Position Paper
Auto-generative High Pressure Digestion

Billions of Nm^3 green gas, recovery of raw material and drug residues as well as clean water in just one circular process

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1. Introduction

This paper aims to inform policymakers and opinion leaders about a completely new technology, Autogenerative High Pressure Digestion (AHPD), which has been further developed and perfected over the last ten years, to make green gas of the same quality of the current Slochteren natural gas, from wastewater, sewage sludge and kitchen waste.

Bacteria, naturally present in the wastewater and sewage sludge, build up high pressure in a closed system. Pressure and biological conversion lead to production of green gas and the disposal of CO_2 without adding additional energy to this process. This gas can be directly imported into the existing gas network and can be stored there.

This process has been tested and improved over the last two years in a test facility at EnTranCe, the experiment location of the Groningen University and the Hanze University of Applied Sciences. It turned out that the addition of hydrogen to the system, obtained by non-saleable solar- and wind energy, can double the greengas production.

Also the experiments to remove important residue materials proved to be successful. Phosphorous, nitrogen, residue metals and probably also drug remnants can be recovered and/or removed.

When applied in the Netherlands nationwide, 3 to 10 billion Nm^3 gas can be produced per annum. Based on the current sewage sludge- and gas rates, the cost of the installations can be earned back within 7 years, therefore making water treatment and sludge processing commercially attractive.

2. Social impact of the transition from a linear to a circular economy

The transition of the current linear economy to a circular economy is not just an extensive technological-, but also a social evolution. This is caused by the fact that so many, if not all, civil society organisations are based on linear processes. Subsequently, the division of the powers are derived as such. As a result, processes in water-, energy-, waste- and food-sectors are barely or sub-optimally connected (see table 1). This separation of duties and organisations makes the transition to a circular economy even more difficult because of the need to break open vested interests and even statutory responsibilities.

Table 1: Separated responsibilities in the linear economy

Responsible Organisations	Linear sectors			
	Water	*Energy*	*Waste*	*Food*
Water Authorities	Water-level, -safety and -quality		Water treatment	
Water companies	Water supply			
Municipalities	Sewage		Waste collection	
Electricity companies		Electricity production		
Gas companies		Gas production and storage		
Network operators		Energy distribution		
Waste companies			Waste processing	
Agricultural businesses				Production

For example:

1. Whilst Water Authorities are responsible for water treatment and the processing of sewage sludge, they can, legally, only produce energy to sustain their own processes. Because their primary duty is managing the water quality and quantity, the processing of the sewage sludge is just a derived task. To this day, it is considered a cost item and a state prerogative.
2. Both the gas- and electricity markets are completely separated with their own manufacturers and independent price settings. Gas is indeed used to produce electricity, but ‘ the other way round’ is not perceived as an alternative to store surplus solar- and wind energy. For as far as this *is* taking place, attention is especially paid to hydrogen storage, a gas that is not very suitable.
3. Municipalities mostly separate green- and grey waste, but this way of separating is not optimal for the re-use of green waste for energy production, for which kitchen-waste is suitable and garden-waste is not.

How much the responsibilities in the circular economy differ from the responsibilities in the linear economy can be illustrated by Bareau’s new **Autogenerative High Pressure Digestion technology (AHPD)**. This technology integrates water treatment, sustainable energy production, energy storage (by a link between gas production and electricity) and the retrieval of all valuable residual materials in one process with high returns and low costs. With **minimal use of external energy**, green gas of the same quality of the Slochteren natural gas is produced and all valuable and harmful residuals are recovered or removed. Water is used again and remnant sludge is **reduced with 70%,** compared to the current 30%.

A few of the process' main characteristics are:

1. Bacteria, naturally present in household wastewater (possibly mixed with kitchen-waste), build up pressure of 20 Bar and a high temperature of 50^{o}C and more in an anaerobic treatment system. This pressure is used to drive the complete system, amongst which membrane filters.
2. This leads to the production of biomethane in the gas-phase and CO_2 dissolved in water.
3. By adding hydrogen, for example obtained via electrolysis of wind- and solar energy, the hydrogen is linked by the bacteria to the dissolved CO_2 to methane.
   By doing so, the green gas production doubles and the quality of the gas even surpasses the Slochteren natural gas (Power to gas). This gas can be stored directly in the existing gas network and thus contributes to both use of sustainable gas and storage of clean electricity. Through supplementary treatment techniques, phosphate, heavy metals, nitrogen and drug residues can be separated and recovered if so desired, with which fundamental contributions are made to the circular economy and to the conservation of water- and environmental quality.
4. Application of anaerobe water treatment at high pressure and temperature is, in combination with ultra filtration-membranes, an important barrier against the spreading of pathogenic- and antibiotics-resistant bacteria.

