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

DELIVERABLE 3.5

Technical specifications for project bio-waste management solutions

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Sub-Deliverable 3.2.5 – Municipality of Serres Pilot Biogas plant specifications

(Public summary)

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1. General outline

The present deliverable concerns the technical description of the project "Pilot biogas plant for the improvement of soil improvement and cogeneration of electricity and heat of nominal electric power of 40 kWp". The operation of the plant will be based on the process of anaerobic digestion of organic agricultural waste (bio-waste). The unit will be a pilot demonstration project of a circular economy application /activity, which is expected to highlight the potential of bringing important environmental and economic benefits to the business community of the municipality of Serres, particularly within the agricultural, livestock management and food industries/ sectors, as well as to the local society.

The purpose of the respective study is to describe the systems and functions of the plant, as well as the description of the quantities and types of biomass (substrates) to be supplied to the plant for treatment. Further, the types and quantities of anaerobic digestion products that will result from the design and operation of the unit are described. The ultimate goal of the unit's operation is to provide an actual incentive to create synergies between the economic stakeholders (suppliers, customers, multipliers/ traders) and a real-life example of the strengthening of the supply and value chains of the region, the reduction of carbon footprint and deterioration of the region's aquifer, as well as the improvement of the environmental and economic living conditions of the local community.

The choice of the anaerobic digestion (AD) technology for the operation of the plant results from the type of available agricultural-industrial organic waste in the area surrounding the plant site. In particular, anaerobic digestion is the most appropriate technology for recovering the energy content of bio-waste mixtures characterized by a high moisture content of Dry Matter 15% (DM ≤ 15%). Such mixtures of bio-waste arise from the production/ breeding of pigs, calfs, cattle and poultry in combination with green residues from the agricultural production and/or processing of stems and fruits (silages, fruits and vegetables, trees), aqueous residues from craft / food industries (dairies, dairy plants, mills) and with appropriately selected slaughterhouse by-products (Slaughterhouse waste – SHW), derived, processed and evaluated according to applicable hygienic laws and the corresponding regulations.

Within a road distance less than 20 kilometers away from the site of the unit, the following establishments are operating:

- 2 large dairy industries
- 6 dairies
- 2 olive mills
- 1 potato packing and processing unit
- 4 poultry farms
- more than 30 bovine and pig breeding establishments for dairy and meat production
- 1 slaughterhouse

capable of supplying bio-waste suitable for anaerobic digestion and in quantities capable in generating a mixture that will ensure continuous operation of the plant.

Based on the proposed design, the plant is estimated to process **3,285** tonnes (t) of bio-waste per year and beyond the electricity and heat cogeneration from the combustion of biogas produced by the anaerobic digestion process in a CHP system (Internal Combustion Engine (ICE) + Generator), it will produce **3.121** tonnes of aqueous residue (the digestate/ a natural soil conditioner rich in nutrients) for disposal/ deposition in crops adjacent to the unit.

The proposed anaerobic digestion process is thermophilic and provides for the bio-waste mixture to remain inside the digesters/ fermenters for at least **20 days (Hydraulic Retention Time ≥ 20 days)** at a temperature of at least **52 °C**.

The plant will produce approximately **160,000 m^3** of biogas per year. The unit's estimated electricity generation per year of operation amounts to **311.996 kWh**, including own-consumption needs and grid losses, while the estimated heat generation (heat energy) is **356.216 kWh**, including thermal losses and own thermal energy consumption.

The excess electrical energy will be fed to the Low Voltage (LV) grid and its selling price will be offset against the electricity purchase costs of the Municipality of Serres, while the excess thermal energy may serve the heating needs of a greenhouse adjacent to the unit's site.

It has been proven in practice by the operation of such facilities around the world that biogas production is part of the nutrient recycling cycle of manure and other organic waste and offer effective means for the recovery of unused energy available in the environment. They are therefor integrated recycling and recovery systems offering:

- Reduced local community energy costs
- Cheap and environmentally safe recycling of manure and bio-waste
- Cheap and efficient crop fertilization means
- Reduction of odors in areas of intensive farming activity.

