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# SUSTAINABLE ENERGY IN WASTEWATER TREATMENT PLANTS

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*Paper approaches theme of energy efficiency and sustainable energy use in WWTPs, by evaluating them separately, as an independent case. Chemical loads of nutrients from wastewater, flow rates, technological lines with different treatment technologies and equipments used, and also power and heat consumption are not the same in all cases, WWTPs do not fit into a pattern and therefore the solution can not be the same. Also, to propose good sustainable energy solutions for each WWTP, it has to be made an evaluation of all energy needs and all sustainable energy sources for each of the WWTPs first.*

**Keywords**: wastewater, sustainable, energy, biogas

## 1. Introduction

The humans should take all appropriate measures to prevent and abate the pollution of the rivers, lakes and seas. The main task is to reduce or stop, if possible, the discharges of toxic and other harmful substances like the load of phosphorus and nitrogen compounds. The Contracting Parties apply effective treatment of municipal and industrial wastewater, aiming at the reduction of discharges of harmful substances, organic matter and nutrients to the environment. But this comes with a big cost, which is the power consumed by all the necessary equipment in order to treat the wastewater.

Municipal wastewater treatment plants (WWTPs) are major consumers of energy in national energy system and the cost of this power consumption is an important part of the operating costs.

In wastewater treatment plants is very difficult to make power savings because the process is continuous. On the one hand the water continuously enters from the sewage system into the wastewater treatment plant and, on the other hand the treatment technology is based on processes (physical, chemical and especially biological) that can not be off or disconnected from the mains supply. Following the

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above considerations is clear that reducing operating costs can not be achieved except through the use of compensational regenerative sources of energy, both heat and power.

This study is based on the idea of identifying unconventional energy sources that can be economically used in wastewater treatment plants in order to achieve the goal, which is to obtain important energy savings from reducing operating costs significantly. Unconventional solutions are in the forefront of many developing countries to achieve energy self-sufficiency [1].

## 2. Presentation and analysis of purposed solutions

The application of the anaerobic digestion for the treatment of the industrial organic fraction of municipal solid waste (OFMSW) has currently been of special interest [2]. A very good solution to reduce or even eliminate energy costs in wastewater treatment is anaerobic digestion of the sludge, in order to produce biogas and to use it for the plant's own energy needs. This solution proved to be very advantageous and can be implemented in almost all medium and big municipal wastewater treatment plants, or where sewage influent has a very high biological load, such as wastewaters from different livestock farms, slaughterhouses [3], etc.

The potential of using the biogas as energy source has long been widely recognised and current techniques are being developed to upgrade quality and to enhance energy use [4]. Biogas from anaerobic digestion of biological wastes is a renewable energy resource [5].

The problem with the use of sludge anaerobic fermentation for biogas production is the amount of heat required to maintain a constant high temperature inside the digesters. This amount of heat can be obtained by implementing a cogeneration unit of heat and power (CHP). Such unit will produce a large part of the electricity needed for the proper functioning of the equipment in wastewater treatment plant. Also, whether it is equipped with internal combustion engine or gas turbine, such a cogeneration unit will produce a large quantity of waste heat that can be used to meet the digester's thermal energy needs and to cover the needs for space heating and the heating of water. The key determinant of whether or not would be of use the combined heat and power technology, is the nearby need or purpose for the captured waste heat. While electricity may be transferred reasonably efficiently across great distances, hot water or steam are not efficiently transportable at all.

The climate of the Europe is of a temperate, continental nature and the temperature during the summer period are over 15-17 °C (day and night average). This means the heat needed in order to keep an optimum temperature inside the anaerobic digestion tank is way smaller during the summer than in the cold season. Based on the fact that it is most common to install a CHP system based on the hot water or steam needs of the establishment, and since a wastewater treatment plant doesn't have so much need for the heat in the summer, the question arises: is a heat and power cogeneration unit a good solution for the wastewater treatment plants in order to reduce the power and heat needs? Well first of all we have to analyze it in terms of reducing pollution and should be analyzed each component separately. By implementing anaerobic digestion tanks, that amount of methane, contained in the biogas that will be captured, will not be released into the atmosphere anymore, as would have happened if the sludge was left to ferment on the beds of sludge. So methane emissions in the atmosphere will be reduced to almost zero. By using biogas as primary fuel in a CHP unit to produce the heat and the electricity needed, $CO_2$ emissions to produce these amounts of energy will be reduced. The $CO_2$ footprint of the wastewater treatment plant will be significantly lowered so this type of solution is definitely an advantageous one in terms of reducing pollution. Now let's take a look at the solution in terms of profitability. The installation of a CHP unit is sized considering the thermal energy needs. As heat demand during summer is very low, then during the warm period of the year a large part of the heat produced by cogeneration unit will not be required, so it will be lost, thus reducing the overall efficiency of the CHP unit. But if the heat and power cogeneration is not so efficient, than what is to be done? Selling the biogas produced and using those money to buy the power needed is not an option, as it would imply several additional costs.

