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BIO4GAS: EVALUATION AND ANALYSIS OF WASTEWATER TREATMENT FACILITIES IN THE SCOPE OF BIOGAS PRODUCTION MAXIMIZATION AND ENERGY PRODUCTION OPTIMIZATION

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ABSTRACT: The present work presents some of the results of five reports developed in the scope of optimization feasibility studies carried out at 6 small- and medium-sized wastewater treatment plants (WWTP) in Portugal. These 6 WWTP are operated by five companies that belong to the Águas de Portugal holding. The objective of the studies was twofold: to assess to which extent the production of biogas could be increased by means of operational modifications and/or by the implementation of co-digestion regimes; and also to simulate different scenarios for feed-in tariff of electricity taking in account energy prices calculated based upon the DL n.º 225/2007 of 11th May. In this way, several co-digestion scenarios were defined based upon standard available organic residues. The results obtained showed that the implementation of co-digestion regimes represent a considerable potential to increase the production of biogas, in some cases, over 600%. Even though, it was concluded that in some cases the costs of introducing new regimes of energy management were not supported by the increase of energy production, so a scale factor is associated to the revenues. This study contributed to the establishment of specific needs in terms of information management (digester operation, energy production/consumption, strategy for optimisation).

Keywords: anaerobic digestion, co-digestion, electric energy revenues, net present value, valuation

INTRODUCTION

Nowadays, and as a growing tendency in Europe, sustainability-based management of wastewater treatment facilities has increased the need of reliable valorisation solutions that could allow the efficient use of resources (sludge, biogas, nutrients). Usually targeted for large-scale wastewater treatment facilities, the identification of new opportunities for valorisation was somehow neglected for small and medium facility size and/or facilities with low strength organic loads. In that scope, several works have been carried out to re-assess the potential of energy valuation in such facilities 0, but its application still lacks further consolidation in countries like Portugal 0. Sludge produced from aerobic treatment, together with other solids from diverse stages of the whole treatment process, are usually treated by means of anaerobic digestion. This technology has proved in different countries and locations, to be a valuable solution in the scope of valorisation 0. In Portugal, and in the scope of the targets for sustainable energy production, waste management and CO2 emissions reduction, established by the European Commission a couple of years ago, together with the increase of prices for green energy defined by the government in 2007, biogas production has started to gain interest in different sectors. Landfill valorisation of biogas and also biogas production in WWTP is nowadays a subject of intense project development. Associated costs of process infrastructures, access points to feed-in into the grid and biogas storage and upgrading, are in most of the cases, together with the lack of expertise, causes of process malfunction and unsuccessfully projects. In that regard, optimisation activities should start with an assessment of local conditions, state of infrastructures, installed capacities and historic of the facility performance when available. This study was developed together with several companies that belong to the Águas de Portugal holding, the main utility of water supply and wastewater treatment in the country. The aims of the project were to establish a bottom line of the current situation in several wastewater treatment facilities, to assess to which extent the performance of the facilities could be improved and to give insights of the possible scenarios for energy revenue from electricity produced from biogas. Data from six wastewater treatment facilities from different locations in the country are included in this study.

METHODOLOGY

The work was carried out based on a structure of four stages: The *first stage* was the collection and analysis of essential information, by the filling in of individual questionnaires defined according to each case. These questionnaires included a full description of the facilities, equipments, operational parameters, treatment capacity, variations of organic and volumetric loads during the different seasons of the year, as well as current project capacity and horizon of the project capacity. Meetings were carried out with managers and technical staff of each facility. In a *second stage*, 3 different scenarios of valorisation were defined and applied according to each treatment facility characteristics for the calculations:

- Scenario 1 (SC1): *Business as usual* (anaerobic digestion of the sludge (S));
- Scenario 2: (SC2): Anaerobic digestion in a co-digestion regime. Co-substrates like organic fraction of municipal solid wastes (OFMSW), livestock wastes (LW) and cheese whey (CW), were chosen accordingly with their local availability;
- Scenario 3 (SC3): Anaerobic digestion of pre-treated sludge. In this study, ultrasound technology (U) was chosen as the pre-treatment technology for the sludge (between several other mechanical, enzymatic and thermal technologies) 0.