2. Anaerobic digestion process and bio-waste substrates

Anaerobic digestion is a microbial process during which degradation of the organic fraction of Dry Matter (oDM), or percentage of volatile solids (VS%), of a mixture of bio-waste substrates, under conditions of abscence of oxygen, leads to the production of biogas inside bio-Digesters/ fermenters/ reactors (Bio-digesters). The process involves a series of micro-organisms contained in the bio-waste mixture and its main derivatives/ products are biogas and digestate. Biogas is a fuel gas that consists mainly of methane (CH_4), carbon dioxide (CO_2) but also containing minor amounts of other gases and trace elements. The digestate is the mixture that is coming out of the Bio-digesters, after degradation has taken place, which is rich in nutrients (Nitrogen, Phosphorus and Potassium (NPK)) and therefore suitable for use as a naturally derived fertilizer.

The pilot plant will be receiving the types of organic bio-waste (Substrates) described below in Table 1. The same table describes the annual received quantity of each substrate, their supply days per year, and the quantity of each substrate per day of supply. In the same table, the code of each substrate is presented, in accordance with the European Waste List (EWL) (as per Annex to Decision 2000/532/EC, as amended by Decisions 2001/118/EC, 2001/119/EC and 2001/573/EC of the European Commission).

Raw material	t/day of supply	Days of supply/year	t/year	EWL Code
Dairy cow slurry manure	6.27	200	1,254	**02 01 06**
Cow manure	5.91	200	1,183	**02 01 06**
Calf manure	0.51	200	102	**02 01 06**
Cattle manure	0.73	200	146	**02 01 06**
Poultry manure	0.32	104	33	**02 01 06**
Cheese whey	1.78	156	278	**02 05 01**
Rotten potato pulp	1.00	32	32	**02 01 03**
Olive mill waste	2.37	32	76	**02 03 01**
Slaughterhouse waste - Intestine content	1.44	104	150	**02 02 01**
Slaughterhouse waste - Stomachs and fat	0.24	52	13	**02 02 02**
Slaughterhouse waste - Blood	0.35	52	18	**02 02 02**
Total			**3,285**	

Table 1. *Substrate mix composition, yearly supply schedule and yearly supply quantities*

The livestock from which the quantities of manure to be supplied, per species of origin, is presented in Table 2. The livestock is counted as the number of heads for each species. The quantity of manure produced per tonne per head of livestock species per year has been calculated on the basis of data contained in Decision (GR) No. 1420/82031-GG B 1709 / 17-8-2015 (Code of Good Agricultural Practice for Water Protection by nitrate pollution of agricultural origin).

Manure origin	t/head/year	heads/year
Dairy cow slurry manure	20.13	62
Cow manure	19.20	62
Calf manure	6.62	15
Cattle manure	0.73	200
Poultry manure	0.05	711

Table 2. *Livestock for the plant's supply with manures*

3. Design principles and approach

The proposed design is based on the principles of portability and scalability. The portability of the design lies in the option chosen for installing separate small volume "container-type" metal bio-digesters (BDs), which will receive and process the mixture in parallel. This option allows for fast mountings and connections, while also allowing for the easy and fast installation of additional BDs in the future for the purpose of increasing the plant's capacity to process larger quantities of bio-waste annually and thereby increasing the installed power generation capacity in terms of both electrical and thermal energy production.

The proposed design for the entire infrastructure of the plant permits for a future additional processing capacity of 1,950 tonnes of manure per year (with the involvement of additional manure suppliers lying in the unit's adjacent area) and for the upgrade of the installed power generation capacity to 50 kW_{el} in order to reach an estimated 400,000 kWh_{el} annual electricity production, including self-consumption needs and network losses.

The procurement and installation of 3 BDs of volume of 60 m^3 each is envisaged (in a non-binding manner) allowing for a total digesting volume of 180 m^3, to be warmed-up by a closed hot water circuit. The scenario of increasing the processing capacity of the unit can be achieved by adding two (2) identical BDs so that the total digesting volume can be increased to 300 m^3 in the future.

The bio-waste's substrates' mix will be fed into the bio-digesters in a controlled manner by two displacement-type pumps from two bio-waste mix reception tanks. One (underground or semi-buried) closed concrete tank, of volume of 95 m^3, for receiving manures and SHWs, fitted with a top-roof shredder, inlet valve, airtight closing, an air-tightly closed opening in the top-roof and an agitator and one (underground or semi-buried) closed tank of volume of 65 m^3 made of concrete or stainless steel, for the reception of whey, rotten potatoes pulp and olive mill waste, also fitted with a roof-mounted shredder, inlet valve, air-tightly closed opening in the top-roof and an agitator.

