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Zero-waste energy-efficient agricultural communities in the Greece-Republic of North Macedonia cross-border area

DELIVERABLE 3.3

Guidelines for effective bio-waste management

5/2020

Sub-Deliverable 3.2.3 – Operational plan for the long-term sustainable operation of the pilot bio-gas

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1. Introduction

The present deliverable focuses on the contribution to the development of an operational plan for the long term sustainable operation of the pilot bio-gas unit. In the framework of the work, the operational flowchart with the detailed inputs and outputs for the bio-gas unit is presented.

2. Development of operational plan

Circular economy and resource efficiency have received increasing attention in research and environmental policy agenda in recent years. Circularity can be a catalyst for productive reconstruction and has a clear regional dimension, where the "value" of waste is a key element. Within the concept of circular economy, waste, energy and water consumption need to be minimized (Sariatli, 2017; European Investment Bank, 2019; Wautelet, 2019), and in any case the corresponding environmental pressures should respect target or limit values. Bioeconomy focuses on the use of biomass/biowaste in primary production procedures (e.g. agriculture, forestry, fisheries) and substantial valorization of raw materials (Vea et al., 2018). Biomass is expected to substantially support the achievement of the EU renewable energy targets (European Commission, 2009a).

Undoubtedly, there is a strong linkage between bioeconomy, circular economy, bioproducts and bioenergy (Cobo et al., 2018; Ng and To, 2020). Streams of excess or end-of-life materials, previously regarded as waste, that originate from anthropogenic activities can be channeled through available technologies (e.g. anaerobic digestion, gasification, pyrolysis) and transmute into useable energy carriers, organic biofertilizer abundant in nutrients and, in general, original and innovative materials (Al Seadi et al., 2018; Gontard et al., 2018; Awasthi et al., 2019; Lin et al., 2020; Wainaina et al., 2020). A characteristic example is the production of biofuel (biogas or syngas) which can be characterized as a major means of energy recovery from biowaste streams. An appreciable amplitude of different technological solutions is currently available for small, medium or large-scale Units of Alternative Biowaste Treatment (UABT), with emphasis on the production of bioenergy and other bioproducts. Such solutions are based on applications that extent from tailor-made systems which incorporate existing available facilities (e.g. pumps and storages in an existing farm, buildings for the Combined Heat and Power (CHP) installation etc.), to specialized concepts that diverse, where main parts have been pre-manufactured (e.g. Mc Cabe et al., 2018). Although there are many solutions (International Solid Waste Association, 2013), biowaste disposal in landfills -or in the worst case in uncontrolled open dumps- is still an existing practice internationally. This cannot be considered as proper managerial approach for biowaste, having in mind the intense environmental load imposed. Apart from aesthetic degradation, impacts comprise air pollution and GHG emissions, soil and water contamination, reduced land values and landscape blight. Consequently, optimal biowaste management constitutes a critical activity that reinforces environmental sustainability by minimizing impacts, especially related to uncontrolled discard.

3. Process Operational Flowchart

An ACBW was identified in the Region of Serres. Specifically, available land for the installation of an BWTI was sited in Serres Farm (distance of 2 km from the municipality and 7 km from Neos Scopos, where the local slaughterhouse is located). This public area is easily approachable, while in close proximity there is a municipal vegetable garden. In addition, the site location is adjacent to sources of manure as defined in Animal By-Products (ABP) Regulation (European Commission, 2009) rotten potato pulp, olive mill waste, cheese whey and ABP from the slaughterhouse (Category 2 and 3). Slaughterhouse wastes are characterized by a high lipid and protein content which can significantly increase biogas production.

Figure 1 illustrates the supply based on the annual reception quantities (t/a) of biodegradable streams (substrates), as well as the arrangement of the different substrates received by the IBWT. Due to the seasonality of potato production (April - May) and olive production (October - November), the corresponding bio-wastes will be supplied to the plant only during 8 weeks per year (4 days per week). All the other substrates will be supplied 52 w/a (3-4 d/w, the SHW 1-2 d/w). The biodegradable wastes under consideration will be collected from their production areas using a truck (simple or container if needed) and transported to the IBWT. Considering that the production sites are situated within a distance < 10 km from the IBWT, the costs for waste transportation were estimated as 2 €/t or approximately 6,200 €/a.

