Feasibility analysis for Biomethane production – SPAIN

Deliverable:	Guidance for feasibility analysis covering biomethane investment projects
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Version:	Final
Quality review:	Stefano Proietti (ISINNOVA)
Date:	11/10/2022
Dissemination level:	Public

Grant Agreement N°: 857796
Starting Date: 01-06-2019
Duration: 42 months

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Table of Contents

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1 The purpose of this document

This paper has been produced by the Spanish Biogas Association (AEBIG) under the Work Package 6 of the REGATRACE project (www.regatrace.eu). The Guidance for feasibility analysis covering biomethane investment projects is designed to assist project developers in realizing biomethane investment projects based upon the analysis of political, economic, technical, environmental, route to market (on or off grid), optimal scale and financial factors influencing the feasibility of the biomethane investment projects.

The document is based on a general guidance on European level and tailored with Spanish information.

This paper contains the cash flow calculations for an imaginary biomethane plant in Spain that treats olive mill waste and with imaginary numbers. The related numbers shown in the text and in tables have no practical meaning, they serve exclusively illustration purposes and must not be used as a reference in any case.

Currently there is a great problem related to the correct management of livestock and agri-food by-products in Spain, especially in relation to waste from oil production and manure. Thus, currently most of these by-products and residues are intended for direct use in agriculture within the provisions of Royal Decree 1310/90 of October 29, which regulates the use of sewage sludge. and in Law 7/2022, of April 8, on waste and contaminated soil, which establishes the operation of direct application on soil. This operation entails a series of problems on many occasions, such as health problems, odors, CH_4 emissions,

The main objective of this facility is the production of biomethane, a renewable gas similar to natural gas, and a stabilized material resulting from the anaerobic digestion process (digestate) whose direct application in the field does not cause the problems mentioned above. When the volatile organic compounds are converted into CH_4, bad odors are eliminated and through their partial sanitization, animal parasites, eggs and larvae, and weed seeds are eliminated. Therefore, the output product of the digestion process will be an improvement for the region's farmland compared to slurry, since it is stabilized matter with nutrients that are more easily digestible by plants.

This project is included within the framework of the circular economy. On the one hand, biomethane is generated, which is of renewable origin and negative in CO_2 emissions, from the purification of biogas, which is the most mature technology for producing renewable gas. On the other hand, the final product of the anaerobic digestion of the waste, which is known as digestate, is applied to the field due to its properties as a fertilizer and in this way, the circle is closed.

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Illustration1. Plant for the production of biomethane and digestate rich in nutrients. Example of a circular economy model

2 General data of the project

The project would consist of implementing an organic waste recovery plant based on the following technology:

- Biogas production by anaerobic digestion.
- Biogas enrichment which is subsequently purified by means of a membrane upgrading unit.

Biomethanization technology basically consists of subjecting organic waste to a controlled anaerobic digestion process. The main by-product of the biomethanation is the biogas, a combustible gas that has been removed carbon dioxide and other gases and pollutants that it might contain, such as N2, O2, H2S or VOCs, so the percentage of methane is increased above 96%, so that it meets the natural gas quality standards. The biomethane generated is injected into the natural gas distribution network.

Other product of the biomethanation is the digestate, which will be subjected to a separation of its solid and liquid fractions. The solid fraction will be distributed as high-quality organic

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amendment. The liquid fraction will be acidified and stored in a raft for agricultural application on the nearby farmland.

The biogas plant described in this report involves a series of improvements, so much environmental as well as socio-economic:

- Management and purification of organic waste.
- Reduction of greenhouse gas emissions.
- Production of thermal energy from renewable sources.
- Production of thermal energy from heat recovery from biogas compression and cooling processes.
- Production of digestate with better fertilizing properties than by-products of origin, alperujo (olive mill waste), slurry and manure.

3 Core elements of a Feasibility study

3.1 Technical feasibility

The first element deals with technical feasibility of the proposed investment, the technical feasibility study will determine if it's a technically viable action.
This part of the feasibility study should answer – for example – the following questions:

- *What raw materials (substrates) are available at what conditions for the anaerobic digestion unit?*
- *Sustainability of agri-feedstock substrate?*
- *What is the most appropriate technology to process the raw materials (yields, material balances, etc.)?*
- *What will be the volumes and characteristics of the main product (biomethane) and the by-products (digestate, carbon dioxide, etc)?*
- *What are the regulatory standards surrounding the main product, the by-products, and their use?*
- *What investments are needed for realising the production?*
- *How will the energy consumption of the facility be covered (energy balances, etc.)?*
- *What are the technical conditions for grid connection?*
- *What are the considerations and conditions for the site selection?*
    - *Environmental and urban protection regulations*
    - *Animal by-products regulation*
    - *Electrical regulations*
    - *Additional Industry Regulation*
    - *Health and safety regulations*
    - *Construction Regulations/Structures*
- *What are the technological considerations?*
    - *Justification of the technology adopted*
    - *Anaerobic digestion technology and alternatives*
    - *Biogas combustion technology in boiler and alternatives*
    - *Summary of technologies and alternatives contemplated*
    - *Material balances*

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  - *European List of Waste Codes input waste*
  - *Input materials in the installation*
  - *Output products in the installation*

The above questions can be used both in case of transforming an existing biogas plant to a biomethane producing facility and in case of a new, green-field investment.