The biogas produced from digestion is collected into three biogas depots (Balloons) of volume of 36 m^3 each, made from PVC, each mounted on the top of each BD and air-proofly connected to the inner compartment of the BD. From there the biogas is driven after purification, dehumidification/ dehydration and controlled compression towards the CHP system for combustion. Purification of the biogas lies in its desulphurisation and is proposed to be implemented biologically through the use of an air injection scrubber in each biogas depot. Dehydration of biogas is achieved by using one moisture trap in which the vapor formed in the pipelines during the biogas's transfer route from the depots to the CHP ends-up and removed. After purification and dehydration, the biogas is compressed into a blower and passes through a flowmeter before entering the ICE's inlet for combustion. In the event that biogas flow towards the ICE's inlet becomes greater than 20 m^3/ hr, biogas flow is diverted via a switch-valve device for controlled combustion/ burning in a flare.

The CHP system consists of the ICE and the Generator. The Generator is connected to the ICE through the ICE's rotating shaft. The CHP system is installed inside a soundproof compartment of the control unit (Technical container) of the unit. The exhaust gases from the biogas combustion pass through a Shell and tube heat exchanger located inside the CHP compartment to warm-up the hot-water closed-end circuit which in turn warms-up the BDs and the substrates' mix inside them.

Also lying inside the CHP compartment, is a second heat exchanger, a plate one, which serves for the cooling of the ICE through the water of the closed hot water circuit returning after having passed from the BDs. The water's circulation inside the closed hot water circuit is achieved by the operation of a horizontal centrifugal recirculation pump.

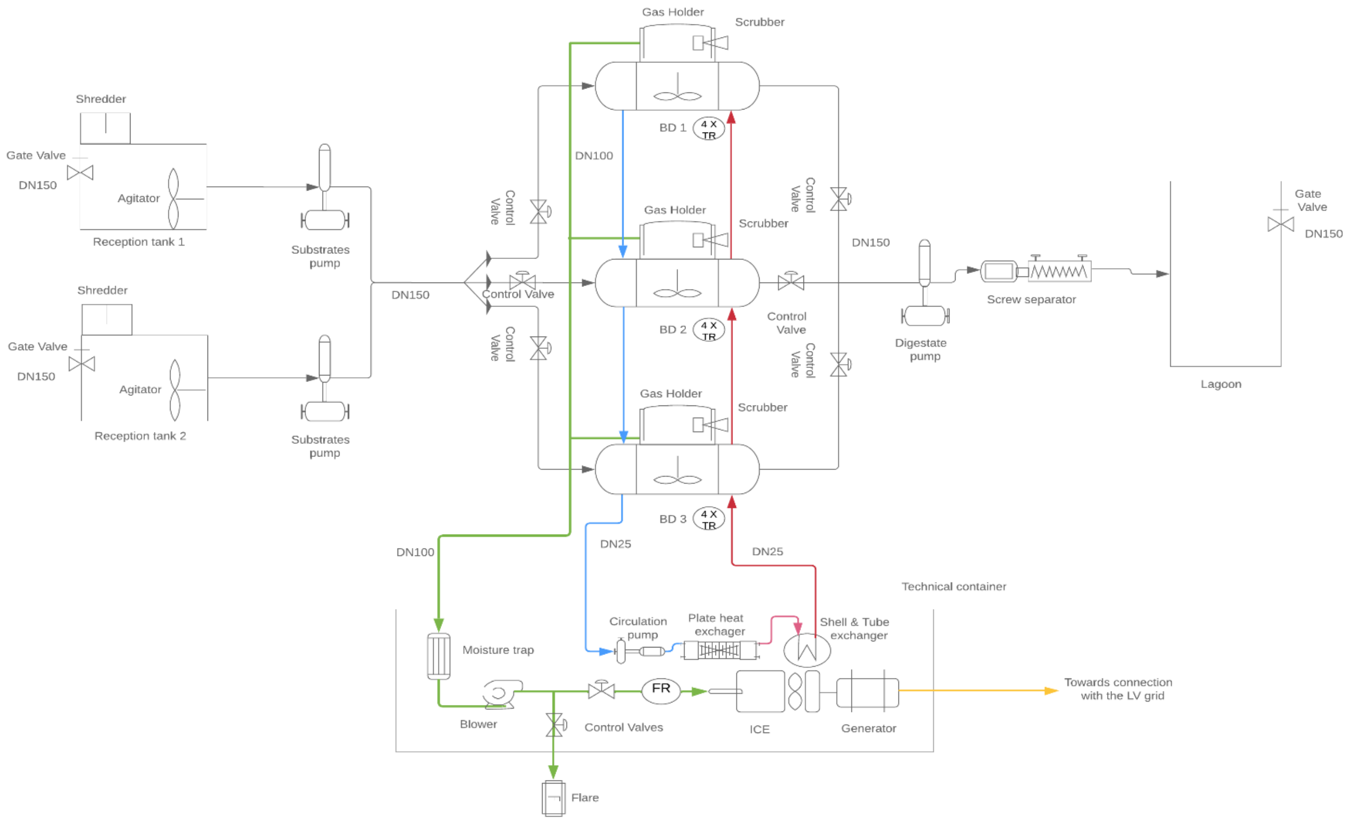
Inside the technical chamber and in front of the CHP compartment the central Low Voltage switchboard of the unit will be installed. Also installed there, will be one rack containing equipment (modules) for recording selected critical operating parameters of the unit from corresponding electronic sensors (thermometers, flow sensors, ICE's operating data) whose signals will be collected by weak currents' wiring. The operating parameters of the unit will be monitored and controlled locally and remotely via a SCADA system.

