Analysis of Energy Consumption and Saving in Wastewater Treatment Plant: Case Study from Ireland

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ABSTRACT

Worldwide, high energy consumption affects the wastewater industry and it is second in cost only to manpower for most wastewater treatment plants (WWTPs). The need to meet the new effluent limits and water quality standards, has led to implementation of new technologies, which has also led to considerable increased energy consumption in WWTPs. At the same time, energy price is on the rise and as oil prices continue to fluctuate, thereby increasing their operating costs. Those increases will be compounded by the need to meet additional stringent regulations that will require energy-intensive treatment processes to achieve the required effluent quality. Energy production, usage and saving in wastewater treatment plant (WWTP) have been reviewed and discussed while one WWTP in Ireland have been examined in order to: (i) identify energy/resource recovery strategies, (ii) explore the potential applications in the plant, (iii) to promote the commercial, and large-scale application at WWTPs.

Keywords: Anaerobic digestion; biogas; energy efficiency; energy production; wastewater treatment

1. INTRODUCTION

Achieving the energy neutrality is the goal in wastewater treatment processes. This will require a holistic energy management approach, incorporating conservation practices and generating renewable energy through the management of water resource recovery and its by-products (Hao et al., 2015). According to a United Nations report (Intergovernmental Panel on Climate Change-IPCC), renewable energy sources such as biomass, could meet nearly 80% of the world’s energy supplies by 2050, if governments implement policies to harness their potential (IPCC, 2011).

Across Ireland, drinking water and wastewater systems are facing a series of daunting challenges, such as increasing in throughput requirements, energy cost uncertainty, ageing infrastructure and climate change etc. (Energy Point Consulting, 2015). These challenges may be overcome or partially overcome through more efficient operations, saving operating costs and improving environmental performance. Sustainable Energy Authority of Ireland (SEAI) has identified that energy used in water services varied between 55% and 70% of the total energy consumed by local authorities (SEAI, 2013). Energy consumption per capital showed an average value of over 105 kWh on water and wastewater. This is a huge energy consumption and cost to the economy.

Indeed, wastewater treatment consumes large amounts of energy and materials to comply with discharge standards. Whereas,
wastewater contains resources, which can be recovered for secondary uses if treated properly. This study attempts to strike the balance between the compelling issues of energy generation and consumption, energy savings, and resource recovery by taking the largest Irish WWTP, Ringsend Wastewater Treatment Plant, as example. The findings of this study can hopefully assist in reducing the financial burden by making wastewater treatment plants in an energy neutral manner.

2. ENERGY IN WWTP

2.1 Demand and consumption

Regarding the energy requirement at a conventional WWTP, the most common energy conversion is the use of electrical energy to provide oxygen for aerobic biological system, such as activated sludge treatment. Such kind of energy use is affected by: population of aerobic bacteria, influent loading, effluent quality, process type, size and age of the treatment plant. The second most common energy conversion is the use of electrical energy through mechanical pumping to move wastewater around the treatment plant. A great deal of energy is lost in this process due to friction in the channels and pipes, and through the inefficiencies of pumps and motors. In addition, anaerobic digestion (usually for heating) and sludge dewatering (belt press etc.) also consume considerable energy. According to WEF (2009), pumping requirements depend on the topography of the facility site, while diffused aeration efficiency depends on the aeration basin depth, factors which cannot be changed at a reasonable cost. It is good to point out that, some WWTP can improve beyond this benchmark, while others can be fully optimized and still not meet the benchmark. In addition to this, for all WWTP sizes, up to 50-60% of the overall energy is consumed in biological treatment (Malcolm et al., 2011; Taylor, 2005; USEPA, 2006). For example, it has been reported that the aeration, wastewater pumping, anaerobic digestion, lighting and buildings as well as sludge belt press contributed to energy consumption of 54.1%, 14.3%, 14.2%, 8.1% and 3.9%, respectively Science Applications International Corporation (SAIC, 2006), in total energy requirement in WWTP although anaerobic digestion can recover biogas for energy generation.