3.2 Market feasibility

The second element focuses on understanding the market environment for the proposed investment. It examines issues like whether the main product (biomethane) and the by-products can be placed on the market at reasonable prices or if there is a marketplace for them at all. Regarding renewable energy projects (among them biomethane investment projects) the available national support schemes are of crucial importance.
Market feasibility should answer – for example – the following questions:

- *What market segments are targeted (transport fuel, heating, industry)?*
- *Who are the potential customers and how many of them are there?*
- *How will biomethane and the by-products be sold?*
- *What are the available support schemes and what are the conditions for participating?*
- *Duration of the agreements for sale of biomethane*
- *Are there realistic export possibilities?*
- *What are the prices and conditions for external energy supplies?*
- *What are the costs of raw material supplies, is there a competition for raw materials?*

Market feasibility is a very important part of a feasibility study when an investment into new production is planned.

3.3 Commercial feasibility

Commercial feasibility is an element of the study focused on the probability of commercial (economic) success. It is mainly focused on studying whether the planned investment can be financed and whether it can generate enough income and profit.

The questions that require answering as part of the commercial feasibility study include, for example:

- *What are the potential sales volumes in different segments?*
- *What is the pricing structure applicable on the market?*
- *How far is the feasibility dependent on state aid (financial support)?*
- *What are the sensitivity points for the business in terms of revenues?*
- *What are the expected financial indicators of the investment project (IRR, NPV, PI, DSCR)?*
- *How much own funds are required to realise the investment and start operating?*
- *What are the conditions for securing external finance?*

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3.4 Overall risk assessment

The fourth element focuses on the major risks the proposed investment plan can entail. The overall risk assessment part of a feasibility study examines the different ways the project company (the investor) can reduce the risk of embarking on the new venture.

The overall risk assessment should answer the following questions:

- *What are the major risks associated with the operation?*
- *What is the survival outlook for each of the above risks?*
- *Merits of a National co-ordination and design authority to support ongoing and continuous improvements to AD biomethane developers, market exploitation, new products/innovative technology research, management support services?*
- *How sensitive are the profits?*
- *What are the best ways to minimize these risks?*

The aim is to try to cover all the possibilities and create a risk assessment map, which deals with the probability of the risk and the impact it would have on the project. It's aimed at recognizing the risks that can make or break the project from the smaller, more manageable risks.

4 Key factors for successful project development

The different (political, technical and financial) factors influencing the feasibility of biomethane production are addressed in several chapters of this paper. Here we place only a short summary to assist the reader on focusing on the main issues.

- Bridging the funding gap between the prevailing natural gas prices and the costs of biomethane production is the biggest challenge for every biomethane project. Measures can and should be taken to lower the costs of investment and operation as much as possible, but the business plans must not assume that achieving natural gas parity is only a question of time. The biomethane projects remain dependent on political support **stable, long-term political commitment** towards renewable energy deployment and – specifically – towards utilisation of biodegradable feedstock for biogas/biomethane production.
- Among the operational costs of biomethane production the **costs of raw material supplies** have a decisive importance. The project developers must assess the present and future biodegradable [raw] material supply possibilities very carefully and should elaborate alternative plans to handle any disruption. If possible, it is advisable, that the owners of raw materials (for example agricultural producers, food/beverage industry or waste management companies) are involved in the biogas/biomethane projects as shareholders – to secure their long-term interest in backing-up the venture, under pinned by off take agreement for biomethane.

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- Project developers should never assume that the raw material supply patterns remain unchanged through the 15-20-25 years lifetime of the project. It is strongly advisable to install **technologies** which have the needed flexibility to adjust to changes in raw material composition. Under these considerations the basic engineering plan of the facility must foresee place/connections for adding equipment in the future, detail design preconstruction.
- In any case, **locations** offering guaranteed long-term sustainable substrate supplies must be preferred. The best chances are on places where the feedstock is co-located with infrastructure, deep integration to respective agricultural or industrial activities is possible (for example: co-location of animal slurries/manures, sugar factories, breweries, etc.). The distance to an existing gas grid must be carefully evaluated.
- Organic **waste streams** (collected source separated) offer good possibilities for installing biogas/biomethane facilities but only if the future competition with other biogas/biomethane plants for the material can be avoided [excluded]. (The experience shows that the gate fees paid by organic waste owners tend to decrease and even disappear with the increasing number of biogas plants in the region.)
- Mature and efficient anaerobic digestion and biogas upgrading technologies are available from several technology suppliers. There is a strong competition among these companies today which puts investors in good negotiating position. With selection of **proven and reliable technology** future operational difficulties can be avoided. It happens quite often that the investors focus too much on the purchase price and do not consider other important elements, like the performance guarantees and operational support services offered by the supplier(s). These should be negotiated as part of the initial package and where possible consider "Clustering of AD plants" in negotiating Capex and O&M contracts.
- The **long-term placement [biomethane purchase agreement – BPA]** of produced biomethane must be secured from the start in view of underpinning the project, the existing political priorities, and financial incentives. From this viewpoint regions with developed CNG-LNG fuelled transportation are especially attractive. Long-term supply agreements with companies distributing gas for heating can also serve as a solid base for an i
- Investment decision. A successful and bankable BPA can be secured either thanks to a feed-in-tariff or feed-in-premium systems, or a biofuels quota system where obligated parties have an incentive to commit purchasing biomethane long-term avoiding paying penalties.
- The **placement of the fermentation residue [digestate or bio fertilisers]** from the anaerobic digestion is a key issue of any successful biomethane project. As a function of local agricultural conditions, digestate can be a revenue although minimal, or a cost to the biomethane plant, depending on the value of organic fertiliser, the possible contaminants to be eliminated, possible local excess of

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nitrogen in the soil etc. The residue is usually separated into a solid and a liquid fraction. The solid fraction can be used as organic fertiliser and – as such may even have a market value. The liquid fraction causes no problem if sufficient cultivated arable land is available in the vicinity of the biogas plant for spreading it on the fields or further processed as a bio active/stimulant. In absence of such possibility the liquid fraction needs to be processed, i.e., cleaned to a status accepted for letting it out into the nature. Such treatment of the fermentation residue triggers extra investment and operational costs, which may have a negative impact (5-10€/t) on the feasibility of the venture.

