

ENHANCED DIGESTION WITH EXELYS™ DLD — A DIRECT PATHWAY TO A SUSTAINABLE AND COST EFFECTIVE WASTEWATER TREATMENT PLANT

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ABSTRACT

There is an increasing need for large wastewater treatment plants to generate as much electricity as possible from biogas. This not only ensures significant operational cost savings, but also improves the environmental profile of the plant. Enhanced digestion through the use of the Exelys™ continuous thermal hydrolysis process has the potential to help a large wastewater treatment plant move towards electrical energy neutrality. This article aims to use a modern European wastewater treatment plant as a case study to investigate the potential advantages an Exelys™-DLD process could provide. The results indicate that despite already having an effective and efficient digestion process, through implementation of the Exelys™-DLD process, the plant has the potential to cover 65% of its total electrical needs from biogas. This is 33% more than the current situation. When looking to the future, through the optimisation of the wastewater treatment process and the application of the Exelys™-DLD, large WWTP's have the potential to be completely electrical energy neutral. This would be a significant financial advantage as electrical prices rise and carbon taxes are enforced.

KEYWORDS

Energy neutral; Continuous thermal hydrolysis

1. INTRODUCTION

When considering options available to reduce energy costs and carbon footprint at a waste water treatment plant (WWTP), engineers and operators will typically evaluate methods to reduce energy consumption and methods to recover energy from waste streams. While improvements in aeration, pumping and process control technologies are effective methods to lower energy consumption, the only way a wastewater treatment plant can produce significant amounts of renewable energy is to utilise the energy available in biosolids. Anaerobic digestion of biosolids has been the process of choice for this purpose for several decades, because it is a relatively simple, stable process that yields methane gas (CH₄), thus recycling a significant portion of the energy in biosolids to heat and power (Jolis, 2008).

Anaerobic digestion follows four process steps: hydrolysis, acidogenesis, acetogenesis and methanogenesis, with hydrolysis being the rate limiting step in the reaction (Gavala et al, 2003; Perez-Elvira et al, 2006). By improving the rate of the hydrolysis step, solid substrates are more accessible to anaerobic bacteria, accelerating the digestion, increasing the volume of biogas produced and decreasing the amount of sludge to be disposed of (Fdz-Polanco et al, 2008). Faster anaerobic degradation rates can also save on digester volume (Phothilangka et al, 2008). The principle pathway to achieving this enhanced biogas digestion is to apply a pre-treatment process to the sludge before digestion (Fdz-Polanco et al, 2008; Perez-Elvira et al, 2006). Thermal, chemical, biological and mechanical processes, as well as combinations of them have been studied as possible pre-treatments to accelerate sludge hydrolysis (Climent et al, 2007; Kim et al, 2003; Weemaes and Verstraete, 1998). Enhanced biosolids digestion through the use of a pre-treatment is now the benchmark method for energy recovery from biosolids. The physical properties of untreated biosolids also puts a practical limit of approximately 5% total solids on anaerobic digestion operations as the mixing, heat transfer and pumping all become inefficient and expensive at greater total solids contents (Jolis, 2008). Therefore a pre-treatment process that can allow anaerobic digestion at greater total solids contents would

have the potential to defer costly capital improvements for anaerobic digestion facilities that face capacity, and therefore, compliance problems (Jolis, 2008). As can be seen in Figure 1, the application of an enhanced digestion process (in this case the Exelys™-DLD process) is an important contributor to the shift towards conceiving and realising energy producing wastewater treatment plants.