It has been well recognized that the unit electricity consumption for wastewater treatment is well related to the size of the treatment plant (EPRI, 2002). Generally, the unit power decreases asymptotically as facilities size increases, and increases as effluent requirements becomes more stringent. For example, the unit power requirement for an activated sludge process of a 4000 m³/d WWTP is 0.591 kWh/m³ while this requirement for a 378,500 m³/d WWTP is 0.272 kWh/m³. For the same scale plant of 4000 m³/d when using the advanced wastewater treatment nitrification, the unit power requirement is 0.780 kWh/m³ (EPRI, 2002). There are a number of physical factors (such as topography, pumping cost, depth of aeration tank etc.) that influence facility energy consumption and need to be considered in a more detailed analysis.

The expected increase in energy demand due to population growth and the corresponding growth in the contaminant load to be treated, as well as increasing stringent regulatory and environmental protection standard for effluent quality and residual water reuse will further put pressures on the treatment plants. These changes are expected to result in more energy intensive processes (Schosseler et al., 2007).

2.2 Energy efficiency

Energy efficiency can be defined as a ratio between an output of performance, service, goods or energy generation and an input of energy. It is clear that an improvement in
energy efficiency enables achievement of the same result with less energy or achieving an improved performance with the same energy (SEAI, 2013). Energy efficiency can contribute to security of supply, competitiveness and protection of environment through reduced greenhouse gas (GHG) emissions. The economic benefits via energy efficiency to WWTP include direct savings, lower fuel costs and a reduction in the need for investment in supply. All these can be achieve through technological, behavioral or economic changes.

Therefore, it is safer to say that a decline in energy use with increasing benefits always corresponds to increasing energy efficiency. Energy efficiency can be seen as the sum of myriad of actions. Thus, optimizing design, optimization of energy consumption, efficiency of equipment, optimizing operational strategy, energy recovery processes, and good management of energy pricing are all increasingly considered in wastewater treatment. As a fall out of this, higher energy efficiency means lower energy consumption, lower greenhouse gas emission, and lower operating costs for WWTP (Zhou et al., 2008).

3. ENERGY INSPECTION OF RINGSEND WWTP IN DUBLIN, IRELAND

3.1 Overview of the plant

Ringsend Wastewater Treatment plant is modelled on the design, build, and operate (DBO) contract, undertaken to provide up to tertiary treatment for a 1.7 million P.E (Fig. 1). Operation began in 2003 following construction which started in 1999. Ringsend is home to the largest double decker sequencing batching reactors (SBR) design in the world and is also fundamental to Dublin Bay’s blue flag status. The plant used a number of innovative technologies to cater for the large pollution load on a constrained site. Sludge is treated using Cambi Thermal Hydrolysis Process (THP) and anaerobic digestion (AD) before being thermally dried. More details of the plant can be found from Celtic Anglian Water website (CAW, 2014).

![Figure 1](image-url) Overview of Ireland and the Ringsend WWTP (Dublin City Council, 2014)
3.2 Present energy demand

The energy consumption is derived from the two streams: direct power consumption from wastewater treatment, and indirect power consumption from sludge processing. The direct power consumption is for each of the treatment processing (primary, secondary and tertiary), which includes: driving power and pumping for influent fine screen; aeration and pumping for SBRs; aeration, pumping and solids separation for deep shaft systems; denitrification system pumping; UV disinfection, and lighting and building. Indirect power consumption from sludge processing consists of the THP/digestion systems and dryer power consumptions.

If the indirect power consumption is estimated first, the power consumption from the THP/digestion systems and the dryer can be seen as follows: The THP/digestion system has a net power consumption of approximately 0.26 MWh/tDS processed, as indicated from the system parameter. Based on the installed capacity of the plant of 57,000 tDS/yr, the power consumption should be 14,820 MWh/yr. However, Ringsend WWTP has potential to improve upon this consumption rate by limiting the energy losses resulting from flaring digester gas and by operating the steam generators downstream of the CHP engine more frequently. In addition, if the stream generator is operated as suggested, then there will be a slight increase in steam generation operation, thereby achieving further reduction in unit power consumption to 0.15 MWh/tDS. This can translate THP/digestion system “energy savings” to about 6,270 MWh/yr, while the total consumption is 8,550 MWh/yr.