The output of the generator will be connected to the Low Voltage LV/ 0.4 kV grid via an underground power cord to the unit's point of connection to the grid, within the unit's installation plot, as indicated by Hellenic LV Grid Operator HGO. At an appropriate point within the CHP compartment, it is foreseen to construct an inlet-outlet pair on the closed hot water circuit for possible future extension of the circuit in order any excess heat produced by the plant's operation to be used for the heating purposes of an adjacent to the plant greenhouse.

The substrates' mix inside the BDs, after staying there for at least 20 days and after degradation (i.e. as digestate), is pumped in a controlled manner by one displacement pump and inserted into one liquid-solid screw separator of compressed-filter type, in order to be separated into a liquid and a solid fraction. The liquid fraction is then deposited inside a Lagoon, sealed with respect to the soil, with a layer of HDPE material and a geotextile and covered by a multi-layered PVC-PE-EPDM film. The Lagoon will have of a total volume of 2,525 m^3. The liquid fraction form the Lagoon will be pumped through an outlet valve by container trucks which will subsequently deposit the Liquid fraction on crops adjacent to the plant's site for soil conditioning/fertilization purposes during appropriate fertilization periods. The solid fraction, after being dried in ambient conditions for three to four days, will be bagged and will also be available for fertilization in adjacent crops, also during periods suitable for fertilization.

The suggested Process and Instrumentation Diagram of the plant is depicted in the following paragraph 4.

4. Process & Instrumentation Diagram



5. Brief description of the plant's operation

The bio-waste (manures, whey, SHW, rotten potatoes' pulp and olive mill residues) will be collected from their production and disposal sites and transported by container trucks and/or simple trucks to the plant where they will be introduced into the reception tanks in order to be mixed through agitation and formulate the final substrates' mix for anaerobic digestion. The mix will then be pumped and transferred (via the displacement pumps) to the BDs in order the digestion process to take place, the biogas to be released from the respective biodegradation of the mix, the biogas to be collected and transferred to the CHP for combustion in the ICE and finally, electrical and thermal energy to be produced. The produced electricity will be injected to the LV/ 0.4 kV grid and the thermal energy will be partially used to heat the substrates' mix inside the BDs through the shell-type heat exchanger which will conduct the heat from the ICE's exhaust gases to the closed hot water circuit passing through the BDs. At the closed hot water circuit's return, the water, at a lower temperature than that when coming out of the shell-type heat exchanger, will pass through the plate-type heat exchanger where it will be pre-heated and simultaneously it will cool the ICE, before passing through the shell-type heat exchanger again and again rise its temperature from the exhaust gases of the ICE.

The exit mixture (Digestate) from the BDs will be pumped in a controlled manner and transported to the screw separator which will recover its solid fraction to be bagged, while the liquid fraction will pay off the Lagoon. The solid fraction bags will be picked up by trucks and the liquid fraction will be pumped and transported by tank containers, both in order to be deposited in adjacent crops during eligible fertilization periods.

The reception of the bio-waste streams of Table 1 will be carried out in two tanks (Reception Tanks). The first reception tank (Reception 1) will receive manures and SHWs, while the second (Reception 2) will receive whey, rotten potatoes' pulp and olive mill waste.

