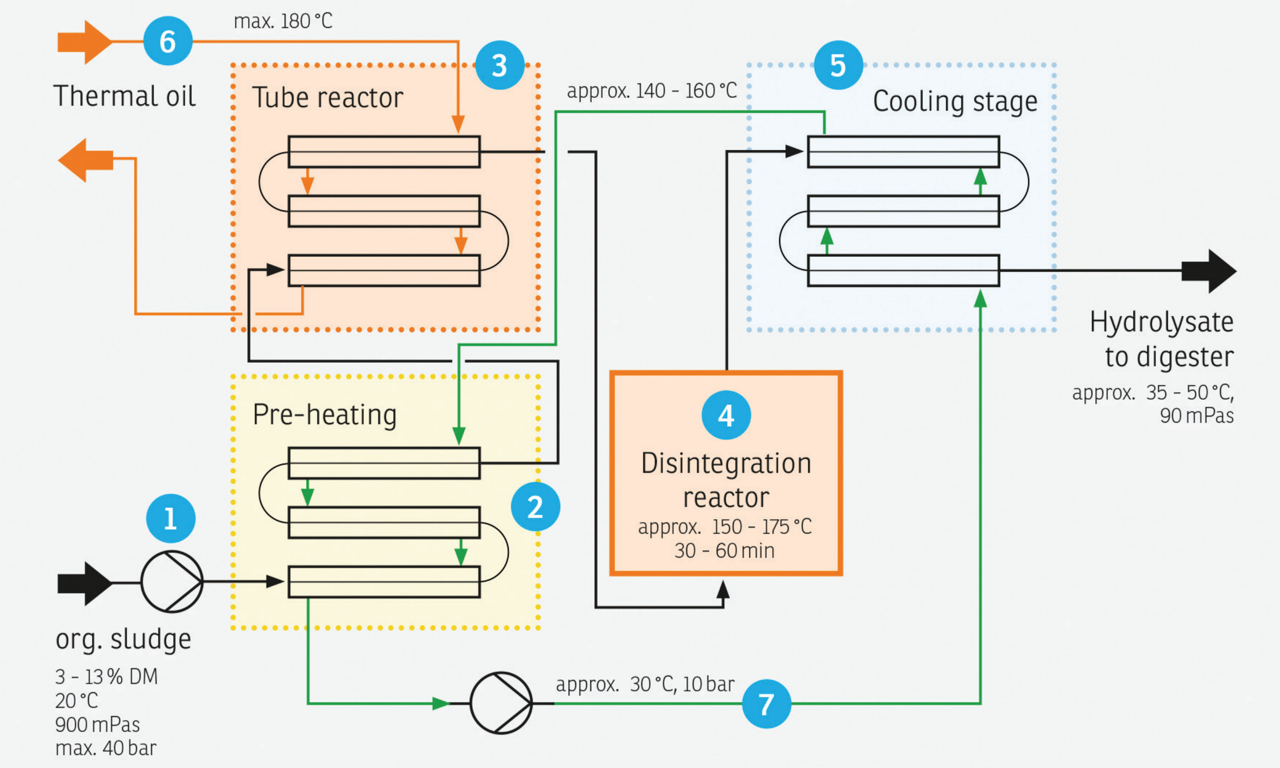
Each of the three existing digesters at Amersfoort WWTP has a volume of 2,700m^3 and is coupled with one Lysotherm sludge hydrolysis module. Application of the technology resulted in the throughput capacity of the existing digesters achieving the new processing capacity while avoiding the need to add conventional digester volume. A diagram of the new process configuration is shown in Figure 2.

The application of this thermal pressure hydrolysis brings the following advantages:

- Increased capacity of existing digester volume;
- Increased gas production;
- Reduced production of biosolids;
- Increased sludge dewatering capability;
- Reduced chemical consumption for sludge dewatering.

Innovation

An important innovation is the fact that, in contrast to traditional thermal pressure hydrolysis systems, this technology does not require steam as a driver. Instead, a combination of two counter-current heat exchangers uses the heat produced by the Combined Heat and Power (CHP) engines to heat the digesters and drive the hydrolysis process. The first heat exchange loop uses the cooling water of the final stage of the hydrolysis process to pre-heat the feed to the Lysotherm unit. The second one consists of a thermal oil circuit that captures the exhaust heat from the CHP engines. A diagram of the heat exchange concept is shown in Figure 3.



• Sludge is fed via the sludge pump (feeding pump, 1) into a multistage heat exchanger system. The feed constitutes a continuous process.

• Pre-heating takes place at the first stage of the heat exchanger system (2) , then the sludge is heated to hydrolysis temperature in the tube reactor (3).

• The proper hydrolysis process takes place at the pre-determined reaction temperature in the hydrolysis reactor (4), where the sludge usually remains for 30–60 minutes. After the hydrolysis is completed, the sludge is cooled down in cooling stage (5) to the temperature required for entering the digestion tank; alternatively, it can be mixed with cold primary sludge and cooled down to digestion temperature.