A solution would be to install a cogeneration unit that will only run in winter. Thus, throughout the warm season the amount of biogas will be stored in tanks designed according to the production of biogas from half a year. Cogeneration plant will be sized according to the maximum of heat demand, and will produce with the maximum efficiency the entire amount of heat and power needed during winter for the operation of the wastewater treatment plant. Depending on the quantity of biogas available, if it is greater than necessary to cover the needs of power and heat, the CHP unit can charge electricity in the national energy system. For this amount of power injected into the network a customer can be found to buy it, but this version is almost impossible, as you have found a consumer who has a consumption curve in accordance with the surplus power produced by the cogeneration unit, plus the fact that if the consumer is not at a short distance, then the transportation costs has to be deducted from the amount of electricity sold to the consumer. A better solution for the power injected into the network would be to make a contract with one of the major national distributors of electricity, so that surplus power to be supplied during the peak of the daily load curves of the national energy system. Thus, the power will be sold for a higher price than if sold to an insulated consumer. Ok, the solution is to store the biogas produced in summer, and burn it during winter in a cogeneration unit to provide electricity and thermal energy needs, and to inject power into the network, thus bringing the money in the station's budget. But this solution is incomplete because in summer electrical power and a quantity of heat to raise the temperature of sludge from the ambient temperature at the anaerobic fermentation required temperature are still needed.

An energy-efficient and economical solution to meet those energy needs during the summer can only be a complex one. Money obtained from selling surplus electricity in winter can be used to buy a part of the power supply in the summer, the difference will need to be covered by implementing a solution to the source / sources of renewable electricity generation, such as photovoltaic panels, wind turbines, depending on where each is located sewage treatment plant.

Unit processes of wastewater treatment plant (retaining solids on grids, flotation, sedimentation, biological processes, etc.) require varying sequences of using the equipment. Thus, for grates, mechanical cleaning process of the panel bar is discontinuous, and electric motor operate about one third of 24 hours. In the biological process - aeration tanks - oxygen equipment run continuously. However in this case blowers, being controlled by the oxygen sensor - to save energy and optimal operation under unified process, come into operation dependent on oxygen demand.

Operating costs for wastewater treatment include different types of costs that are specifically related to the following factors: load and nominal capacity [6], age of the treatment plant, plant location and situation topographic, hydro-geological, rate of utilization and charges related to the nominal capacity, drainage characteristics and efficiency, process technology and the concept of treatment, sludge treatment and energy used, standard process control and SCADA system, solid waste and sludge management, and management structure.

The power consumption in the studied Wastewater Treatment Plant had a medium value of 502,000 kWh per month in 2008 and a medium value of 497,400 kWh per month in 2009. Power consumption recorded for the months April to June in 2010 are as follows:

April, 2010 - 473,620 kWh
May, 2010 - 511,670 kWh
June, 2010 - 490,470 kWh

As you can see they are part of normal evolution of consumption recorded in 2008 and 2009. Thus, it can be said that the electricity needs of the wastewater treatment plant is about 600,000 kWh per year.

Renewable energy sources (RES) have the advantage of their survival and negligible impact on the environment, since they do not emit greenhouse gases [7]. Although biomass combustion releases a quantity of $CO_2$, this amount is absorbed during its growth, the balance is zero. At the same time, these technologies do not produce hazardous waste, and dismantling at the end of their life, unlike nuclear plants, is relatively simple.

Like any other energy technology, the use of RES also has some inconveniences. The impact of wind turbines on the landscape, the risk of soil contamination and leakage of methane from gasification, disrupting the ecological balance by the small hydropower plants (SHP) are only a few. The major inconvenience, however, are those related to land area required and intermittent in operation and availability.