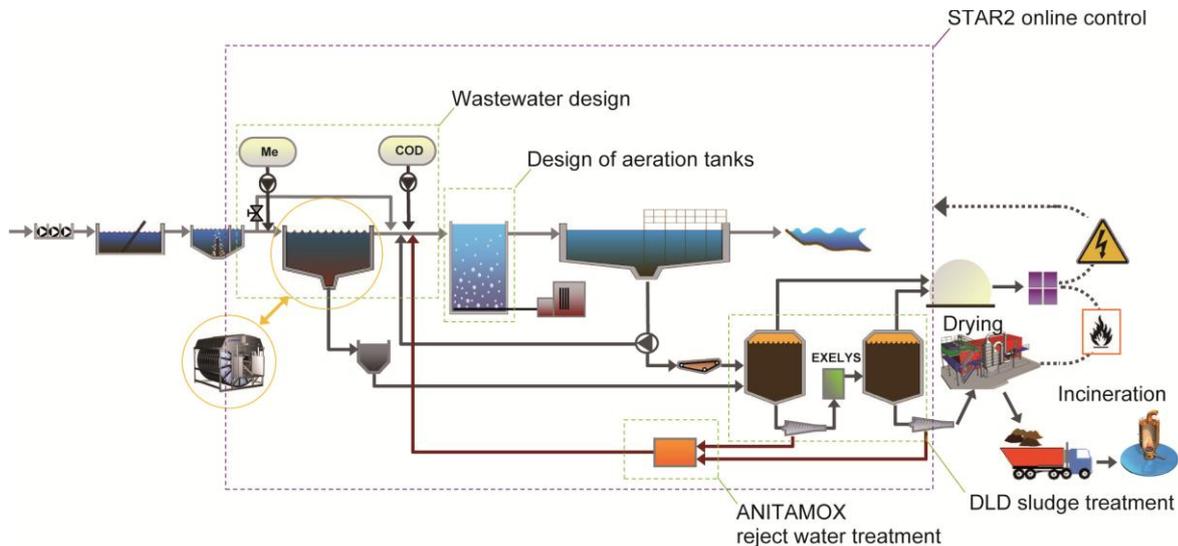


Figure 1: A concept for a net energy producing large wastewater treatment plant

1.1. Thermal sludge hydrolysis

Over the last decades, thermal hydrolysis has been recognised as one of the most reliable and effective pre-treatment solution for enhanced digestion (Perez-Elvira et al, 2006; Phothilangka et al, 2008). In the thermal hydrolysis process, high temperatures and pressures are applied over a period of time. Thermal hydrolysis is generally achieved when temperatures of between 140-200°C and pressures of 6-25 bar are applied for at least 30 minutes (Chauzy et al, 2005; Climent et al, 2007; Dwyer et al, 2008; Perez-Elvira et al, 2006; Phothilangka et al, 2008). These operating conditions imply a significant consumption of energy (usually steam), which must be constantly weighed against the enhanced biogas production due to the thermal hydrolysis pre-treatment.

During this process, both living and dead cells are lysed or disintegrated, permitting the release of intracellular matter that is then more accessible to anaerobic microorganisms (Climent et al, 2007). At the same time, some suspended solids are solubilised and long chain organic compounds are broken down through hydrolysis reactions (Chauzy et al, 2005). The thermally hydrolyzed sludge is a Class A pasteurised product that has a very low viscosity and a high concentration of soluble COD. These conditions mean that a digestion process following thermal sludge hydrolysis will produce significantly more biogas, significantly less sludge and save by a factor of 3 to 5 the energy required for mixing and pumping (Fdz-Polanco et al, 2008; Jolis, 2008). Another key result is that the dewaterability of the final sludge cake is dramatically improved through the application of thermal hydrolysis pre-treatment (Fdz-Polanco et al, 2008; Panter, 2009; Phothilangka et al, 2008).

Earlier available systems operate in a batch mode which leads to a loss of energy in each cycle and over-sizing of key equipment (Fdz-Polanco et al, 2008). Although the batch systems are proven and effective, its application has so far generally been limited to large wastewater treatment facilities. Continuous thermal hydrolysis would potentially provide the process advantages to overcome the constraints faced by batch thermal hydrolysis. The development of a more efficient and cost effective continuous thermal hydrolysis process could revolutionise enhanced biosolids digestion and make it more attractive for a wider range of treatment facilities and contribute to increase production of sustainable energy. While some patents and literature are available that describe processes which approach continuous operation conditions, there is little information available regarding their effectiveness (Fdz-Polanco et al, 2008).

1.2. Exelys™ continuous thermal hydrolysis

The Exelys™ solution (patent pending) is a new, truly continuous thermal hydrolysis system that operates in the temperature range of 140°C-165°C and at pressures between 9-11 bar(a). Although the process requires energy, the majority of this comes from energy recovery and waste heat utilisation. Due to the greater removal of organic matter in the digestion system after the Exelys™ (compared to traditional digestion) and the physical properties of the hydrolyzed sludge, the dewaterability of the final sludge is significantly improved. The Exelys™ process is heavily insulated to minimise heat losses and therefore can operate effectively outdoors without standing in a building, saving on civil construction costs.

The Exelys™ continuous thermal hydrolysis system is illustrated in Figure 2. Dewatered sludge (>20% w/w) from a storage silo is fed into a progressive cavity pump which is continuously feeding sludge to the Exelys™. The ability of the Exelys™ to hydrolyse high solids content sludge means a significant advantage over traditional batch hydrolysis.