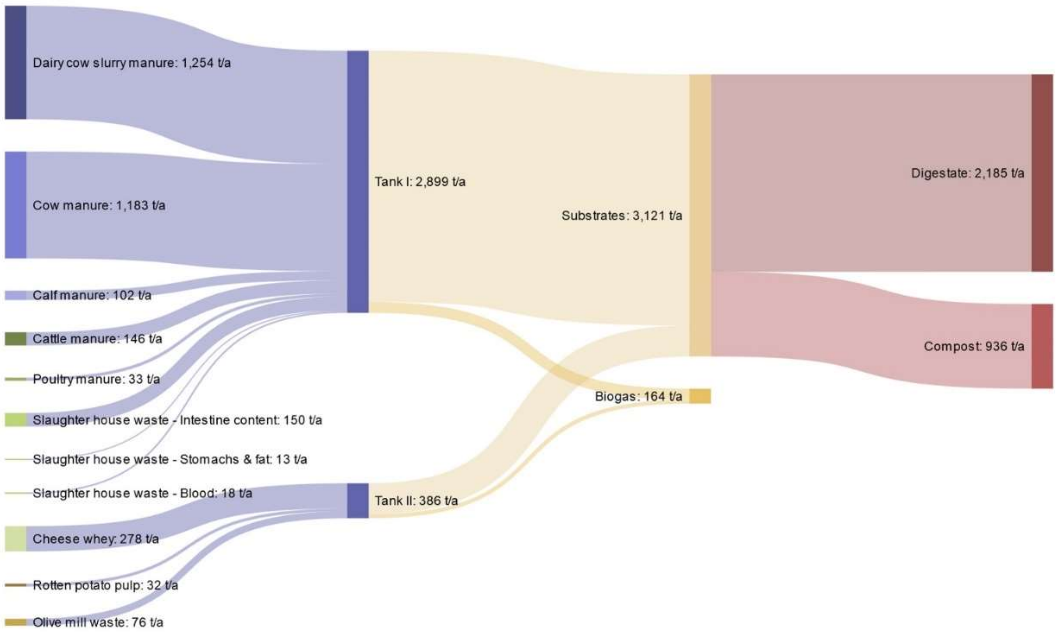

Figure 1. Supply of input, process, and output of final products

The biodegradable "cocktail" of different waste types will be introduced into the biodigesters via two displacement-type reception pumps from two mix-reception tanks. Tank I (Reception A) is a 95 m^3 tank for receiving manures and hygienized slaughterhouse wastes. Tank II (Reception B) is a 65 m^3 tank for the reception of whey, rotten potatoes pulp and olive mill waste. Both tanks will be airtightly closed (underground or semi-buried to minimize the release of odors), fitted with a roof-mounted shredder, an inlet valve, an air-tightly closed opening in the roof-top and an agitator for the necessary blending, to form the final mixture of substrates. The substrates before entering the reception tanks, will be pre-treated via shredding (i.e. hygienized ABP, rotten potato pulp and olive mill waste) and water will be added to form a pumpable slurry. After each use, the shredder will be washed-out with water.

The homogenized mixtures are then joined into a single flow of 9 t/d, which feeds the biodigesters. The latter consist of 2 x 85 m^3 containerized plug flow reactors, equipped with mechanical agitators, and operated under mesophilic conditions (35°C). Analytical dimensioning and a detailed description of the technical specifications can be found elsewhere. The capital expenses (CAPEX) of the proposed IBWT are estimated at the order of 300,000 €. Considering an expected 15 year lifetime and an average of 6% interest the annualized CAPEX is 31,000 €/a.

Based on the proposed design, the IBWT is estimated to process 3,285 t of input waste. The expected output is 160,000 m^3/a of biogas, 400 MWh/a electricity and 450 MWh/a thermal energy. The economic benefit from electricity introduction into the grid can be thus calculated as 84,000 €/a (considering a current price of 210 €/MWh as reported in the legislative framework for Greece). The generated thermal energy is expected to be valorized for digester heating (approximately 200 MWh/a) and the remaining (250 MWh/a) for adjacent agricultural (e.g. greenhouse heating) or agro-industrial activities. By this way it is possible to replace around 25 toe/a, corresponding approximately 15,000 €/a.

The output from each biodigester feeds the liquid-solid screw-press separator. The separator dehydrates the digestate and separates the liquid fraction (2,185 t/a) which is subsequently disposed-off to the stabilization (storage) lagoon. The lagoon is constructed using High-Density Polyethylene geomembrane and a geotextile and covered by a multi-layered PVC-PE-EPDM film. The lagoon will have of a total volume of 2,500 m^3 designed in accordance with the provisions of Decision No 1420/82031-GG B 1709/17-8-2015 (Hellenic Republic, 2015). Figure 2 illustrates the composition of the organic wastes with respect to both their nutrient content (N, P, K) and total mass of nutrients remaining in the liquid digestate. Considering the current market price for nitrogen (approx. 600 €/t), phosphorus (approx. 750 €/t) and potassium (approx. 200 €/t) the value of the liquid digestate becomes equal to 7,000 €, 4,000 €, and 4,000 € respectively. The latter will be pumped from the lagoon through an outlet valve by container trucks will be subsequently deposited on crop land adjacent to the plant's site for soil conditioning/fertilization purposes. The remaining solid digestate fraction (936 t/a), is accumulated below the separator where it is dried and collected periodically into bags and used for adjacent fields fertilization (estimated value of 10 €/t).