With regard to the dryer power consumption, it has been reported that the volatile suspended solids (VSS) destruction rate in the digesters is approximately 55% and the ratio of VSS to TSS is approximately 80% in the plant. Therefore the overall mass destruction in the digesters is approximately 44%, implying that for every tonne of sludge fed to the THP/digestion system, 0.56 tonnes will be fed to the dryer system. This will be mechanically dewatered to approximately 22% dry matter. Therefore, for every tonne of sludge fed into the dryer, approximately 760 kg of water is evaporated. At water evaporation rate of 0.978 kWh/kg (O & M manual), approximately 0.75 MWh of natural gas is consumed per wet tonne of sludge fed to the dryers or 3.4 MWh/tDS at the current feed solids concentration. Since only 56% of the solids fed to the THP/digestion system are fed to the dryer, the dryer energy consumption, as applied to sludge produced, is 1.90 MWh/tDS. Thus, the total indirect power consumption is the sum of that devoted to THP/digestion system plus the dryers or 2.05 MWh/tDS (0.15 + 1.90) MWh, i.e. 116,850 MWh/yr.

Typically the anaerobic digestion consumes approximately 14.2% with dyers says 20% of the total power consumption. The direct power consumption will be the remaining 80%, i.e. 467,400 MWh/yr. Thus, the total power consume for all operations will amount to 584,250 MWh/yr. Additionally, if 5% is added to take care of errors or inadequate quantities in the calculated assumptions, total power consumed at the plant is 613,462.50 MWh/yr.

3.3 Present energy production (biogas)

One of the main advantages of Cambi THP process is the improvement of volatile solids destruction, and hence improved biogas yield at low retention times in subsequent mesophilic anaerobic digestion (CAMBI, 2014). According to McCausland and McGrath (2012), the biogas yields at Ringsend WWTP have remained relatively constant with the yearly average of 410 m³/tDS. Accordingly, the CH₄ content in the biogas is averaging at 56%. Currently, the biogas generated in the anaerobic digestion processes is 45,000 m³/d
and is used to fuel boilers and to generate electricity and recover heat through the Combined Heat and Power (CHP) system, which can generate more than 2 Mega Watts (MW) of electricity, covering over 50% of the heat and electricity required at the plant. The CHP system also generates electricity from natural gas to supply for the plant total energy demand. A total of 4 MW of capacity is installed at the plant (CAW, 2014).

4. PROPOSED ENERGY SAVINGS STRATEGIES FOR RINGSEND WWTP

The energy saving strategies can be proposed in the following two aspects: the management strategies to reduce energy consumption and implementation of energy conservation measures, and the technical strategies for more energy recovery and to improve their operations. These can also be adapted by other WWTPs in Ireland.

4.1 Technical strategies

4.1.1 Aeration (real-time power monitoring and sub-metering)

Wastewater aeration consumes greater than 50% of wastewater treatment plant total energy use. Energy savings can be gained by designing and operating aeration systems to match, as closely as possible, the actual oxygen demand of the process. The energy optimization should therefore begin with an evaluation of the efficiency of the aeration systems, as it offers the greatest opportunity to minimize energy consumption, greenhouse gas (GHG) emissions and costs. Changes in the biological treatment processes to anaerobic or anoxic microbes have the potentially reduce the energy demand at a treatment works.

The most energy efficient measures are either to decrease the aeration to the process or to invest in new aeration control systems (Kjellen and Andersson, 2002). Therefore, because of the variability of the influent wastewater, the oxygen added to the aeration process should be controlled and adjusted by on-line measurements (Magnusson, 2006). For examples, in Sweden wastewater treatment plant, the electrical energy consumption decreased by 10% by introducing an in-feed filter system for the blowers (SWWA, 2005). In another Swedish WWTP study carried out by Andersson and Holmberg (2006), indicated that, consumption could be decreased by 15% in the aeration process by using two oxygen sensors in each aeration line instead of one. According to Energy Sector Management Assistance Program (ESMAP, 2012), the introduction of such control measures or strategy will not only show energy savings, but also deliver a better oxygen distribution. Thus an improved environment for the microorganisms will lead to higher sludge quality. The total costs of the proposed energy saving will include investment cost of the new aeration control system, maintenance, service, spare parts, and repairs. However, the operating costs will be determined by oxygen transfer efficiency of the aeration system being used, the characteristics of the influent wastewater as well as the specific site conditions.