Reception tank 1 will be made of concrete, with basis also made from concrete and will have an indicative wall thickness of 150 mm. The reception tank 2 will be made of concrete with basis also made from concrete and again with a wall thickness of 150 mm or from stainless steel of thickness of 6 mm. Table 3 illustrates the weekly plant's supply schedule based on the annual reception quantities of the bio-waste streams (substrates), as well as the arrangement of the different substrates received between the two reception tanks.

Raw material per Reception tank	t/day of supply	days of supply/ week	Weeks of supply/ year
Reception tank 1			
Dairy cow slurry manure	6.27	3 to 4	52
Cow manure	5.91	3 to 4	52
Calf manure	0.51	3 to 4	52
Cattle manure	0.73	3 to 4	52
Poultry manure	0.32	2	52
Slaughterhouse waste - Intestine content	1.44	2	52
Slaughterhouse waste - Stomachs and fat	0.24	1	52
Slaughterhouse waste - Blood	0.35	1	52
Total	**15.78**		
Reception tank 2			
Cheese whey	1.78	3	52
Rotten potato pulp	1.00	4	8
Olive mill waste	2.37	4	8
Total	**5.15**		

Table 3. *Weekly supply schedule of the plant and substrates' arrangement per reception tank*

It is noted that due to the seasonality of potato production (April - May) and olive production (October - November), the corresponding bio-wastes will be supplied to the plant during 8 weeks over each year. The volume of reception tank 1 was calculated based on an average of eight days of availability without refill and was 95 m^3, while the volume of the reception tank 2 was calculated under the assumption for availability of 60 days of olive mill waste without refilling and was 65 m^3.

The substrates entering the reception tanks the shredders, will be introduced to the shredders in the presence of a water stream so that the final material to be pumpable. After each use, the shredder will be washed-out with water.

Agitation of the substrates in the reception tanks aims at homogenizing the mixture before being introduced into the BDs. The aim is to avoid high concentrations of one type of substrate in certain areas of the reception tanks and to best distribute the micro-organisms of the substrates throughout the mix. A successful agitation process results in a homogenized mix, which in turn when decomposed/ degradated into the BD is digested faster and to a greater extent than a non-homogenized mix. In addition, a well-homogenized mix provides the conditions for achieving a stable temperature field within the BD, which also contributes to a faster and more efficient degradation of the organic fraction. However, the mix's agitation should not be overly intense, as a large amount of forces exerted on the mix inhibit the biological activity of the microorganisms / bacteria in the mix. An optimum agitation time per reception tank per day is approximately 40 minutes.

The feed towards the BDs will be continuous and the substrates' mix from the reception tanks will be sumped, at the steady state of operation of the unit, at a rate of **9 tn/ day**. The rate of digestate sump from the BDs will be the same. After separation, the liquid fraction is deposited in the Lagoon and the solid fraction will be bagged after 3 to 4 days of drying under ambient conditions.

The mix will be fed to the BDs via a displacement-type pump per reception tank. A similar type of pump will sump digestate from the BDs towards the separator.

The substrates' mix will enter the air-tight, water-resistant BD's chamber. The BD's chamber space will be heated by a hot water closed circuit that will be heated respectively by the CHP unit's ICE's exhaust gases through a shell type heat exchanger.

In the steady state of operation of the unit, **the anaerobic digestion process will be thermophilic**. **The mix will remain in the digester for at least 20 days at ≥ 52 ° C inside the BD's chamber**. **The Hydraulic Retention Time (HRT) of the unit will be ≥ 20 days**.

From the previous AD process, the primary product is the biogas to be combusted in the ICE of the CHP. The total solids of the annual amount of the substrates' mix for anaerobic digestion is 13.35%, while its organic fraction or volatile solids content is 10.95%. Through the thermophilic anaerobic digestion process the organic fraction of the total solids of the bio-waste mixture is expected to be decomposed/ degraded at a percentage of 45% and according to the amount of each substrate introduced in the total annual mix for AD it **leads to the production of 159,949 m^3 of biogas per year**. Taking into account the percentage of methane contained in each substrate and the quantities of the substrates in the total annual mix to be digested, the annual methane content of the mix is 56.98%, which results in **91.139 m^3 of annual methane production**.

For the AD closed space, it is suggested to use "container-type" BDs, with an effective digestion volume of 60 m^3 each. The built-in piping in the BDs walls, floor and ceiling will be connected to the pipeline of the hot water closed circuit passing through the shell-type heat exchanger in contact with the CHP unit exhaust gases for the purpose of warming-up the substrates' mix inside the BDs.