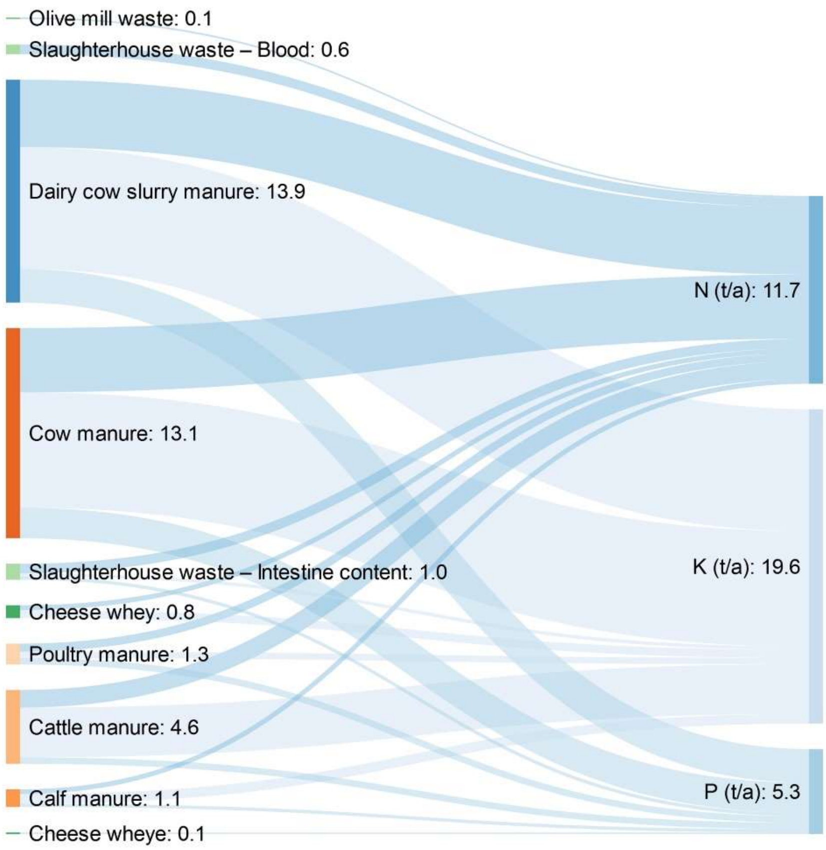

Figure 2. Plant's digestate's production nutrients content

Semantic inspection marks in this procedure are the receipt of the biodegradable waste, the receptor tanks and the biodigester. Critical parameters such as organic matter content, digester pH and volatile fatty acids, polyphenolics content, nutrients and trace elements will be routinely monitored. The digester temperature, the incoming waste flowrate and the generated biogas flowrate should be daily monitored and evaluated by specialized full time personnel. Especially for the hygienized ABPs, special recording and control is necessary. More specifically, the certificates of the veterinarian on duty at the slaughterhouse that supplies them will be requested and received upon receipt, which must necessarily accompany their transfer and delivery to the IBWT. In any other case, the ABPs will not be received.

Considering the above information, the capital and operational expenses of the proposed IBWT facility are summarized in Table 1. The latter include maintenance of the CHP, electricity consumption, labor (one part-time operator for waste receipt, quality control and equipment maintenance) and digester monitoring. It is evident that the proposed facility is depreciated within a 7-to-8-year period. Clearly, the financial incentives and target support planned by the EC methane strategy will further accelerate the biogas market and ensure feasibility for such small-size IBWTs. To this end, it is more than vital that technology providers should also develop biogas specific solutions and ensure economies of scale for decentralized energy production.

Table 1. Indicative economic balance for an IBWT with anaerobic digestion (40 kWel) treating biodegradable wastes mixture

Parameter	Estimation
CAPEX (€)	300,000
CAPEX (€/a)	31,000
OPEX (€/a)	50,200
Waste transport (€/a)	6,200
CHP maintenance (€/a)	10,000
Labor (€/a)	20,000
Electricity consumption (€/a)	7,000
Other costs (€/a)	7,000
Total annualized cost (€/a)	81,200
Total benefit (€/a)	123,000
Feed in tarrif (€/a)	84,000
Thermal energy (€/a)	15,000
Nitrogen & phosphorus (€/a)	15,000
Compost (€/a)	9,000
Total profit (€/a)	41,800
Depreciation period (a)	7.2