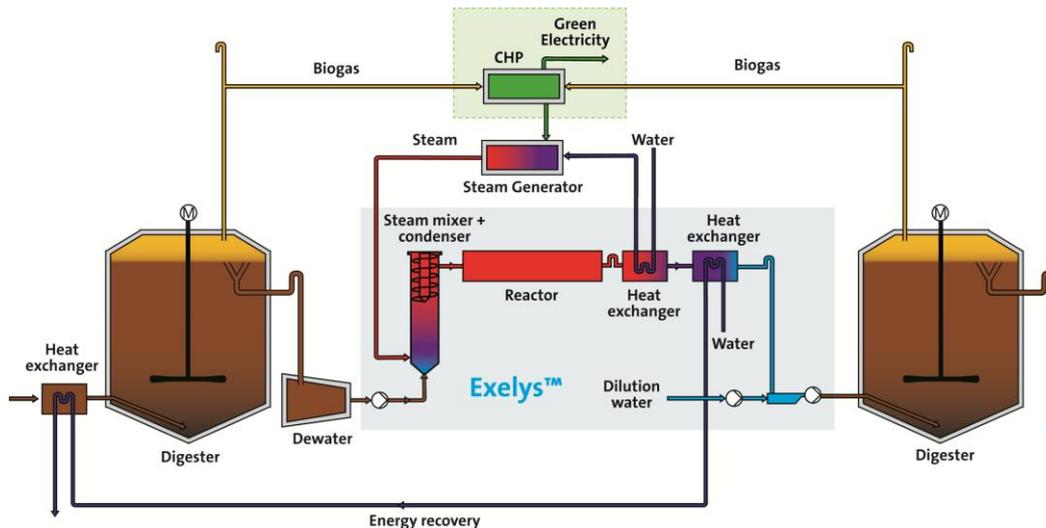


Figure 2: An illustration of the Exelys™-DLD process configuration

The hydrolysis reactor is the larger pipe section illustrated in Figure 2. In this section the sludge flows at a very low velocity, leading to plug-flow conditions for the sludge. This ensures that no sludge can short-cut the reactor and that all of the sludge is exposed to the hydrolysis conditions for the required amount of time. A heat exchanger system is used to cool the sludge after the hydrolysis process and recover energy for other uses. Boiler water for the steam generator can be pre-heated in this system along with other process water which can be used to heat other processes, buildings, or even exported to a district heating network. The heat exchanger is used to control the temperature of the hydrolyzed sludge so that the final product from the Exelys™ can be used as the sole heat source for the following digestion process. After the heat exchanger system, there is the possibility to inject pasteurised treated wastewater into the sludge. This can be used to dilute and cool the sludge if this is required by the following digestion process. The final part of the Exelys™ thermal hydrolysis system is the pressure holding pump. This pump operates in such a way that it can control the pressure in the Exelys™ system. This ensures reliable and effective pressure control, a vital ingredient for the hydrolysis process. The pressure holding pump can in most cases also be used to pump the Exelys™ hydrolysate to the following digestion process.

The Exelys™ can be utilised in a number of process configurations. Normally it would be installed before digestion, with either all of the sludge or only the secondary sludge fraction being hydrolyzed before digestion (Exelys™-LD). In each case, the capacity of any existing digesters can be increased, or the capital expenditure in any new digesters reduced. This could provide an operator the opportunity to import biosolids to the site, thereby increasing biogas production and generating income from both sludge import and energy export.

However, if digester capacity is not an issue, the Exelys™ can be incorporated into a new process configuration designed to optimise electricity generation and export. The process configuration is called Exelys™-DLD and involves the incorporation of the Exelys™ between two digesters, as shown in Figure 2.

After primary digestion, the sludge volume is reduced and dewaterability improved. This allows for a smaller Exelys™ unit compared to Exelys™-LD, and lower energy requirement. The hydrolyzed sludge is then digested again with the remaining biogas potential in the sludge recovered. All of the biogas can then be used for electricity production, with the waste heat being recovered to operate the Exelys™. In this way, the capacity of the digesters is not improved, but the energy recovery from the sludge is further optimised.

1.3. Case study – Big European WWTP

This article will focus on presenting a comparative case study of two sludge treatment systems. The current operational process is sludge pasteurisation, thermophilic digestion, dewatering and then disposal. The biogas is used to produce electricity and heat for the pasteurisation system.

The plant is relatively new and incorporates a modern and effective wastewater treatment system. Incoming average wastewater flow is 350.000m³/day. Of the total sludge production, a significant proportion is activated sludge from the BNR process. Normally, the biogas potential of such sludge is very low, and therefore the site is ideal for the application of the Exelys™. The calculations undertaken in this paper are based on design data and may not reflect the current operational conditions at the plant. However, they provide a useful basis to work from and make a comparative study.