Because AHPD is made applicable in the process of existing sewage plants, the gas yield is much larger than in the current situation where only sewage sludge is digested.

The ultimate green gas production, with broad application of the AHPD technology, leads to production of **3-10 billion Nm^3** in the Netherands, per annum. This technology therefore fundamentally contributes to the **storage of sustainable energy** and to the **recovery of valuable substances that can be re-used**. Moreover, water treatment and sewage sludge processing become more profitable, so they can be transferred to the private sector. In addition, the current water treatment taxes for both citizens and businesses can be significantly decreased.

A complimentary advantage of this technology is that the implementation can be attuned to the general investment pace of the Dutch Water Authorities by an initial application for the residual sludge. Furthermore, the AHPD technology can be very well combined with local projects aiming for energy neutrality. When adopted in the current water treatment process, other innovative technologies regarding the removal of nitrogen, sulphur and phosphate can be easily integrated in the AHPD process. This also counts for innovative nanofiltration to remove drug residues and hormone disruptors from wastewater and sludge.

Figure 1 shows this schematically. It is obvious that a circular economy not only technologically, but also organizationally, fundamentally differs from a linear economy. Only when established parties adjust their linear economy roles in time to the demands of a circular economy, they have a chance to survive. In addition, they will have a chance to contribute to the acceleration of the fundamental transformation and by doing so, becoming part of the new economy**.**

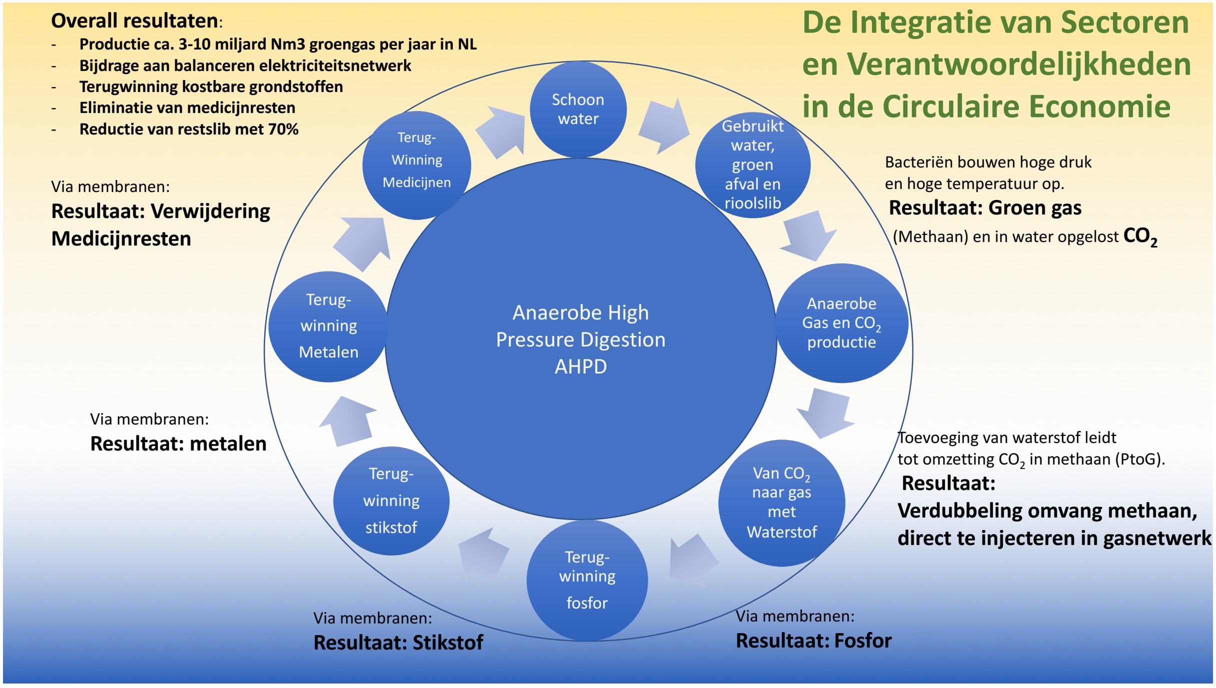
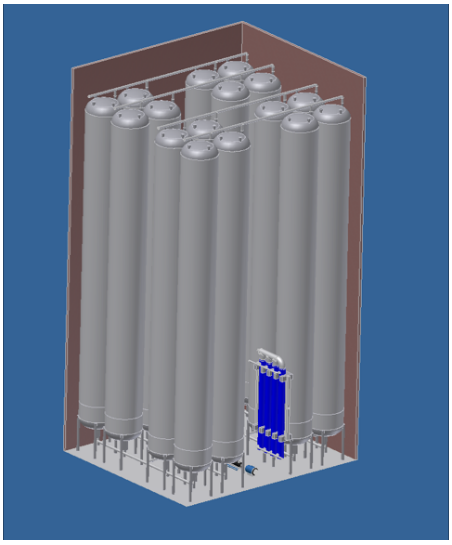