- The **liquefaction of biomethane** can prove to be an interesting alternative, either because the gas grid connection is too costly/too weak to offtake the gas, or because the off takers are ready to pay a premium for bio-LNG which is the form of biomethane offering best storage options for maritime & heavy trucking. This deserves to be studied for plants above 500 Nm^3/h to afford the significant extra capex/opex which amounts to 10-15€/MWh.
- **Good communication to local stakeholders** is key to prevent NIMBY issues, especially in densely populated areas. Studying and communicating the positive impacts of the biomethane plant is relevant herein, such as job creation, economic value creation in rural territories, chemical fertilisers avoided, waste treated etc. Furthermore, transparent communication about odour and traffic control is advisable.

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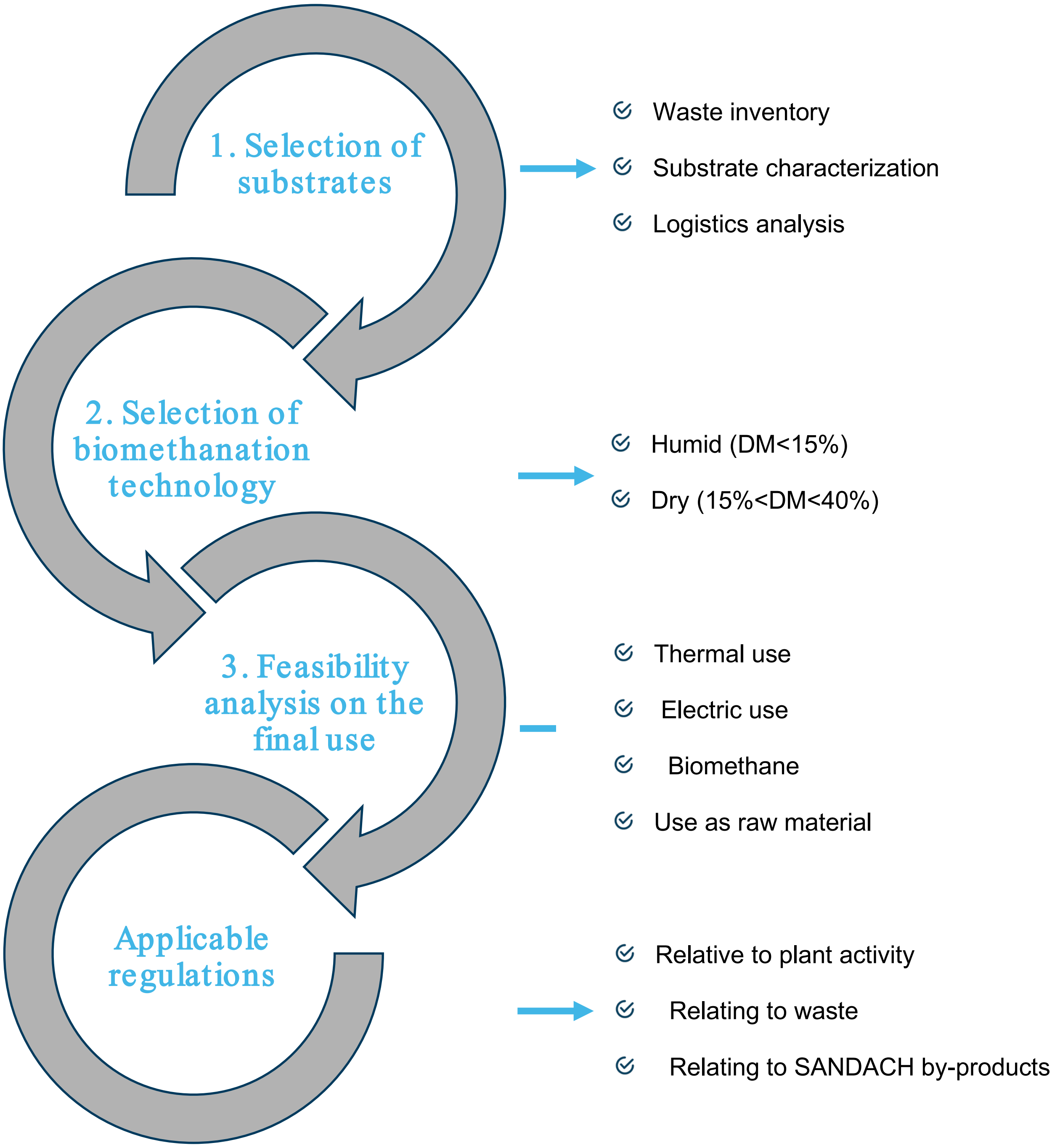
5 Roadmap for the evaluation of biogas projects



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5.1 Selection of waste

The main objective of the biomethane and digestate production plant is to value livestock by-products, alperujo and some glycerin generated in a possible project in Spain.

In relation to the origin of the substrates, these will be of local origin, to minimize logistics and transport needs.

Below is the list of the ELW codes of the waste that is expected to be used in the biomethane plant, according to the European List of Wastes (ELW):

The ELW codes that would be managed within the facility are those of the by-products and non-hazardous organic waste that are treated in other biomethane facilities and that the promoter therefore requests. These residues are included in the list of biodegradable organic waste collected in Annex IV of RD 506/2013, on fertilizer products.