While the plant already incorporates an energy efficient and effective way to achieve the required sludge product, with the application of the Exelys™ process this can be improved again – producing a sludge that is suitable for composting and land disposal, but recycling as much of the potential energy as possible back to the WWTP.

2. METHODS

2.1. Scope

The key focus of this study is to determine the electrical production potential of the sludge treatment system. This electrical production potential will then be compared to an assumed electrical consumption to determine how electrical self-sufficient it is. Therefore with regards to the scope, it is assumed that thickened sludge from the current pre-pasteurisation buffer tank is the feed to the system. The final product is sludge cake for disposal to composting.

Two sludge treatment scenarios will be compared:

1. The current process configuration
2. Exelys™-DLD with first thermophilic digestion followed by mesophilic digestion

The Exelys™-DLD process was chosen as it produces a completely pasteurised product similar to that already produced.

2.2. Calculation parameters

The raw sludge has the following characteristics as shown in Table 1. The operational conditions for the two comparative scenarios are shown in Figure 3. The data used in this assessment is design data, and therefore it is likely that the results calculated in this study will vary from the actual performance seen at the site today.

Table 1: Sludge design characteristics based on design data.

	Q (kg-TS/d)	VS content (% TS)	Solids content (% w/w)	Temperature (°C)
Primary sludge	28,420	80	6	10
Waste activated sludge	44,000	70	6	10
Grease and fats sludge	12,180	80	6	10

For electrical production, the efficiency of the biogas combined heat power (CHP) unit was set to 40%. The price for electricity was set to €0.096/kWh excluding VAT (Energy.eu, 2010). Energy consumption was assumed to be 0.453 kWh/m³ of wastewater.

3. RESULTS AND DISCUSSION

The key process results are presented for both scenarios in Figure 3 and Table 2. The results indicate that the application of an Exelys™-DLD system could have a significant positive impact by producing more biogas and electricity, and producing less sludge for disposal. The quality of the sludge cake after the Exelys™ process is also improved due to the impact of the thermal hydrolysis process. With the current process design, 49% of the electricity required for the whole WWTP is covered by electricity generated from biogas production. However, if the Exelys™-DLD process was implemented at the site, the increased electrical generation potential would mean that 65% of the WWTP's requirements could be covered by local electrical generation. This is a significant step towards energy neutrality on the site.

In this assessment it is assumed that the plant consumes 0.453 kWh/m³ of wastewater. However in the future, through the implementation of for example on-line control, new aeration techniques and effective removal of TSS before the BNR process (as shown in Figure 1) the electrical energy requirement of this wastewater treatment plant could be reduced to 0,293 kWh/m³ wastewater. In this case, the current process system could provide 76% of the electricity required, while if the Exelys™-DLD was applied, the plant could become energy neutral i.e. 100% of the electrical needs for the plant could be provided by locally generated electricity. This could be further improved if a biogas fuel cell was utilised to generate electricity rather than a CHP, as a fuel cell can provide an electrical generation efficiency of at least 50%, compared to 40% for a CHP.