• The system is heated via two heating circuits:

- The thermal oil circuit (6) to create the necessary process heat in the tube reactor;

- The regenerative circuit (7) using water as heat transfer medium. This circuit makes the heat recovered from the hydrolysed sludge in the cooling stage available for pre-heating

Figure 3. Diagram of Lysotherm® thermal pressure hydrolysis.

Avoiding the need for steam generation has a positive impact on economic viability, safety requirements, plant availability and operability. It also improves energy efficiency as no gas is used to boil water to generate steam, leaving more for the generation of electricity.

A Sankey diagram of the overall system energy flows from biogas through to the excess heat available after digester heating is shown in Figure 4. Please note the high efficiency of the system means that only five per cent of energy is lost.

Efficient Construction And Operation – And No Odour Emission

The plant was manufactured, assembled and tested in Eliquo's factory in Germany prior to shipment to site. This resulted in on-site assembly being reduced to a minimum, which had a very positive impact on the project schedule as well as safety. The system is modular in configuration, which also simplifies construction and provides flexibility in capacity. A photograph of the installation on-site is shown in Figure 5.

Other major benefits of this technology are that it is a continuous process and does not have any major down-time for cleaning or maintenance purposes. As far as maintenance is concerned, periodic, short and fully automated Cleaning In Place (CIP) is sufficient to keep the system running efficiently.

Lastly, as the system is fully enclosed and no flash tank is used in the process, no additional odour emissions occur. No negative odour impact on the environment is another advantage for the plant owner, as it

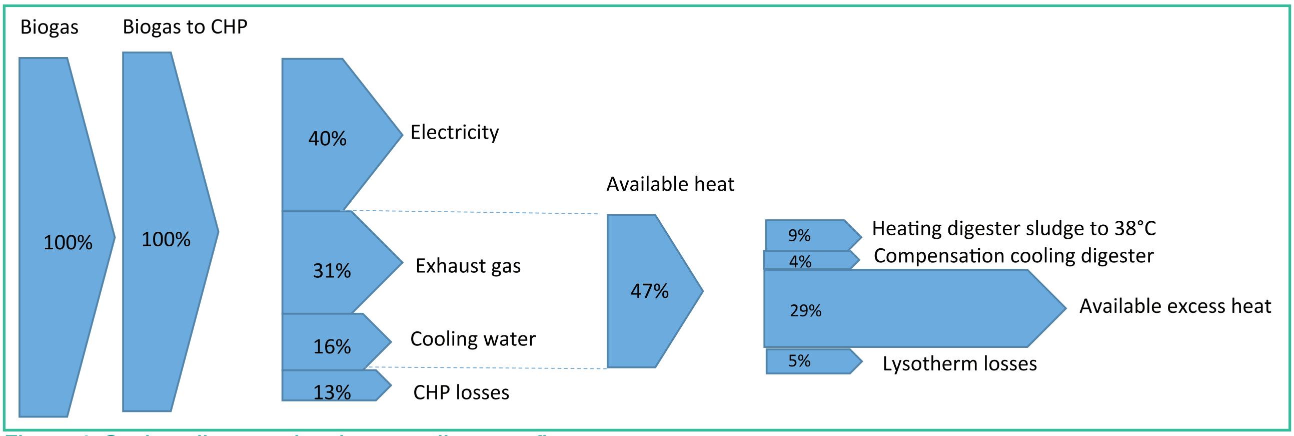


Figure 4. Sankey diagram showing overall energy flows.

will not result in any complaints from nearby residents, which can lead to regulatory pressure on the operating permit.

Achieving An Energy-Positive Status

Three new 500kW Combined Heat and Power (CHP) units with increased electrical efficiency have been installed to recover energy from the total flow of biogas produced.

The combination of the increased gas production by application of Lysotherm technology and new CHP units results in the new Amersfoort WWTP becoming energy-positive, i.e. a net producer of energy. On an annual basis, approximately two million kWh of electricity will be sold back to the grid.

PHOSPHORUS RECOVERY

Like oil, phosphate rock is a non-renewable resource and the reserves of high-grade phosphate are becoming increasingly scarce, while demand for phosphorus is expected to increase in the long term due to population growth and changes in diet.

In Europe, the sustainable supply of phosphorus was identified

Figure 5. Lysotherm installation at Amersfoort WWTP.

FIVE YEARS' OPERATIONAL EXPERIENCE AT LINGEN WWTP

The water board responsible for Lingen WWTP in Germany wanted to upgrade the existing facilities to a thermal/electrical self-sufficient plant with a capacity of approximately 195,000 PE. This was achieved by introducing Lysotherm thermal pressure hydrolysis to enhance the existing sludge digestion and a CHP unit to recover energy.

In the initial stages of the project, one of two existing anaerobic digesters was equipped with a Lysotherm system, while the other one remained in a conventional configuration. For a period of five years the results of both digesters were compared, while both were subjected to the same process conditions. This resulted in an improved understanding of the thermal pressure hydrolysis process, its impact on the anaerobic digestion and system optimisation.