ELW	DESCRIPTION	SPECIFICATIONS
02 01	Waste from agriculture, horticulture, aquaculture, forestry, hunting and fishing	
02 01 03	Vegetable tissue waste	
02 01 06	Animal faeces, urine and manure (including rotten straw) and effluents collected separately and treated off-site	
02 01 07	Forestry residues	Biomass
02 03	Waste from the preparation and processing of fruits, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco; canning production; production of yeast and yeast extract, preparation and fermentation of molasses.	
020303	Solvent extraction residues.	Orujillo: Solid residue from extractors that use chemical methods to obtain pomace oil; It is made up of all the organic residue (stone, pulp and skin) and solvent residues.

Table 1. List of waste codes employed in the project

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The management of this type of waste at the biomethane plant allows for an increase in the production of biogas, thereby increasing the production of biomethane, and in turn gives added value to its management, since products that are currently applied directly to the field are recovered. converting waste into a source of renewable energy and digestate with high added value.

Specifically, the biomethane plant is designed to manage 36,500 t/a, which is equivalent to a maximum of 100 t/d.

5.1.1 Waste inventory

The Project I know situate in the town of Extremadura, that this lying in the Southwest of the Peninsula Iberian, a scarce kilometer of the border with Portugal. This city is belonging at the Province of Badajoz, in the Community autonomous of Estremadura.

The matter organic available for the generation of biomethane it is:

- Alperujo: 27,374 Tons/year. The reception I know will perform it length of two months, Y I know will store in the facility
- Slurry: 9,125 Tons/year
- Glycerin: 1,130 Tons/year

5.1.2 Characterization of the substrates

ALPERUJO

ALPERUJO					
	Base	**Sample_1**	**Sample_2**	**Sample_3**	**avg**
Humidity (%)	wet	78.4	74.1	77.5	76.67
ashes (%)	dry	6.9	7.3	7.2	7.13
vs. (%)	dry	76.9	77.6	77.2	77.23
qw gr (MJ/kg)	dry	22.9	23.5	22.2	22.87
Q.p. net (MJ/kg)	wet	2.7	3.9	2.8	3.13
	dry	21.3	21.9	20.7	21.3
Coal (%)	wet	50.93	52.13	49.8	50.95
	dry	53.11	54.32	52.14	53.19
nitrogen (%)	wet	2.21	1.89	1.77	1.96
	dry		1.97	1.85	2.04
hydrogen (%)	wet	6.97	7.13	6.69	6.93
	dry	7.27	7.43	7	7.23
chlorine (%)	wet	0.33	0.36	0.35	0.35
	dry	0.34	0.38	0.37	0.36
Sulfur (%)	wet	0.02	0.02	0.02	0.02
	dry	0.02	0.02	0.02	0.02

Table 2. Alperujo analytics

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GLYCERIN

GLYCERIN	
Water	55.90%
Glycerin	35.20%
impurities	1.90%
Na2SO4	0.00%
NaCl	6.90%
NaPTS	0.00%
Na2HPO4	0.10%

Table 3. Glycerin analytics

5.1.2.1 Co-digestion of substrates

Co-digestion is the joint anaerobic digestion of two or more substrates of different nature. There are biodegradable wastes, which have a relatively low biogas production potential due to their low content of organic matter or poor biodegradability. That is why this technique is used to combine various mixtures of biodegradable organic substrates, increasing the potential for biogas production and providing additional stability to the system.

The anaerobic digestion of alperujo is a well-studied process, observing how inhibitory substances such as phenols can limit methane production.

The lignocellulosic structure of the residue does not help.

- Anaerobic co-digestion of two or more substrates is a well-tested option, for:
- Balance the C/N ratio
- Dilute the concentration of inhibitory substances in the reactor
- Improves the hydrolytic activity of bacteria.

The total biogas production expected is as follows:

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Initial substrates for digestion	Tons (t/year)	MS	volatile	Biogas (Nm3 / t SV)	Nm3/year
Alperujo (olive waste)	25.000	28%	92%	600	3.864.000
pork slurry	12.000	4%	90%	450	194.400
Glycerin	3.000	50%	90%	900	1.215.000
Cow dung	2.000	22%	85%	400	149.600
chicken manure	5.000	30%	90%	550	742.500
Digestate liquid fraction	12.000	2%	90%	200	43.200
Hourly production of biogas (Nm3/h)	642,5				
% CH4 Biogas	59,0%				

Table 4. Expected biogas production

5.1.3 Logistics analysis

The substrates are generated in a radius of 10 km around the biogas plant. Logistics is acceptable.

5.2 Selection of Biomethanization technologies

It is planned to provide this facility with the following infrastructures:

- Vehicle weighing scale with its disinfection bow
- Control container and offices in which the hygiene and well-being infrastructures of the workers will also be located, dimensioned in accordance with the provisions of RD 486/1997, of April 14, which establishes the minimum safety and health provisions in workplaces and in the DB-SUA instruction (Safety in use and accessibility) of the Technical Building Code.
- Transformer.
- Upgrading Unit for the purification of biogas to biomethane
- Equipment for feeding solid and liquid substrates to the digesters.
- Reception tanks for liquid waste and accumulation of rainwater and intermediate products: The facility will be equipped with the following tanks and capacities for use in the reception and storage of liquids:

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- 1 underground tank with a net volume of 178 m3
- 1 tank of 100 m3 capacity, for glycerin
- 2 tanks with a capacity of 100 m3 for clean rainwater, which will be used as process water and contact rainwater,
- Biomass boiler for heat production in a 20-foot sea container
- A CSRT thermophilic digester18 meters in diameter and 8 meters high.
- Two CSRT mesophilic digesters, wet-based configured as cylinders 24 m in diameter and 8 meters high. Both the thermophilic and mesophilic digesters will be finished off at the top by means of a plastic and elastic element, called a gas holder, which will be in charge of retaining the biogas for its subsequent capture, purification and distribution in the gas network.
- Screw separator for digestate
- An alperujo reception pool in concrete with ramp for access of a manitou or similar.