In order to propose a solution for a wastewater treatment plant, an evaluation of its energy needs and an evaluation of the biogas production has to be made. Please note that each of the treatment plant should be treated independently and studied as a separate case [8], because the loads, flow rates, technological lines, power consumption and heat consumption are not the same in all cases and therefore the solution can not be the same in all cases.

In the studied wastewater treatment plant, heating units are installed in the four methane tanks for heating the sludge at 36°C required for digestion process, and heating units are also installed for space heating in the administrative and industrial buildings, where the employees are working [9]. Heat requirement is covered with heating units with heat supplied by a distribution network of pipes made of steel. The thermal agent flow through a steel pipes distribution network and feed the heating elements where heat transfer is achieved. The pipes are insulated and heaters will be fitted with stopcocks on both tour and return, and vent valves.

Thermal energy needs inside the wastewater treatment plant consists of the sum of heat consumption:

a) technological heat consumption for heating the methane tanks;

b) heat consumption for administrative buildings space heating during the cold period;

c) heat consumption for industrial buildings space heating during the cold period;

d) heat consumption for preparation of the hot water.

Technological heat consumption in a wastewater treatment plant is different during a year. During the warm season the heat inputted to maintain the temperature at 36 °C in methane tanks is much smaller than during the cold season.

In conclusion, we have calculated two average technological heat consumption, as follows: for the cold period (hereinafter called "winter") was calculated technological winter heating needs for 193 days per year, while during the warm season (hereinafter called "summer") was calculated technological summer heating needs for 172 days per year.

The total amount of heat required to maintain process temperature from methane tank was calculated as the sum of the heat required for fresh sludge heating, and the amount of heat required to cover the heat losses through elements of the methane tank: foundation, walls and dome. Average daily flow of fresh sludge obtained from the studied wastewater treatment plant is 13.37 $m^3$/h.

The calculated thermal power for heating fresh sludge are 503 kW in winter and 347 kW in summer. These values include the amount of heat necessary to cover losses through the wall, foundation and dome of the methane tank both in winter and summer. In this calculation was taken into account the heat transfer surface areas, the width of each material, the conduction coefficients, the convection coefficients, and also the average temperatures of the exterior environment, both ground and air, during both summer and winter.

The space heating period of time was considered 4632 hours within a year, and the period of time for both technological use and preparing the domestic hot water was considered a whole year. The period during which space heating is done in both the administrative pavilion and the technological buildings was established based on geo-climatic characteristics of the location of sewage treatment plant studied. Were considered average wind speed, average temperatures of the air outside, average soil temperatures and also the climate type of the region.

The calculated heat demand for domestic hot water needed in the wastewater treatment plant was considered constant throughout the year, with a value of 4.05 kWh on a period of 8640 hours.

Calculated heat necessary for space heating in the administrative pavilion varies, on a period of 4632 hours within a year, from a minimum value of 30.11 kWh up to 120.45 kWh.

The heat consumption for space heating in the technological buildings varies, on a period of 4632 hours within a year, from a minimum value of 42 kWh up to 208 kWh.

All the peak values, of each of the thermal energy consumption considered in this article, occur in the same period of time, namely when the temperature of the environment is minimal during the cold season. Therefore, the graphical representation overlapped during the entire period of the cold season, the values in descending order, from the maximum of all thermal energy consumption, to their minimum values. The four different heat consumptions are represented in figure 1.