The biogas produced from each bioreactor will be collected by natural flow in biogas depots (Balloons) which will be hermetically mounted, each on the roof-top of the respective BD. Each depot will be made from PVC, with an indicative volume of 36 m^3 each, with indicative biogas storage pressure capacity of up to 50 mbar. From the depots the biogas will be directed through a sloping pipe (within the ground) to the CHP unit after being purified and dehydrated. In order for the biogas to be used as a fuel in an ICE, its hydrogen sulfide content must be less than 700 ppm. Desulphurisation is carried out inside the biogas depots by biological oxidation caused by air blowing under concentration ranging from 2 to 8% on the collected biogas. This is achieved by adapting to each depot an air intake blower, called otherwise a "scrubber", with a blowing nozzle positioned relatively far from the biogas outlet point towards the ICE to avoid depressing the outlet pipe.

The moisture content of the biogas produced in the depots is 100%. In order to protect the ICE from corrosion, the biogas must be dehydrated. Partial dehudration is accomplished by cooling the biogas inside the pipelines during transport from the depot to the ICE. This occurs on the walls of the pipes where the water is condensed and eventually due to the slope of the pipes it is collected by a moisture trap placed at the lowest point. After dehydration, the biogas passes through a compressor so that after passing through a flow meter to be directed towards the inlet of the ICE of the CHP unit.

If more biogas is produced than can be introduced into the ICE for combustion (e.g. it may occur if the plant is shut down due to maintenance), the biogas is diverted to a controlled safety flare burning unit

(Flare). This is achieved by using a feedback system, where as long as the flow meter records a flow of more than 20 m^3/ hr, it then activates a signal circuit breaker and closes a pneumatic valve in front of the flow meter, while simultaneously opening a pneumatic valve in the branch to the safety Flare and thus the flow from the compressor is directed towards the torch of the Flare, which is also activated.

The biogas enters the ICE's inlet for combustion in order to convert the chemical energy contained therein into electrical, via the ICE-connected generator and thermal. For this purpose the biogas enters the combustion chamber of the ICE where it is mixed with ambient air and ignites. The combustion gases pass through the shell-type heat exchanger and are discharged into the atmosphere after being passed through a silencer to reduce noise. The nominal installed electrical power of the unit will be able to reach 54 kWel, while based on the proposed design in the steady state of operation of the unit, **the electric power output is adjusted to 40 kW_{el}**. Table 4 below presents the proposed main operational and technical characteristics of the plant's CHP unit.

CHP unit's technical characteristics (ICE+Generator)		
	Metric unit	**Value**
Electric Power	kW_{el}	40
Substrates' mix's biogas energy content	kW_{el}	103.42
Electrical efficiency[1]	%	33.46
Total efficiency[1]	%	82.84
ICE (Indicative model: MAN E0834 - E302)		
Thermal power (Exaust gas temp.: 120°C)	kW_{th}	45.67
MAX biogas consumption[2]	Nm^3/h	20.5
Thermal efficiency[1]	%	49.38
NO_X emissions	mg/Nm^3	< 500
Generator (Indicative model: Leroy Somer LSA 42.3)		
Power width	kVA	25 - 60
MAX efficiency	%	93,7
Output power	kW	40
Operational frequency	Hz	50
Operational voltage	V	400
Protection standard		IP 23
Rotational velocity	rpm	1,500
[1] *Safety margin set at 3,7%*		
[2] *Based on LHV at 6 kWh/Nm*^{3}		

Table 4. *Operational properties and technical characteristics of the CHP unit*

In the table above, the total available annual power from the substrates' mix is calculated on the basis of the average energy production capacity per cubic meter (m^3) of methane produced from the anaerobic digestion (see Table 4), which is c. 10 kWh / m^3. This calculation results in an annually **available biogas power from the substrates' mix anaerobic digestion of 103 kW**.

Assuming a yearly CHP unit's availability of 89% and assuming the unit operates at 40 kWel, taking into account the electrical and thermal efficiency levels and the generator's efficiency, the estimated annual electrical and thermal energy outputs is **311.996 kW_{el}/ year** and **356.216 kWh_{th}/ year** respectively.

6. Energy balance of the plant

The plant's own electricity consumption needs mainly relate to the needs for operating the unit's mechanical equipment at characteristic/ indicative time intervals per operating day based on its installed capacity. Table 5 gives the detailed daily energy balance of the unit.