5.2.1 Other technical aspects of the digestion

The anaerobic digestion is carried out in a circular tank that is fed with the same organic load. The first reaction, which is hydrolysis, is carried out in a thermophilic digester with a working temperature range between 52-55ºC in order to facilitate the digestibility of phenols by methanogenic bacteria. The rest of the reactions are carried out in two mesophilic digesters with a temperature range between 37-40ºC.

The minimum retention time of the substrates inside the digester must be greater than the time necessary for the methanogenic bacteria to develop and carry out methanogenesis and ranges between 40, 35 and 60 days under constant conditions (absence of O2) in depending on the type of substrate. Due to the large amount of water carried by the substrates, a large volume of digester is necessary to ensure the minimum retention time of 35 days in the event that the digester is fed with another substrate that requires more time, such as the straw contained in the manure. Another influential parameter in the sizing of the plant and in the preparation of the feed diet of the biogas plant is the concentration of ammoniacal nitrogen inside the digester. It is very important that the Carbon/Nitrogen ratio is within the interval [20:1, 30:1].

The net volume of the mesophilic digester is 3,257 m3 and the thermophilic one is 1,832m3. A configuration of a primary digester (thermophile) and two secondary digesters (mesophile) is established.

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Both the floor and the wall are made of sulfur-resistant reinforced concrete HA-35/P/20/IV+Qc and the roof is a semi-permeable membrane to gas, to store the biogas generated, while preventing the entry of oxygen into the system.

A polyethylene sheet with a protective coating of epoxy-based paint is installed in the area in contact with the gas (which corresponds to the interior wall of the digester and central column, and the finishing of the concrete walls).

The internal diameter of the mesophilic digester is 24 m and the external diameter is 24,4 m, the height of the wall is 8 m and the maximum filling level is 7,2 m, leaving 0,8 m of free upper level.

The internal diameter of the mesophilic digester is 18 m and the external diameter is 18,4 m, the height of the wall is 8 m and the maximum filling level is 7,2 m, leaving 0,8 m of free upper level.

5.2.2 Upgrading of biogas

The biogas enrichment system has been proposed to treat a flow rate of up to 800 Nm3/h of biogas. For this maximum biogas flow, around 500 Nm3/h of biomethane and 300 Nm3/h of off-gas would be generated. The proposed membrane system is a three-stage membrane system for the enrichment of biogas to biomethane. It consists of the following equipment:

- Compressor

The screw compressor is a positive displacement design, twin shaft rotary piston machine that operates on internal compression. The biogas is compressed inside the smaller and smaller chambers and is finally discharged into the pipe connected to the outlet flange of the compressor.

The biogas compressor is fully assembled, with automatic drains, oil cooler, pre-gas and after-cooler, instrumentation, controls, safety and relief valves.

An oil separator installed after the compressor is also included. The bearings and rotors are lubricated by means of injection passages of optimal dimensions and with an oil pressure that depends on the discharge pressure; this eliminates the need for an oil pump. The amount of injected oil is controlled by temperature in such a way as to ensure that the final compression temperature is adjusted to the required specification.

- Ugrading

The biogas will be enriched in a biomethane upgrading unit. The separation technology will be that of membranes. Gas separation membranes are often successfully used in industry for gas separation such as hydrogen purification, nitrogen production, removal of carbon dioxide, moisture and other substances.

Gas separation is based on the difference in the permeability of molecules of different sizes through the membrane. The size of the molecules, the pressure difference between the inlet and the permeate side, as well as the gas temperature, are the main driving forces for gas separation.

The methane and carbon dioxide in the feed biogas must be separated in such a way that the product gas has a higher methane content, which is equivalent to natural gas, i.e., the Wobbe Index of the product gas must meet the tolerances of the local gas network.

For the realization of CO_2 removal, the separation properties of the membranes are specially designed for biogas applications.

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Membrane biogas enrichment units can produce high-yield biomethane, with a recovery of over 99.5% and losses of less than 0.5%. Furthermore, they have low maintenance costs, no chemicals are required to clean the biogas and methane losses are minimized.

Illustration2. Membrane upgrading unit

5.2.3 Storage of biogas

This biogas plant will be equipped with three gasholders, 500 Nm3 in the therophillic digester and 1.000 Nm3 in each of the mesophilic digesters.

5.2.4 Minimizing gas leakages

Due to the economic, safety and environmental significance of methane losses, biomethane plants need to be designed, planned, built, and operated considering the minimization of methane losses. These are the technical and organization measures to reduce the emissions in this project:

Technical mitigation measures:

- Gas-tight covering thanks, e.g., storing or mixing tanks.
- Installing an exhaust gas treatment (RTO)

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- Right dimensioning of biogas pipes
- Regular replacement of aged gas holder membranes

Organizational mitigation measures:

- Perform leakage tests before operation and instalment of regular leak detection thereafter.
- Emission measurements after the renewal of plant components
- Gas holder filling level preferably at 50%
- Regular maintenance of openings
- Adjustment of substrate feeding regime before planned maintenance.
- Sufficient aeration during post-treatment
- Analysis of residual gas potential in the digestate.