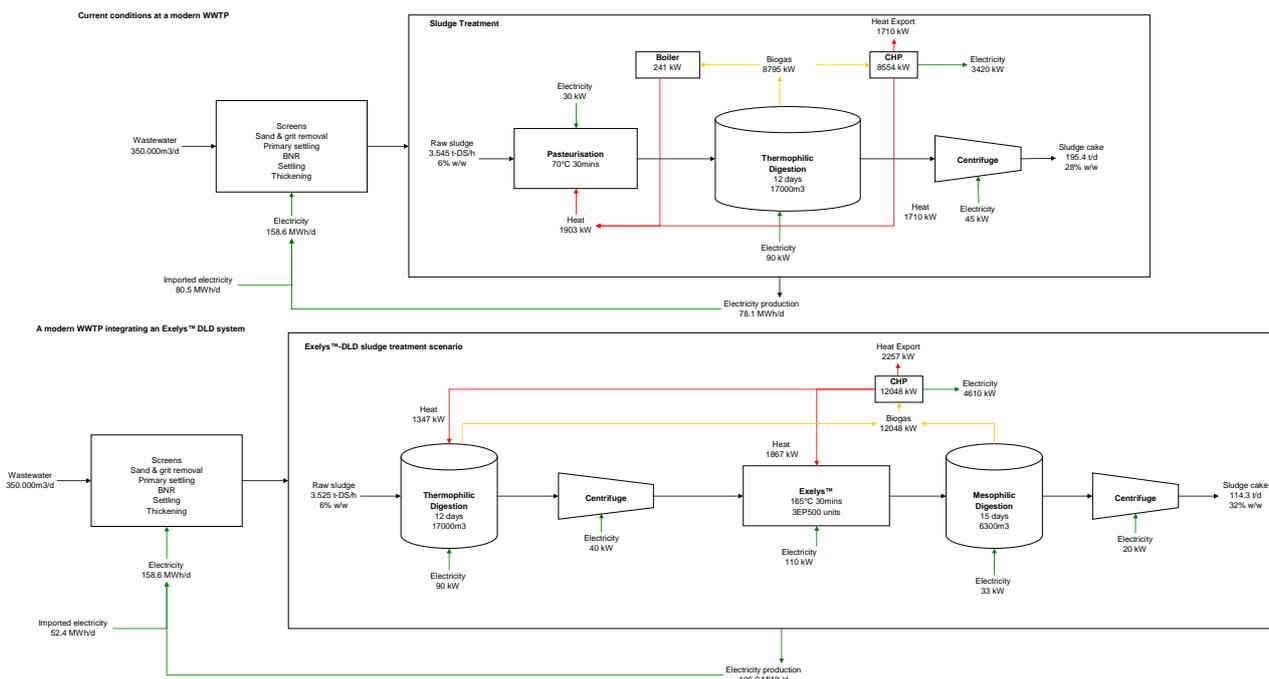


Figure 3: Process calculation results for the two scenarios. Top - current situation with sludge pasteurisation followed by thermophilic digestion and then dewatering and disposal; Bottom - integration of an Exelys™-DLD with double digestion, thermal hydrolysis and finally dewatering and disposal.

The financial bottom line is also an important consideration for an operator of a large wastewater treatment plant. Even with extra capital investment required for the Exelys™-DLD option, the NPV will be significantly better than the current situation. The result for the current situation is common for large wastewater treatment plants, where the savings caused by local electrical generation generally cover the energy expenses for the remainder of the wastewater treatment plant. However, it is clear that by installing the Exelys™-DLD that the potential energy savings actually generate a positive value when looking at

energy finances. This is an important step forward as it indicates that it is possible through the application of a single process solution such as the Exelys™ to change the financial landscape at a large wastewater treatment plant. As shown in Table 2, when looking towards the future and far-reaching optimisation of the entire wastewater treatment process, all electrical requirements for the wastewater treatment plant can be covered by local generation from biogas. This in effect removes one of the largest financial costs for a wastewater treatment plant, and represents a significant change in how wastewater treatment plants should be viewed – as energy neutral potential sources of income rather than financial burdens. Once an effective carbon tax system is in place and enforced, the energy neutral wastewater treatment plant will have even greater potential to generate income for the operator.

Table 2: Results from the comparative electrical energy assessment.

		Current situation	Exelys™-DLD	Energy optimised WWTP
Electricity saved	MWh/d	78	106	106
	€/yr	2,700,000	3,700,000	3,700,000
Electrical self-sufficiency	%	49	65	100
Electricity import	MWh/d	80	52	0
	€/yr	2,800,000	1,800,000	0
Digester volume	m ³	17.000	23.300	23.300

4. CONCLUSIONS

The paradigm shift in large wastewater treatment plants from water treatment facilities to energy producing facilities will present a range of opportunities to improve not only their environmental profile, but also their financial performance. And as energy and carbon prices increase, even recently built wastewater treatment plants may need to re-evaluate what will drive their development into the future. The aim of this paper was to show that this development can occur in a financially responsible manner.

A key area where energy can be recycled back into the plant as electricity is through enhanced sludge digestion. The development of the efficient and effective Exelys™ thermal hydrolysis process now provides large wastewater treatment plants the opportunity to cost effectively enhance their digestion process, leading to greater income and lower costs. A modern European WWTP was used as a case study to compare well performing current technology with potential of the Exelys™-DLD process.

The key results from this assessment are:

- The Exelys™-DLD process configuration provides a series of benefits even when compared to a traditional digestion system that is performing well.
- The current process configuration can provide 49% of the total energy requirement of the plant. Through implementing the Exelys™-DLD alone, this can be increased to 65%.
- The results indicate that new large wastewater treatment plants could benefit financially and environmentally by investigating the opportunities possible in enhanced digestion technology such as the Exelys™-DLD.
- When looking to the future, an optimised wastewater treatment process followed by an Exelys™-DLD process can lead big WWTP's being completely electrical energy neutral. This leads to greater financial sustainability, which will be improved even more once carbon taxing is enforced on wastewater treatment plants.

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