All scenarios considered mesophilic conditions for the anaerobic digestion process and also, co-generation of electricity and heat 0 as the valorisation process for the produced biogas. *Stage three* included all the calculations for the scenarios applied to each treatment facility based on collected information. Calculations included solids removal and biogas production (in the case of SC1, verification of the performance of the facility). Some facilities don´t have biogas storage capacity. In those cases, this capacity was also dimensioned and considered as a parameter for the calculations. Finally, *Stage four* focused on electricity production and heat generation. Based on the production of biogas expected and cogeneration equipment characteristics, the production of electric energy was modelled, together with the simulation of the associated feed-in tariff revenues based on different injection timetables. For the calculations, *tariff 1*; *tariff 2* and *tariff 3* correspond to periods of operation, from 14, 16 and 20 hours, respectively, concentrated in peak hours, while *tariff 4* would correspond to 20 hours of production, from which only half n peak hours. Prices of energy were calculated based on DL n.º 225/2007 of 11th May, and also from consumer tariffs from the corresponding energy supply company. For each scenario, and based on the revenues calculated from the energy values, the specific revenue (€/ton dry matter) was calculated, where € stands for the energy revenues and the dry matter stands for the processed dry matter that generated that revenue. Additionally, investment and maintenance costs for each scenario, and its economic viability, through the determination of its Net Present Value (NPV) were estimated. **¡Error! No se encuentra el origen de la referencia.** summarizes some relevant characteristics of the selected wastewater treatment facilities (WWTP) studied in the scope of the project:

Table 9: Map of wastewater treatment plants (WWTP) and its characteristic, and scenarios studied in each case.

Wastewater treatment facility	**WWTP A**	**WWTP B**	**WWTP C**	**WWTP D**	**WWTP E**	**WWTP F**
Valorisation Scenarios	**SC1**- S	**SC1**- S	**SC1**- S	**SC1**- S	**SC1**- S	**SC1**- S
	SC2 - S + CW	**SC2** - S +OFMSW	**SC2** - S +OFMSW	**SC2** - S +OFMSW	**SC2** - S +OFMSW	**SC2** - S +OFMSW
	SC2 - S + CW + OFMSW		**SC3**- S +U	**SC2** - S +LW	**SC2** - S +LW	**SC2** - S + LW
	SC2 - S + CW + LW					
	SC3- S + U					
Life time of the facility (projected) [years]	26	28	28	14	23	13
Treatment capacity [Max. inhab-equiv.]	57000	33000	60000	35000	32000	80000
Amount of treated sludge in life time of the facility (estimated) [tdry matter]	43600	20300	27800	6200	20700	17800
Aerobic treatment setup	CA	CA	CA	EA	EA	EA
Anaerobic digestion	Y	Y	Y	N	N	N

CA – Conventional aeration; EA – Extended aeration

RESULTS

For every scenario considered for each WWTP, the potential energy that can be produced was estimated (Figure 1). As observed, co-digestion scenarios show higher energy potentials. Scenarios with OFMSW as the co-substrate show the highest enhancements compared to business as usual (WWTP F with a value of 635% on increase), while pre-treatment technology has only about 30% of increase (WWTP A and C).

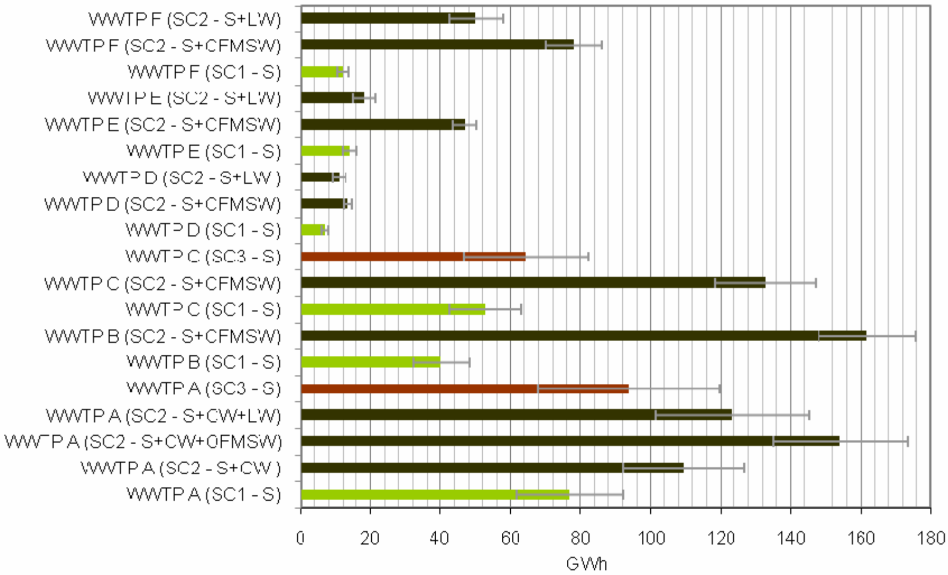

Figure 1: Estimated potential energy that can be produced in each WWTP based upon the defined scenarios.