No	Energy consumption	Quantity (Pcs)	Power (kW)	Working hours/ day	Energy/ day (kWh)
1	Shredder	2	11.19	1.75	19.57
2	Reception agitator	2	7.46	0.64	4.77
3	Biodigester agitator	3	11.19	7.25	81.09
4	Substrates' mix pump	3	4.47	1.75	7.83
5	Biogas Scrubber	1	0.09	24.00	2.16
6	Hot water circulation pump	1	0.71	8.00	5.68
7	Biogas blower	1	0.19	24.00	4.47
8	Separator	1	5.50	24.00	132.00
9	Biodigesters' thermal losses	1	6.89	24.00	165.33
10	Thermal energy for substrates' mix warming	1	18.38	24.00	441.00
Total:			**66.05**		**863.91**
	Energy production				
1	CHP (Electrical)		40.00	21.37	854.78
2	CHP (Thermal)		45.67	21.37	975.93
Total:			**85.67**		**1,830.72**
Balance:	**Positive**				**966.80**
1	Excess electrical energy				597.20
2	Excess thermal energy				369.61
Overall unit's efficiency:					
	(+) CHP electric energy production				854.78
	(+) CHP thermal energy production				975.93
	(-) Electric and thermal energy consumption				863.91
	Substrates' mix's biogas energy content		103.42	24.00	2,481.97
				Efficiency:	**38.95%**

Table 5. *Energy balance and overall plant's energy efficiency*

The total efficiency of the plant is **38.95%**, while the excess electricity is estimated at 70% of the total produced and the excess thermal energy is estimated at 38% of the total generated. From a construction point of view, on the closed hot water circuit inside the CHP unit's compartment an inlet/ outlet pair is foreseen to be constructed for the purpose of a future extension of the circuit in order to satisfy the heating needs of an adjacent to the plant's site greenhouse.

6. Mass balance of the plant and digestate management

From the BDs, the digestate is pumped uniformly via a displacement-type pump and is driven for separation in the screw separator. The detailed mass balance of the plant is shown in Table 6 below.

	Input			Output	
Raw material	t/year	oDM/VS (t/year)	Degradation of VS (%)	Biogas (t/year)	
Dairy cow slurry manure	1,254	100.31	40%	40.2	
Cow manure	1,183	94.60	40%	38.0	
Calf manure	102	20.45	51%	10.5	
Cattle manure	146	23.38	45%	10.5	
Poultry manure	33	10.00	60%	6.0	
Cheese whey	278	25.00	48%	11.9	
Rotten potato pulp	32	3.73	13%	0.5	
Olive mill waste	76	57.72	54%	31.3	
Slaughterhouse waste - Intestine content	150	18.87	62%	11.7	
Slaughterhouse waste - Stomachs and fat	13	2.29	51%	1.2	**Digestate (t/year)**
Slaughterhouse waste - Blood	18	3.17	44%	1.4	
Totals	**3,285**	**359.52**	**45%**	**164**	**3,121**

Table 6. *Plant's mass balance*

For the estimated annual quantities, the density of the substrates' mix was taken equal to 0.98 kg/ m^3 and that of biogas's was taken equal to 0.722 kg/ m^3.

From the digestate separation and according to the specifications of the UTS's Pressure Screw Filter Indicator Specifier (model FSP A-52/10), a solid fraction of approximately 30% of the annual digestate quantity entering the separator will be obtained. This fraction after having been dried in ambient conditions for three to four days and having been bagged it will be being picked up by crop growers for deposition over crops laying in the proximity of the site unit's site during the eligible fertilization periods.

The liquid fraction will be deposited into the Lagoon which will be sealed by a layer made of HDPE material and a layer of geotextile in relation to the soil, while it will be covered by a PVC-PE-EPDM laminate. Its shape and dimensioning have been determined in accordance with the provisions of Decision (GR) No 1420/82031-GG B 1709/ 17-8-2015 (Code of Good Agricultural Practice for the Protection of Water from Pollution of Agricultural Origin). In this way, its volume is calculated for the remaining of the digestate's liquid fraction in the Lagoon during a period of 5 months per year. Its shape is symmetric prismatic and a storage capacity of up to 1,520 m^3 of liquid fraction at a total depth of 6 m and a maximum fill height of 5 m. Its side walls have a slope based on a width to height ratio of 1 / 1.5 and its construction volume is 2,525 m^3. The liquid fraction will be being picked up by crop growers for deposition over crops laying in the proximity of the site unit's site during the eligible fertilization periods.