5.2.5 Material balances

The following indicates the consumption of **waste intended for anaerobic digestion**:

Annual input of substrate	Quantity [y/y]	Quantity [t/d] [1]	ST [%]	SV [%]
Alperujo	24,366	66.8	24.6%	93.9%
Pig slurry	2,997	8.2	5.0%	78.0%
Glycerin	4,159	11.4	44.1%	80.0%
Cow manure	796	2.2	25.0%	80.0%
Chicken manure	3,961	10.9	43.4%	71.7%
TOTAL	**36,500**	**99**	**27%**	**87%**

Table 5. Input substrates in the AEBIG project for biomethane production. ST: Total solids (ST= 100%-% Moisture); SV: Volatile solids

[1] For the calculation, the waste captured in the safety screening that is collected in the previous roughing to which the waste is subjected once unloaded in its storage units has been discounted. Annually, it is estimated that 221 t (stones, containers, iron bars, etc.) of the 36,500 t of substrate input will not reach the digesters as they will be trapped by the roughing grids or manually by the operators.

Supply and treatment systems.

The trucks are unloaded in the material reception and process feeding areas set up for this purpose, from where they will be supplied to the previously described anaerobic digestion treatment line. The waste will be unloaded in the unloading area set up for this purpose and stored under the conditions described above.

In addition, it is necessary to count as raw material the **biomass intended for combustion in boiler** which will add up to a total of **427 t/y**.

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5.2.6 Energy supplies

The processes where thermal energy will be required are:

- Heating of substrates from room temperature toinlet temperature to the thermophilic digester (55ºC). A daily input stream of substrates of 133 t is required to be heated.
- Temperature maintenance inside the thermophilic digester.
- Temperature maintenance inside mesophilic digesters. Except for the coldest months, during the rest of the year, these digesters will need to be cooled rather than heated.

From the upgrading unit it is possible to recover the electrical energy consumed in the biogas compression and cooling process in the form of hot water, which adds up to 1,261,000 kW/a of thermal energy to be used in the anaerobic digestion process.

The following table specifies the thermal consumption for each of the processes:

overall heat consumption	°C	thermal e. (kWh/a)
Substrate heating	55	2.466.227
Thermophilic digester temperature maintenance	55	334.599
Mesophilic digester temperature maintenance	40	87.139
Safety coefficient (5%)	40	144.398
TOTAL		3.032.364
Upgrading recovery		-1.261.002
TOTAL THERMAL ENERGY REQUIRED		**1.771.361**

Table 6. Heat required by the installation

Therefore, the annual thermal energy required by the installation will be approximately 1.771 MW.

To size the biomass boiler that will provide the heat required for the anaerobic digestion process, the following scenario has been taken into account.

The recovery of heat from upgrading has not been taken into account in order to have sufficient power in the most unfavorable scenario.

The most unfavorable months are considered, when the inlet temperature of the substrates is around 2ºC.

Taking into account the above assumptions and the annual thermal energy required, it follows that the boiler must be sized for a minimum power of 255 kW. The boiler is oversized to foresee the most adverse scenario, when heat recovery from upgrading is not available. One will be selected biomass hot water boiler as fuel with an average consumption of 63 kg/h.

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The electrical energy consumed by the installation is summarized in the following table:

Equipment	You	PN/pc. (kW)	PN(kW)	render	Pabs, max. (kW)	H worked.	Electric power (kwh/a)
WASTE RECEPTION AND TREATMENT							
PRFV deposit	1	4	4	0,8	3,2	876	2.803
Reception hopper (2 mixers)	1	15	15	0.8	40	325	13.000
online shredder	1	4,5	5,85	0,8	4,68	325	1.521
mixing pump	1	18	18	0,8	14,4	1.095	15.768
Endless screw (alperujo)	1	4	4	0,8	3.2	1.095	3.504
feed pump	2	9,5	19	0,8	15,2	650	9.880
Buried tank (agitator + pump + macerator)	1	27,5	27,5	0,8	22	730	16.060
ANAEROBIC DIGESTION				0,8			
mesophilic digester	2	93,2	186,4	0,8	149,12	2.190	326.573
Agitation	3	15		0,8			
Fan	2	0.8		0,8			
thermophilic digester	1	63,2	63,2	0,8	50,56	2.190	110.726
Agitation	2	15		0,8			
Fan	2	0,8		0,8			
Air compressor for desulfurization	3	0,6	1,8	0,8	1,44	1	two
screw dehydrator	1	4	4	0,8	3,2	876	2.803
Torch	1	11	11	0,8	8,8	263	2.314
center pump	2	11	22	0,8	17,6	730	12.848
Feed pumps (dehydrator, pond)	2	1,5	3	0,8	2,4	876	2.102
upgrade unit	1	310	310	0,7	217	8.497	1.843.849
COMMON ELEMENTS							
hot water boiler	1	2,5	2,5	0,8	two	8.000	16.000
Weighing machine	1	0,37	0,37	0,8	0,296	2.000	592
External lighting force panel	1	8	8	0,8	6.4	3,650	23,360
Office container strength box	1	7	7	0,8	5,6	5.840	32.704
bilge pumps	2	1	2	0,8	1,6	1.000	1.600
Pressure group (potable and process water)	2	7,5	15	0,8	12	1.000	12.000
Air under presure	1	5	5	0,8	4	3.000	12.000

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Equipment	You	PN/pc. (kW)	PN(kW)	render	Pabs, max. (kW)	H worked.	Electric power (kwh/a)
TOTAL INSTALLATION			770		585	2.055	2.462.010

Table 7. Installed power of the main equipment of the biogas plant.

- P installed: Rated power of electrical equipment, according to manufacturer. In the case of motors, mechanical power.
- P abs nom: Power absorbed by the equipment, nominal, average.
- Yield: Equipment performance, which is related to electrical power.
- * The operating hours of the biogas plant is an average of the operating hours of all equipment.
- The annual energy consumed by the entire installation will be approx. 2.462.010 kWh/a.