4.1.2 Energy efficient pumps and motors using variable frequency drives

Pumping plays a very important role and can be significant energy draws at WWTPs. According to WERF (2009), the overall efficiency of a pumping system (wire-to-water efficiency) is the product of efficiency of the pump itself, the motor, and the drive system or method of flow control employed. Pumps lose efficiency from turbulence, friction, and recirculation within the pump and also loss incurred if the actual operating condition does not match the pump’s best efficiency point (BEP).
Variable Frequency Drives (VFDs) are used to vary the speed of pump to match the flow conditions. They control the speed of a motor by varying the frequency of the power delivery to the motor. The result is a close match of the electrical power input to the pump with the hydraulic power needed to pump the water. VFDs are a proven technology that is more efficient than these control methods and are ideally suited in situations where the flow rate is highly variable. Ringsend WWTP can consider upgrading their pumping systems with VFDs to replace old energy consuming ones. Energy savings from VFDs can be significant because affinity laws for centrifugal pumps suggest that even a small reduction in motor speed can reduce pump energy by as much as 50%. The pumping system assessment tool (PSAT), developed by the US Department of Energy (DOE, 2009) and a motor selection and management tool (MotorMaster+, http://www.motorsmatter.org/) can help to determine the efficiency of their existing pumping systems and calculate energy and cost savings upgrades.

4.1.3 Heat energy recovery potential and opportunities at Ringsend WWTP

Potential

Apart from the thermal energy recovery from biosolids, thermal energy can be recovered from raw wastewater or effluent by exploiting the often significant temperature differential between wastewater and the ambient conditions. This temperature difference (at least 3-5°C) can be recovered for use in heating and cooling systems, which is generally used for buildings at the plant, and sometimes in the buildings of areas surrounding the plant. The wastewater or effluent is used as heat source or sink for a head pump that can provide heating or cooling energy. In general, the economics favour this type of thermal recovery in colder climate like Ireland, where the fossil fuel prices are also high as compared with EU average.

There are no efforts being made at present to recover influent heat at Ringsend WWTP from the various sewer lines delivering wastewater to the plant. Sewer lines prior to Headwork at the plant provide the greatest locations and opportunity for heat recovery, before the wastewater has a chance to cool in open basin basins. The Irish weather with the attendance of heat usage in homes and industries will mean that the influent wastewater will arrive at the plant with high temperature which can be capture for either on-site reuse or sell excess to the utility company for onward sales to the district around the plant. Heat pump uses electricity to recover low-temperature heat from the wastewater, and to make this heat available at suitable temperatures for both heating and cooling. Therefore, the plant can consider installing these technologies (Heat exchangers, Heat pumps and screens) at the sewer prior to headwork, filtrate and effluent discharge channels.

Schmid (2008) reported that, there are over 500 wastewater heat pumps in operation worldwide, with thermal capability ranging from 10 kW to 20 MW. Also, large-scale district heating using residual heat from wastewater has been applied in Japan, China and some European countries (ESMAP, 2008; Friotherm, 2012; Funamizu and Sakakura, 2001; Turku Energia, 2014).

Opportunities

Regarding Ringsend WWTP, the heat energy recovery technology from wastewater can provide many possibilities (influent, effluent and filtrate) on heat recovery options. Influent heat recovery by intake structure using HUBER ThermWin™ system is an option. This can be done via an intake structure, where a portion of the sewage will flow from the sewer into a screen that retains the coarse solids. The pre-screened wastewater is lifted and flows by
gravity through the above ground installed HUBER RoWin Heat Exchanger (with self-cleaning mechanism). These will create continuous stable hydraulic conditions and ensure controlled heat transfer (clean water) to heat pump. The cold wastewater then flows back to the sewer along with the screenings.

Influent heat recovery using HUBER Tube Win Heat Exchanger Elements is another option. This can be installed directly on the sewer base or at the headwork intake sewer pipes prior to screening. Due to its flat and robust design, it can be installed inside any diameter of pipe. The thermal energy contained within the wastewater flow is transferred to a cooling medium inside the modules so that the wastewater heat can be used by the heat pump. The heat exchanger elements do not need extra space as they are installed inside the sewer (any shape). They can be installed in parallel or in series and also to specific wastewater parameters. All the components are made of V4A stainless steel for a long product life and can be used all the year round, for heating and cooling.