The following table shows the properties of the substrates that the plant receives in terms of their nutrient content (N, P, K) in kg per tonne of substrate and the total mass of nutrients in the digestate produced from the plant's operation per year.

Raw material	kg/t N	kg/t P	kg/t K	t/year N	t/year P	t/year K
Dairy cow slurry manure	3.5	1.7	6.3	4.2	2.1	7.6
Cow manure	3.5	1.7	6.3	4.0	1.9	7.2
Calf manure	3.5	1.7	6.3	0.3	0.2	0.6
Cattle manure	8.0	2.8	22.9	1.1	0.4	3.1
Poultry manure	18.4	14.3	13.5	0.5	0.4	0.4
Cheese whey	1.1	0.2	2.0	0.3	0.1	0.5
Rotten potato pulp	0.4	0.2	0.5	0.0	0.0	0.0
Olive mill waste	1.2	0.2	0.3	0.1	0.0	0.0
Slaughterhouse waste - Intestine content	4.6	1.1	1.1	0.6	0.2	0.2
Slaughterhouse waste - Stomachs and fat	1.6	1.1	1.0	0.0	0.0	0.0
Slaughterhouse waste - Blood	34.5	0.2	0.6	0.6	0.0	0.0
Totals	**3.8**	**1.7**	**6.3**	**11.8**	**5.2**	**19.6**

Table 7. *Plant's digestate's production nutrients content*

The annual operation of the plant will result in digestate's production containing 11,758 kg of Nitrogen. The quantities of nitrogen in the solid and liquid fraction of the digestate are listed in the following table.

Parameter (metric unit)	Value
Total quantity N (kg/year)	11,758
N in Liquid fraction (kg/year)	8,231
N in Solid fraction (kg/year)	3,527

Table 8. *Nitrate mass produced per year in the Liquid and Solid fraction of the digestate*

Given that the nitrogen load on annual crop fertilization should not exceed 17 kg per stremma, the minimum crop area that the produced digestate (wet and solid form) should be deposited is 692 stremmas (see table 9).

Parameter (metric units)	Value
Total quantity N (kg/year)	11,758
MAX deposition quantity of N (kg/stremma/year)	17
MIN deposition surface (stremma/year)	**692**

Table 9. *Calculation of the minimum deposition surface of the plant's produced digestate*

7. Plant's operational management and monitoring

The plant will operate 365 days per year excluding scheduled maintenance days. The plant will be staffed by three persons with the following profiles and responsibilities:

- 1 Lead Engineer with overall responsibility over the overall management/ supervision of operating and maintenance processes

- 1 Operator with responsibility for managing bio-waste reception and disposal of Digestate (liquid and solid fraction)

- 1 Technician responsible for the maintenance of the plant's electromechanical equipment

The operation of the plant will be automated with ability of remote monitoring and control through a SCADA system installed in the control room of the Technical container. The operating parameters of the plant to be recorded and monitored by the system on an continuous basis are as follows.

- Temperature of the BD's chambers from all digital thermometers installed on it
- Volume of biogas supplied at the inlet of the ICE
- Charging level of the BDs
- Generator output power
- CHP unit's operating hours

Controlled monitoring by the SCADA system will be provided for the operation of the following equipment of the plant.

- Substrates' mix/ digestate handling pumps
- Digestate's screw separator
- Closed hot water circuit's circulation pump
- Reception agitators
- BDs mixers
- Scrubbers
- Biogas blower
- All pneumatic valves controlling the circulation of the substrates' mix and biogas in the respective pipelines
- Especially the pneumatic valve diverting the biogas flow towards the safety Flare
- The sparkling torch of the safety Flare

In addition, the following parameters shall be physically checked, recorded and archived:

- Type and quantity of substrates during reception
- Specifically for SHWs, the certificates of the shift slaughterhouse veterinarian of the slaughterhouse supplying them. Those must be requested and reviewed upon reception and must necessarily accompany their transport and delivery to the plant. Otherwise the SHWs will not be received.
- The pH value (alkalinity) of the substrates' mix (daily)
- The composition of the produced biogas (daily)

- The content of the substrates’ mix in short-chained fatty acids
- The phenol content of the substrates’ mix during the supply period of olive mill waste
- Analyses will also be carried out on samples of the substrates’ mix and the produced digestate, in order to detect and record the content of substances/ elements as they are dictated by the applicable laws and at the frequency of checks as required by such laws.

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