5.3 Feasibility analysis on end use:

On May 20, 2021, the Climate Change and Energy Transition Law was published to achieve emission neutrality by 2050 at the latest. An article is dedicated to the promotion of renewable gases in this law. Annual objectives are established for the sale or consumption of natural gas, a certification system and a regulation that favors injection into the network.

As a result of the commitment to replace natural gas with renewable gas at a state and European level, its enrichment to biomethane for subsequent injection into the natural gas network is chosen as the application of biogas.

Alternatives to the process of enrichment and injection into the natural gas network:

Regarding the uses of biogas, there are different alternatives such as combustion in a cogeneration engine to produce electricity and heat or in a boiler to generate heat. These alternatives are ruled out as there are no processes near the installation that consume thermal energy. In addition, the option of electricity generation to feed into the network is not contemplated since with RD 1/2012, of January 27, the procedures for pre-allocation of remuneration and the suppression of economic incentives for new electrical energy production facilities from cogeneration, renewable energy sources and waste stored at high pressure, between 200 and 250 bar in cylinders.

5.4 Applicable regulations

5.4.1 Environmental and urban protection regulations

- Law 7/2022, of April 8, on waste and contaminated soil for a circular economy

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- Royal Legislative Decree 1/2016, of December 16, approving the revised text of the Law on Integrated Pollution Prevention and Control
- Royal Decree 815/2013, of October 18, which approves the Regulation on industrial emissions and development of Law 16/2002, of July 1, on integrated pollution prevention and control
- Law 21/2013, of December 9, on environmental assessment
- Law 9/2018, of December 5, which modifies Law 21/2013, of December 9, on environmental assessment, Law 21/2015, of July 20, which modifies Law 43/ 2003, of November 21, on Forestry and Law 1/2005, of March 9, which regulates the trading system for greenhouse gas emission rights.
- Law 11/2014, of July 3, which modifies Law 26/2007, of October 23, on environmental responsibility
- ROYAL DECREE 952/1997, of June 20, which modifies the Regulation for the execution of Law 20/1986, of May 14, Basic of Toxic and Hazardous Waste, approved by Royal Decree 833/1988, of 20 of July.
- Law 34/2007, of November 15, on air quality and protection of the atmosphere.
- Royal Decree 100/2011, of January 28, which updates the catalogue of potentially polluting activities of the atmosphere and establishes the basic provisions for its application.
- Royal Decree 102/2011, of January 28, regarding the improvement of air quality.
- Law 37/2003, of November 17, on Noise, for acoustic emissions
- Royal Decree 1513/2005, of December 16, which develops Law 37/2003, of November 17, on Noise, in relation to the evaluation and management of environmental noise.
- Royal Decree 286/2006, of March 10, on the protection of the health and safety of workers against risks related to exposure to noise.
- Royal Legislative Decree 1/2001, of July 20, approving the consolidated text of the Water Law.

5.4.2 Urban regulations

- Royal Decree 1812/1994, of September 2, approving the General Highway Regulations and subsequent amendments.
- Royal Legislative Decree 7/2015, of October 30, which approves the revised text of the Law on Land and Urban Rehabilitation.

5.4.3 Animal by-products regulations

- REGULATION (EC) No 1069/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing the health standards applicable to animal by-products and derived products not intended for human consumption and repealing the Regulation (CE) no 1774/2002 (Regulation on animal by-products).
- COMMISSION REGULATION (EU) No. 142/2011 of 25 February 2011 establishing the provisions for the application of Regulation (EC) No. 1069/2009

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of the European Parliament and of the Council establishing health standards applicable to animal by-products and derived products not intended for human consumption, and Council Directive 97/78/EC as regards certain samples and units exempted from veterinary border controls under the same

- RD 1528/2012, of November 8, which establishes the rules applicable to animal by-products and derived products not intended for human consumption.
- RD 894/2013, of November 15, which modifies RD 1528/2012, of November 8, which establishes the rules applicable to animal by-products and derived products not intended for human consumption.

5.4.4 Electrical regulations

- Royal Decree 337/2014, of May 9, which approves the Regulation on technical conditions and safety guarantees in high-voltage electrical installations and its Complementary Technical Instructions ITC-RAT 01 to 23.
- Royal Decree 842/2002, of August 2, which approves the Electrotechnical Regulation for low voltage.

5.4.5 Biomethane regulations

- Resolution of October 8, 2018, of the General Directorate of Energy Policy and Mines, which modifies the technical management standards of the NGTS-06, NGTS-07 system and the detailed protocols PD-01 and PD-02.
- Resolution of December 21, 2012, of the General Directorate of Energy Policy and Mines, which modifies the detailed protocol PD-01 "Measurement, Quality and Odorization of Gas" of the technical management standards of the gas system.
- Royal Decree 1434/2002, of December 27, which regulates the activities of transportation, distribution, marketing, supply and authorization procedures for natural gas facilities.
- Royal Decree 984/2015, of October 30, which regulates the organized gas market and third-party access to natural gas system facilities.
- Royal Decree 949/2001, of August 3, which regulates third party access to gas installations and establishes an integrated economic system for the natural gas sector.
- UNE-EN 16726 Gas infrastructure. Gas quality. H group
- EN 16723-1: Biomethane for injection into natural gas networks.

5.4.6 Additional industry regulations

- Royal Decree 144/2016, of April 8, which establishes the essential health and safety requirements for devices and protection systems for use in potentially explosive atmospheres
- UNE-EN 60079-10-1:2016. Site classification. Gaseous explosive atmospheres.
- Royal Decree 681/2003, of June 12, on the protection of the health and safety of workers exposed to the risks derived from explosive atmospheres in the workplace

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- Royal Decree 2267/2004, of December 3, approving the Fire Safety Regulations in industrial establishments.
- Royal Decree 2060/2008, of December 12, which approves the Regulation of pressure equipment and its complementary technical instructions.
- Royal Decree 105/2010, of February 5, which modifies certain aspects of the regulation of the storage of chemical products
- Royal Decree 656/2017, of June 23, which approves the Chemical Products Storage Regulation and its Complementary Technical Instructions MIE APQ 0 to 10.