Electricity revenues for each WWTP, considering the given scenarios are showed in Figure 2. The values shown consider also both cases in which electricity is sold and in which electricity is consumed at the WWTP.

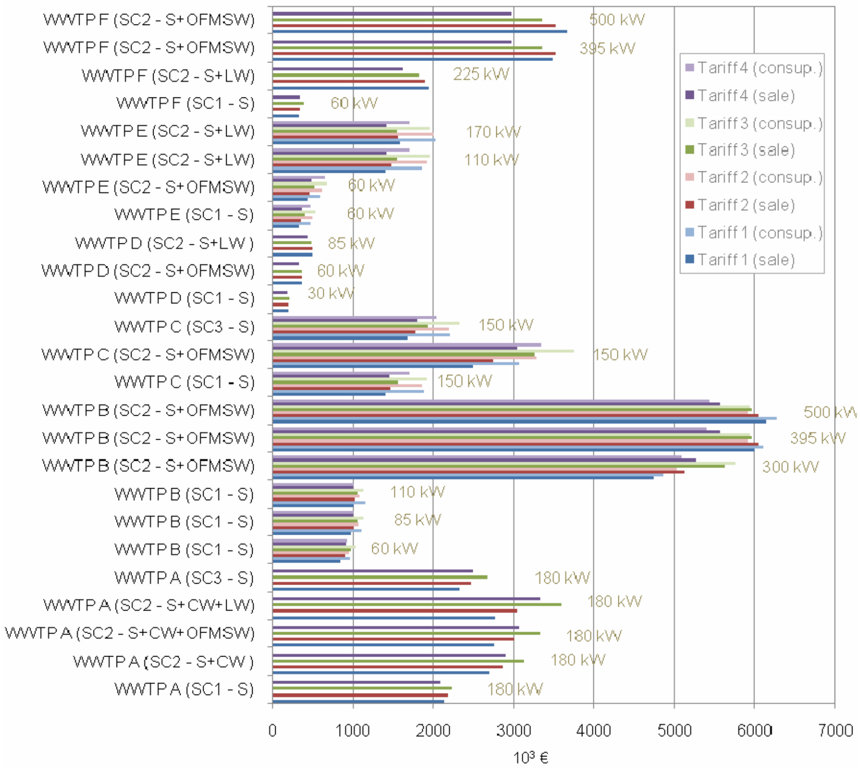

Figure 2: Electricity revenues (at current prices) for each scenario considering both sale and consumption cases and different power capacities.

Figure 3 shows the different values for the specific revenue (€/ton dry matter) of each WWTP in the study. It can be seen that the values change considerably between the different scenarios. SC1 presents values between 16 and 51 €/ton, SC2 presents values up to 146 €/ton, while SC3 shows variations between 53 and 68 €/ton. Additionally, Figure 3 shows the specific energetic value (kWh/ton dry matter). This parameter is also affected by the correspondent tariff schemes applied. Estimated values vary between 131 to 560 kWh/ton for SC1, 155 to 1176 kWh/ton for SC2 and 465 to 644 kWh/ton for SC3.