Energy surplus was achieved through supplementing the WWTP sludge with external substrate and waste from a nearby biodiesel production facility and fitting a Lysotherm unit to the second digester. This provided the opportunity to produce more energy, which led to the plant producing more energy than required for sustainable operation.

as an important factor affecting sustainability and long-term global food security in both the *Communication Towards a Circular Economy: A Zero Waste Programme for Europe,* and the *2011 Roadmap to a Resource Efficient Europe*. This awareness has translated into an interest by Dutch water boards to recover phosphorus from municipal wastewater through the aforementioned 'energy and nutrient factories'.

Uncontrolled Struvite Deposition

Many existing WWTPs, in particular those that have anaerobic digestion, suffer from the uncontrolled formation and deposition of struvite. Struvite is formed when ammonium, phosphorus and magnesium come together at certain pH levels, and appears as a hard, difficult-to-remove deposition. Uncontrolled struvite deposition typically affects mechanical equipment and pipelines, the latter by significantly reducing available diameter for undisturbed flow. The ongoing maintenance costs related to cleaning of pipelines and wear on mechanical equipment can be a substantial burden for the wastewater treatment plant owner/operator.

Phosphorus Recovery At Amersfoort WWTP

Amersfoort WWTP, and the other plants exporting sludge to the Amersfoort sludge-processing facility, use biological phosphorus removal, which means phosphorus is contained in the activated sludge. The phosphorus is recovered from the waste-activated sludge by producing a high quality commercial fertiliser called Crystal Green®.

Phosphorus is extracted from the activated sludge prior to digestion by applying the Waste Activated Sludge Stripping to Remove Internal Phosphorus (Wasstrip®) process. Phosphorus-rich filtrate from the Wasstrip is treated with the reject water from the sludge dewatering in a Pearl® reactor, producing the Crystal Green pellets. The pellets are dried, classified and bagged for transport. The reactor has a capacity to produce two tonnes of Crystal Green per day. Figure 6 shows a bag of Crystal Green as it is filled from the Pearl reactor.

The combination of the Wasstrip and Pearl processes reduces the amount of chemical sludge that is formed when phosphorus is removed from wastewater by chemical dosing via conventional removal methods. It has also proven to improve dewaterability of the digested sludge.

The uncontrolled deposition of struvite is avoided, saving the water board significant ongoing costs

Figure 6. A bag of Crystal Green being filled from the Pearl reactor.

associated with maintenance and replacement of pipelines and mechanical equipment.

Commercial Innovation

Controlled precipitation of struvite at WWTPs is not new. Neither is the awareness of the potential commercial value struvite represents as slow-release fertiliser. The sustainability and commercial aspects have driven many water utilities across the globe to work through numerous business cases in order to commercially recover phosphorus in this way. In the vast majority of cases, however, these projects never came to fruition. This is due to the fact that water utilities do not have an appetite for the marketing and distribution risks associated with the sale of a commercial fertiliser product, because it is simply too far removed from their core business.

This is where the upgrade of Amersfoort WWTP displays another innovation – not so much a technical one, but one of a commercial/contractual nature. The Crystal Green product has significant economic value, so it generates non-regulated revenue for the water board. This revenue is secured through a long-term off-take agreement with the technology provider. The water board is not required to participate in the downstream product sale, as all of the associated marketing and off-take risks are transferred to the technology provider.

PAYBACK PERIOD

The combined application of this thermal pressure hydrolysis and phosphorus recovery system, with a guaranteed long-term off-take agreement, has resulted in a payback period on the investment of just under seven years.

CONCLUSION

The upgraded Amersfoort WWTP is a showcase of sustainability in the public water sector that makes economic sense. It comprises the application of innovative technologies and commercial arrangements to recover energy and nutrients from municipal wastewater and waste-activated sludge. The plant will be a net producer of energy and will be generating guaranteed, long-term non-regulated revenue from the sale of a fertiliser product without additional commercial risk to the water board.

A combination of both technical and commercial innovations allowed all of the water board's project objectives to be met:

1. A regional sludge processing hub is created while re-using the existing assets (digesters);
2. To become energy-positive, achieved by application of innovative Lysotherm technology;
3. To recover phosphorus in a commercially viable way by creating a commercial fertiliser product that is sold via a novel commercial arrangement;
4. To reduce overall sludge processing cost by producing less sludge, making the most of the existing digesters and energy recovery;
5. The project will achieve a payback period on capital investment of just under seven years.

THE AUTHORS

Luc Kox (email: luc.kox@bluehorizonsolutions.com.au) is a Civil/Environmental Engineer who is currently spearheading the market entry of Dutch technology provider Eliquo Water & Energy BV into the ANZ region, focusing on technological solutions for energy and nutrient recovery. Luc started his career as a Process Engineer with involvement in the first application of MBR technology in large-scale municipal wastewater treatment in The Netherlands. He then changed his career to international business development, with a focus on SE Asia (Vietnam) and, later on, Australia.

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