Energy recovery from filtrate after anaerobic digestion is an important option. The state-of-the-art technology offers several sludge dewatering options, but most of these solution disregards the rich energy potential of the filtrate water. At Ringsend WWTP, about 120 t of sludge are treated every day in CAMBI THP and anaerobic digestion, with at least 50% of these coming out as digestate, at a temperature of approximately 36°C. This energy can be extracted from the filtrate by heat exchanger and utilise the thermal energy before it is returned to the beginning of the wastewater treatment process. According to HUBBER, only 18 m³/h filtrate is required to generate about 270 kW thermal output with a temperature of 45°C by using HUBER RoWin Heat Exchanger and heat pump. The coefficient of performance (COP) of >4.5 achieved by the heat pump with energy expenditure of below 60 kW (HUBER, 2015).

Effluent heat recovery using “Tank Version” of HUBER Heat Exchanger RoWin provides one more option. The thermal energy reserves in wastewater after treatment are dependent on the temperature, flow rate, heat transfer efficiency, and specific heat capacity of the water. This can be expressed theoretically (Zhao et al., 2010):

\[ E = \rho \times Q \times C_p \times \Delta T \]  \hspace{1cm} (1)

Where, \( E \) is the thermal energy reserve (kcal), \( \rho \) is the density of the wastewater (kg/m³), \( Q \) is the effluent flow rate (m³), \( C_p \) is the specific heat of the wastewater (kcal/kg °C), \( \Delta T \) is the temperature that can be extracted (°C).

Due to the biological treatment processes, the temperature of effluents from the plants is on the average 2°C higher than the influent. Thus higher amount of heat can be extracted from wastewater effluents than the heat recovery plants installed in sewer systems, making this a more promising option. This version consists of tank that integrates the pipe modules, and due to its compact design, it can be installed directly in outlet channel, existing or designed tank so that no additional installation space is required. The positive aspect is that the biological processes in the sewage treatment plant are not impaired and the discharge of cool effluent is beneficial to the receiving water body. This is because introduction of heat into the receiving water system considerably contribute to eutrophication due to algae growth. The effluent usually runs by gravity thereby avoiding the need for pumping and other associated costs, and this significantly improves the economy efficiency of the plant.

According to HUBER (2015), approximately heat energy of 10 kW per litre per second can be generated when using their products. In general, about 75% of heating and cooling energy can be saved by implementing
the heat pump system with coefficient of performance (COP) >4 thus leading to reduction in greenhouse gas emissions. In Stockhom, Sweden, for example, a wastewater treatment plant with a maximum hydraulic capacity of 450,000 m³/d produces about 597,000 MWh low-temperature heat energy using 199,000 MWh electrical energy via heat pumps (ESMAP, 2008). Therefore, Ringsend WWTP with daily hydraulic capacity of 470,000 m³/d has a potential to produce as much as 600,000 MWh low-temperature heat with similar or lower input energy.

4.1.4 Co-digestion of high-strength organic waste

Co-digestion of wastewater sludge with other biowastes, especially food waste and fat, grease and oil (FOG) becomes in practice (WERF, 2010a). According to the literature review, co-digestion will enhance the biogas production by 50-185% (sewage sludge co-digested with food waste) (Heo et al., 2004; Kim et al., 2004; Murto et al., 2004; Sosnowski et al., 2008) and, 100-410% (sewage sludge co-digested with FOG) (Alanya et al., 2013; Davidsson et al., 2008; Noutsopoulos et al., 2013; Silvestre et al., 2011). Ringsend at present does not accept food waste, FOG, which, if they start accepting, can increase their biogas energy production by 100%, thereby saving them the need to import natural gas being used at present to supplement the anaerobic digestion gas product on-site. These additional substrates also includes; (FOG, food waste, waste organic byproducts). FOG digestion has a high volatile solids destruction rate, reported to have range from 70-80% in mesophilic (35°C) processes. FOG digestion also has a high rate of biogas generation, with reported values up to 1.3 m³/kg VS, as compared to a typical biosolids gas generation rate 1.0 m³/kg VS. Other organic waste that could be used in the co-digestion process include glycerin from biodiesel production, airplane deicing fluid waste, food waste, manure, and other industrial organic wastes (brewery, cheese production etc.). However, information is still very limited on the biogas production enhancement and other performance characteristics of co-digestion and utilization of these feedstocks (WERF, 2010a, b).