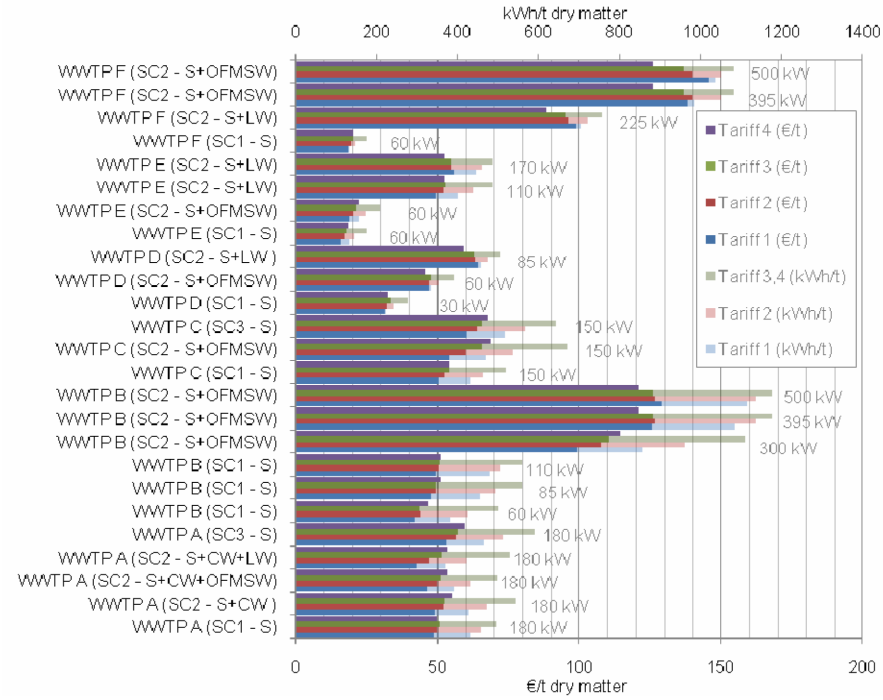

Figure 3: Calculated tariffs and specific energy values based on produced energy and processed dry matter.

Calculated NPV values are presented in Table 2. Results showed that in some cases, energy revenues obtained in most of the WWTP under SC1 and SC2 may be not enough to justify implementation actions. Only WWTP B, C and F are expected to be economically interesting as shown in Table 2, and from those only WWTP B and C present the SC2 as the most attractive scenario. This can be explained based on the fact that SC2 has the highest impact on biogas production increase in small/medium size WWTP or in WWTP that present extended aeration treatments. That is the case of WWTP B (with conventional aeration treatment, but of medium dimension when compared with WWTP F. In order to be able to compare WWTP C with the other WWTP analyzed, calculations did not consider investment costs, only operation costs and revenues from the energy produced. In all scenarios no costs of transportation of sludge/co-subtracts were considered.

Table 2: NPV values for selected WWTP and corresponding scenarios (M€)

	WWTP A	WWTP B	WWTP C	WWTP D	WWTP E	WWTP F
SC1- S	-	<0	0,37 - 0,43	<0	<0	<0
SC2 - S +LW	-	-	0,87 - 1,10	<0	<0	**-**0,13 – 0,10
SC2 - S +OFMSW	-	0,47 - 1,11	-	<0	<0	0,49 - 0,95
SC3 - S	.	-	0,49 - 0,56	-	<0	-

CONCLUSIONS

Co-digestion regimes and pre-treatment technologies present different impacts when considering biogas production optimisation.
Factors like dimension of the WWTP and also treatment characteristics (extended aeration versus normal aeration) have also direct impact in the benefits from optimisation actions. Storage capacity and setup of cogeneration equipment is also of vital importance when considering revenues maximisation.

Direct consumption of the energy produced may be interesting only when energy/tariff scheme is implemented, and restricted to locations where installed cogeneration capacities and also storage capacity allow proper management of the biogas.

Incentives to the production of biogas and further electricity is of vital importance, but economical sustainability of WWTP can only be achieved by means of the implementation of actions and plans for the optimisation of biogas production. To that extent, applied knowledge and process understanding is of vital importance.

As expected, but subject to other factors like installed cogeneration power, availability of storage capacity, local availability of co-substrates, etc., the co-processing of co-substrates in wastewater treatment facilities can have rewarding benefits: optimisation of existing infrastructures, optimisation of energy generation costs, maximisation of energy production and revenues, decrease of project payback times, etc.

Additional information, as for example biodegradability assays, gate-fee schemes and logistics modelling, are needed in order to complete feasibility studies as a basis for action deployment at local scale. This information will provide more accurate indicators to decision makers and WWTP managers.

REFERENCES

Brito A.G, Peixoto J. , Oliveira J. M., Oliveira J. A., Costa C., Nogueira R., and Rodrigues A. (2007). Winery and brewery wastewater treatment: some focal points of design and operation. In: *Residues from the food industry as "by"-products*, Oreopoulu and Russ (ed.), Springer Hamburg.

Brito A.G., Melo L.F. (1997). Operation of UASB and EGSB reactors with low strength acidified wastewaters: a simplified analysis of reaction and mass transfer effects. *Environmental Technology*, 18, 35-44.

Bien, J., G. Malina, J. D. Bien, L. Wolny (2004). Enhancing Anaerobic Fermentation of Sewage Sludge for Increasing Biogas Generation. *Journal of Environmental Science and Health*. Vol. A39, No. 4, pp. 939–949.

Tiehm, A., K. Nickel, M. Zellhorn, U. Neis. (2001). Ultrasonic waste activated sludge disintegration for improving anaerobic stabilization. Water Research. Vol. 35, No. 8. Págs. 2003–2009.

Santos, P. *Guia Técnico de Biogás*. Centro para a Conservação da Energia, 2000.