Figure 1: Integration of sectors and responsibilities in the circular economy, as illustrated in the AHPD process

3. The feasibility of the AHPD process

The height of the high pressure reactor in the pilot plant (4,5 meters) is almost half of the intended reactors in the final installations, so no significant issues are expected when scaling up. In the final installation the reactors will be switched modularly and ranked in boxes of 16 (figure 2). Based on extensive research, ENGIE Services has concluded that 'the system has proved itself and is ready for up-scaling'. They also have concluded that a fully fletched sewage sludge- and kitchen waste system at a sewage plant of 300.000 population equivalents has a return on investment time of 7 years. The AHPD process is fully automated and runs 24/7 on remote control. To build the AHPD-installations, a consortium of several companies has been set up in which all required expertise is packaged.

Various parties in the Netherlands, Luxembourg, Germany and China have expressed their interest to implement the AHPD system.



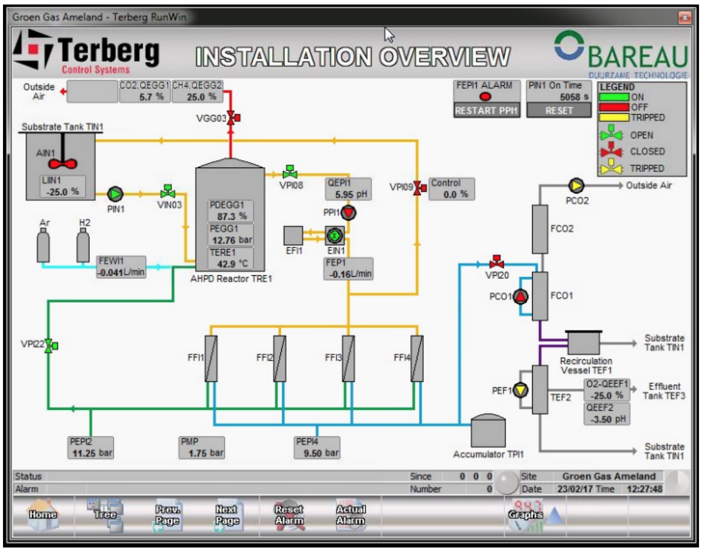


Figure 2: Modular box containing 16 AHPD-reactors (without roof) and AHPD control

4. Perspective

According to model calculations, application of AHPD in the sewage sludge treatment process is feasible up to very low organic substance concentrations in the wastewater flow. The primary settling tank (when present) is replaced by the AHPD reactor whilst aeration is converted to an Anammox system so ammonium is removed. Moreover, by implementing AHPD in the treatment process of wastewater, the risk of spreading resistant bacteria by wastewater discharge is highly reduced. A double disinfection barrier occurs; high pressure with pressure variation is fatal to a number of pathogens, followed by ultra filtration.

Ultra filtration membranes in a AHPD installation, followed by nanofiltration, to remove organic micro compounds and hormone disruptive substances, are an attractive alternative to the costly ‘fourth stage’ in the current sewage treatment plants, existing of an ozone- and activated carbonated process after conventional primary settling, aeration and secondary settling.

Therefore AHPD is a very interesting, disruptive, economical technology for green gas production, disinfection ánd removal of drug residues and hormone disruptive substances.