4.2 Management strategies

Many actions could be considered to achieve a better management towards energy efficiency in the plant. Creation of energy sustainability team is useful to adopt and co-ordinate the “Plant-Do-Check-Act Approach” (Fig. 2) developed by USEPA (2006). This team can involve determining their present baselines; conducting energy audit; identifying priorities; setting improvement goals, and benchmark with other WWTPs elsewhere and set target to implement the action plans, like Energy Conservation Measures (ECMs). Hiring of dedicated energy manager is necessary. The position is responsible to manage and co-ordinate the implementation of energy management technology tools, like Supervisor Control and Data Acquisition System (SCADA) to provide a central location for process monitoring and operational control. It has been estimated that Ringsend WWTP can benefit from this system by integrating it with existing system or adopt it out rightly. This may lead to energy consumption saving of 35% as reported (WERF, 2010b).

At Ringsend WWTP, the General Electric’s Jenbaher gas engines 4 nos (1 MW each) were installed with one of it being used for redundancy purpose. This emergency generator required for redundancy can be employed to decrease energy cost in two strategic ways; reducing the demand charge by operating it, if the peak demand exceeds a targeted value. This can be achieved by implementing supervisory control and data acquisition systems (SCADA), which can monitor the electrical
usage and automatic emergency generator operation; reducing the energy charge by operating when the marginal cost of generator operation exceeds the marginal cost of service provided by the electrical company. Ringsend can save as much as 15% energy bill by adopting this strategy. In addition, lighting accounts for 8-10% of wastewater treatment plant energy consumption. Recent advances in lighting systems provide opportunities to retrofitting existing lighting systems with high-efficiency alternatives, fixtures and by changing how lights are used is a strategic approach to reducing operating costs. Therefore Ringsend WWTP can save up to 60% on lighting energy cost by adopting these strategic:

Advance fluorescent lighting: Replacing or upgrading individual fluorescent light systems will offer high potential energy savings up to 65%. Replacing the old T12 and T8 with “Save It Easy®” T5 adapter, will provide the necessary high-frequency ballast to adapt Switch start and Starter less fittings to accept energy saving T5 fluorescent tubes with simple plug and play speed. This is an easy to switch to more efficient lighting without the need to replace the light fittings or cause disruptions. It gives greater light output with potential to use fewer tubes, longer lasting without lifetime fade and non-flicker which reduce worker fatigue.

High intensity discharge lamp: Upgrade to high-pressure sodium and compact metal halide lamps which are three to five times more efficient than incandescent, and can produce three times the illumination. Maintenance and replacement costs are lower because of the longer bulb life.

Lighting controls: At Ringsend WWTP, simple control can eliminate unnecessary lighting in the areas that do not require continuous lighting. Occupancy sensor has been proven to reduce lighting by 30-50% as compare to manual switching. Dimmable electronic ballasts have proven very successful.

Figure 2  Management strategies implementing “The Plan-Do-Check-Act Approach” flowchart
Regular maintenance: Ringsend can implement a program of regular cleaning, replacement, and maintenance of lamp and luminaries to save energy. Dust, dirt, and other materials on lamps, reflectors and lenses can decrease lighting output by 30% or more. This will reduce the amount of light needed to achieve minimum light levels, resulting in lower first costs and energy saving by about 15%.

**DISCUSSION AND CONCLUSIONS**

The primary purpose of WWTPs is for the removal of various pollutants from wastewater, while the treatment processes require huge energy input in most of the WWTPs worldwide. Actually, WWTPs are performing the role of not only pollutants removal, but also the energy and the resource recovery if the WWTPs are well managed with proper energy strategy developed. The fact is that the wastewater itself contains potential energy as the pollutants are really the source energy (such as various organic matters, oils etc.). The drive now is toward the path of energy self-sufficient and sustainability, which in the long run will help in reducing the greenhouse gas emissions and reduction in the consumption of fossil fuels (Hao et al., 2015).

Two strategic options have been considered and recommended to improve Ringsend WWTP energy efficiency and attainment of energy neutrality, in which other treatment plants in Ireland can adopt. They are technical and management strategies as summarised in the Tables 1 and 2. Various suggestions on technologies to improve the energy management and technical processes are offered, with a view of making the plant energy self-sufficient.