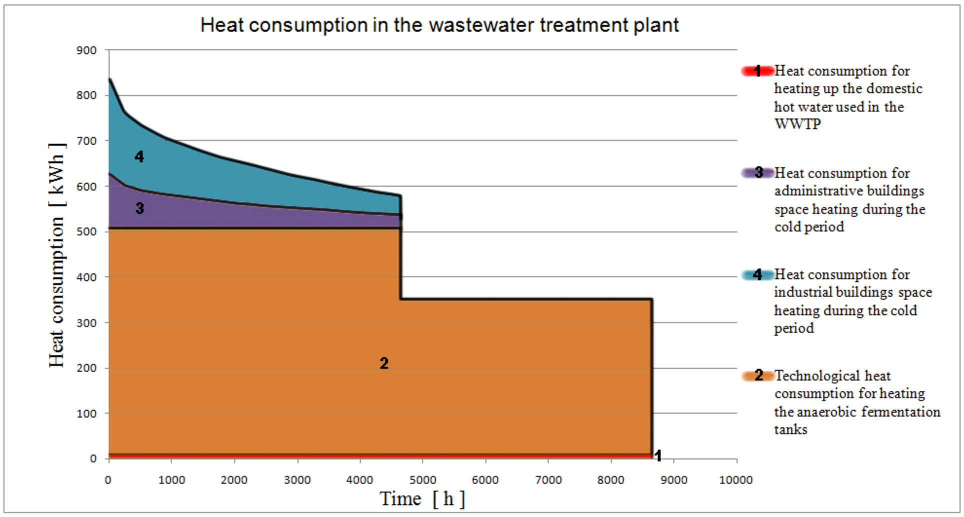


Fig. 1. Heat consumptions in the studied WWTP

Total thermal energy demand for dimensioning the heat generation unit or cogeneration unit, without taking into account the heat losses in the system, is represented into figure 2. Heat losses were neglected because the network of the heating system doesn't cover a very large distance and with good insulation losses can be minimized.

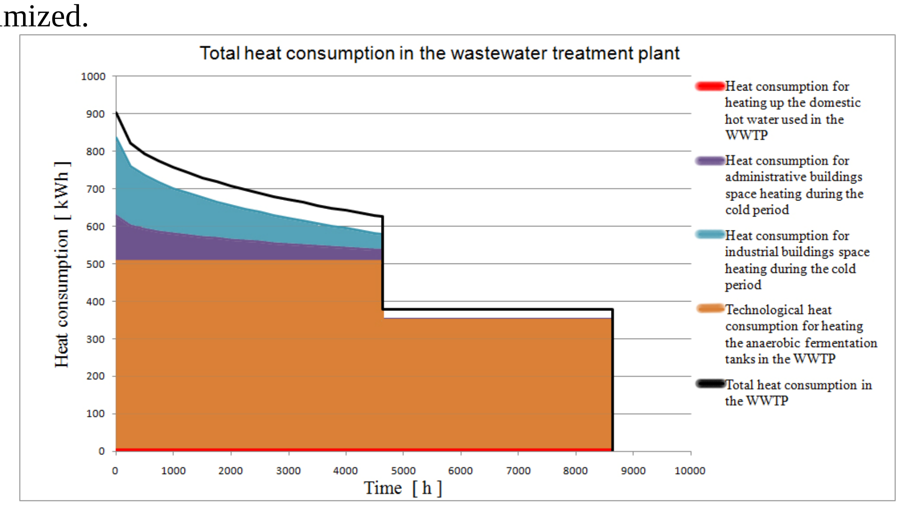


Fig. 2. Total heat demand in the studied WWTP

## 6. Conclusions

The calculations and measurements showed that the mainly thermal energy demand is for technological heating, i.e. the heat consumed for heating methane tanks. Compared with the values obtained for maintaining the process temperature from methane tank at 36 °C, the heat consumed for heating hot water and to heat the administrative pavilion have little value and can be considered almost negligible. The addition of heat requisitions, has resulted in a maximum overall heat requirement, value obtained for the minimum outdoor temperature. The heat required in the studied wastewater treatment plant is partly covered at the moment by burning the produced biogas into heat boilers with a very low efficiency. A very important step is to replace the existing facilities with advanced thermal energy production facilities, which will have a high efficiency, and this way the entire thermal energy needs of the wastewater treatment plant could be covered.

Another important step is to improve the production process of the biogas. Process optimization of the fermentation gas production mainly consists of reducing the heat needs and complete fermentation of volatile solid organic substances. Reducing the heat consumption is achieved by reducing the amount the water contained in the sludge flow [10]. This leads to the need for proper sizing of the sludge thickeners and the need to use the maximum of their performance.

Complete digestion of dry volatile substances is performed under the following conditions:

a) introduction the thickened sludge in the methane tank;

b) maintain the pH value in a very tight range 6.8 ... 7.2, which sometimes requires a sludge conditioning;

c) proper mixing of the sludge in the methane tank;

d) ensuring the fermentation time of 22 days in the mesophilic domain.

Another measure to be taken in order to reduce the heat needed is to achieve good thermal isolation for the fermentation tank. From this point the view it is recommended burying methane tanks, especially in countries with temperate climates, or their outer coating with good thermal insulation. Good thermal insulation of the methane tanks can lead to significantly reduce energy requirement for heating, since they are by far the biggest thermal energy consumers from the wastewater treatment plant.

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