Protection and storage are prerequisite for the final products to sustain their targeted quality values. As discussed, in addition to the manifested content of nutrients, utilization of fertilizer means that high quality standards are strictly followed (EU/2019/1009). Quality emphasizes on sanitary conditions, reduction of pathogens (both animal and human) and to the LVs of physical (plastic, metal) and chemical (organic compounds, heavy metals) contaminants. Both sampling, as well as validation follow the methodological scheme as presented in the EU Regulation 2019/1009 (European Commission, 2019c). It should be underlined that the competent authority or a certification body may guide for obtaining samples that are characterized as representatives of the whole batch, both compost and digestate. In the case under study, Greek legislation incorporates the standard "Soil improvers and growing media – Sampling, EN 12579" that provides specific guidelines on performing an efficient sampling procedure. Representativeness can be accomplished if

"Bundesgótemeinschaft Kompost e.V.'s Sampling liquid digested materials" guidelines are followed both for digestate or from its separated liquid component. For each sample, the plant operator records and provides data related to: (i) Date that the sample was taken, (ii) The type of the sample (compost or digestate), (iii) the reference number or the coded indication of the batch produced and (iv) the personal details of the operator (e.g. name, position etc.).

The decision support framework can be implemented to other geographic areas worldwide, at urban, regional, or national contexts. However, the framework should satisfy different environmental, economic, social-political, technological, and legislative factors in such areas. There are procedural shortcomings of the presented approach that may be related to the specific characteristics in national, regional, and local level. These characteristics must be considered, provided that they have a different influence in the waste generation process. The composition of waste streams differentiates across areas around the globe (United Nations, 2019). The decision maker must take into account the dynamic character of population growth, urbanization rate, local climate, economic aspects and indicators such as the GDP, common lifestyles and seasonality e.g. the waste generation in a tourism area related to high seasonal consumption rate.

Thus, it is crucial that demographical issues between different communities and behavioral patterns, should be considered. Cultural and economic characteristics have a strong influence on the waste streams produced. All these factors present strong interrelations with the technological specifications and implications of such installations. The economic status of the area under consideration plays a crucial role in the adoption of a specific technology. Moreover, the solutions to be adopted depend on the national energy system. On this basis, economies of scale for decentralized IBWTs are more than important to ensure economic feasibility. This is applicable either by increasing biogas market competition (new companies and business models) or by implementing new technologies and the provision of incentives.

On top of the above, challenging industrial issues and putting forward scaling-up projects at similar worldwide urban and regional contexts requires a legislative framework which will define a robust ruling basis for waste management, bioenergy and bioproducts production. Directives and relevant laws, especially in the EU, demand for eco-friendly and more efficient cycles of production, which can be accomplished by the introduction of waste residues and by-products in the energy system. The legislative basis is associated with the political environment in each area and the role of governmental policy targets is crucial in promoting biodegradable waste management products with local policies and regulations. It should be noted that political entanglement should be minimized. These phenomena usually impede such initiatives due to different perceptions.

Based on the above discussion, a holistic assessment is required to put forward a sustainable biodegradable waste management practice, suitable for the characteristics of each area. Adjustment to the specific characteristics and conditions is a prerequisite by combining the requirements of the region's waste sector with demands of the energy sector and other sectors such as agriculture. Considering the above, the decision support framework presented herein provide the whole spectrum of procedures required to evaluate the feasibility and sustainability of biodegradable waste management programs, towards recovering energy and nutrients from wastes and supporting the transition to a low carbon future. Clearly, efforts are required by all stakeholders (technology providers, practitioners, politicians, and scientists) to leverage the penetration of anaerobic digestion technologies. To this end, the EU methane strategy provides the roadmap for environmental legislation revision, financial incentives, and support for further accelerating the biogas market. The role of technology providers to develop sector specific solutions and ensure economies of scale for decentralized energy production is also more than vital.

4. Conclusion

As a general remark, safety and environmental friendliness are the main pillars of this approach. Basic structure and components of the framework can be tractably adopted in other geographic areas around the globe. The bundle of treatment alternative technologies is a strategic decision for a policy maker that should be based on robust criteria (Saveyn et al., 2014). To rationally manage biodegradable waste, the use of anaerobic digestion is a reliable perspective (Escalante et al., 2016; Fagerström et al., 2018; Flores-Asis et al., 2019; Lin et al., 2020). The decision support framework developed and demonstrated supports circularity and bioeconomy in the context of resource efficiency and clean technology for treating biodegradable waste. Bio-based products are expected to take their place in the market in future. Public initiatives can play a crucial role towards BWTI and awareness and participation of the local communities is a crucial factor, especially for small-to-medium scale decentralized projects and to increase public perception; thus, the possibilities of an organized market for bioproducts. A future challenge is the inclusion of life cycle thinking in the proposed framework, by incorporating LCA and the quantification of environmental pressure for all available alternatives.

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