**Table 1** Technical strategies for Ringsend WWTP energy improvements

<table>
<thead>
<tr>
<th>Energy Sources</th>
<th>Treatment Process/ Improvement</th>
<th>Energy Products</th>
<th>Energy use/ Saving potentials</th>
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<tbody>
<tr>
<td>Wastewater Biosolids</td>
<td>Biodegradation:</td>
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<tr>
<td></td>
<td>Anaerobic Co-Digestion of sewage sludge with food waste and/or FOG</td>
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<td></td>
<td>GAS Conditioning and upgrading</td>
<td>Clean gas with high efficiency performance and reduce GHG emissions</td>
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<tr>
<td></td>
<td>Retrofit Gas engines with “lean burn technology”</td>
<td></td>
<td>Over 75% energy savings; Reduce GHG emission; Improve process performance and efficiency</td>
</tr>
<tr>
<td></td>
<td>Upgrading of the digester recirculation pumps (VFDs)</td>
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<tr>
<td>Wastewater Influent, Filtrate (Anaerobic Digestion) and Effluent Heat</td>
<td>Heat Exchanger with Heat Pumps install at:</td>
<td>Waste heat Recovery</td>
<td>Process Heat; Heating and Cooling; (possible to save 75% of heating and cooling energy with COP &gt; 4)</td>
</tr>
<tr>
<td></td>
<td>Sewer (near headwork); Filtrate outlet; Effluent channels</td>
<td>Potential 600 MWh low-temperature energy</td>
<td>Heating and Cooling; (possible to save 75% of heating and cooling energy with COP &gt; 4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Power Generation</td>
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</table>
### Table 2  Management strategies for Ringsend WWTP energy improvements

<table>
<thead>
<tr>
<th>Energy Conservation Measures</th>
<th>Actions expected</th>
<th>Energy saving potential</th>
</tr>
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<tbody>
<tr>
<td>Lighting systems Upgrade</td>
<td>Retrofit or install: Advance fluorescent light (replacing T12 &amp; T8 with T5) (T5 lamps is 40% smaller than T8 lamps and 60% smaller than T12 lamps)</td>
<td>60% -70% savings based on similar upgrade carried out by Energy Sense Ireland; (3-5 times more efficient than incandescent); 30%-50% savings compare to manual switching (Enviroshop, 2015)</td>
</tr>
<tr>
<td>Emergency Generator Operation</td>
<td>Adopt regular maintenance Operate if the peak demand exceeds a targeted value</td>
<td>Reduction in demand charges for peak time 15% energy savings possible</td>
</tr>
<tr>
<td>Operation Controls Upgrading plant control with Supervisor Control and Data Acquisition System (SCADA)</td>
<td>Immediate detection of problems through diagnostic displays, Enabling quick intervention for fast resolutions; Allow operations to compensate for seasonal flow and wet weather by automatically adjusting set points</td>
<td></td>
</tr>
<tr>
<td>Creation of Energy Team/Energy Manager Conduct energy audit and make changes to present situations</td>
<td>Manage and co-ordinate the implementation of ECMs for overall energy efficiency</td>
<td></td>
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<tr>
<td>Energy Conservation Measures (ECMs) Life-cycle of Energy Conservation Measures (ECMs), regardless of any cost analysis; The operating cost of many pieces of low-energy consumption equipment, can be many times greater than the capital costs</td>
<td>Better decision making</td>
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As a matter of fact, energy is becoming a very important cost factor in wastewater treatment, given the increasing energy costs in the recent years. A continuous rise in energy costs in the EU-27 can be seen from the average amount of 0.0756 €/kWh in 2005 up to 0.11 €/kWh in 2011 (EUROSTAT, 2012; Hernandez-Sancho et al., 2011). The biogas...
produced in anaerobic digestion can be transformed into thermal or electrical energy by using a combined heat and power plant (CHP). This can be utilised onsite, but optimisation of the biogas is very important as this is capable of making the plant more energy efficient. Though the energy production from biogas is a main source in WWTPs, other options, such as hydroelectric power generation (using mini turbines) at the effluent discharge points, utilisation of free space for solar power generation on site (roof tops, primary and secondary treatment tank covers, aeration tank covers etc.), could also play an important role in energy saving and generation. It is reasonable to believe that the integration and combination of various strategies from both technical and management aspects will be the best to realise the goal of energy self-sufficient and even net energy production (Hao et al., 2015).

REFERENCES