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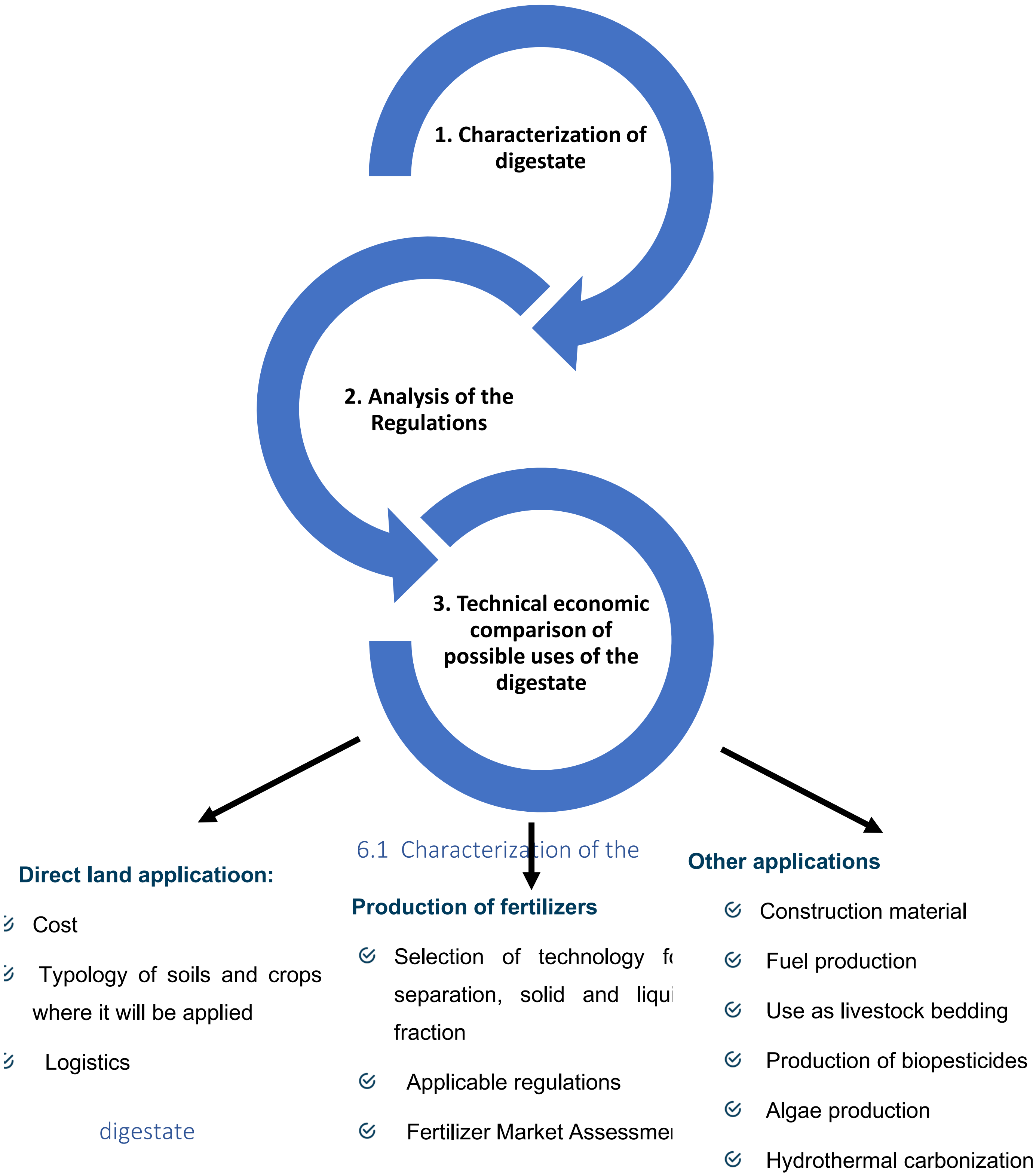
6 Roadmap for the evaluation of digestate handling



6.1 Characterization of the digestate

In total, 42,914 t/y of
digestate with 11.3% TS (117.6 t/d) are obtained. The digestate

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undergoes a primary S/L separation using a screw dehydrator. The solid fraction, a total of 18,742 t/a, is collected in a container located in the lower part of the centrifuge and the liquid fraction, part (12,000 t/a) is recirculated to the digester inlet for the dilution of the mixture of input and the remaining amount (12,172 t/y) are sent to the existing pool. Prior to storage in the pond, it is acidified with sulfuric acid to prevent the evaporation of ammoniacal nitrogen.

Next, the input and output flows of the previous pre-treatment to which the digestate is subjected are specified.

6.2 Applicable regulations

Below is a summary table with the applicable regulations:

	European	National
Waste	Directive 2008/98/CE of the European Parliament and of the Council, of November 19, 2008, on waste.	Law 7/2022, of April 8, on waste and contaminated soil for a circular economy. New aspects concerning digestate. Approved on April 1, 2022
	DIRECTIVE (EU) 2018/851 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of May 30, 2018, amending Directive 2008/98/EC on waste.	
Use of digestate	Directive 91/676/CEE of the Council, of December 12, 1991, relative to the protection of waters against contamination produced by nitrates used in agriculture	Royal Decree 261/1996, of February 16, on the protection of waters against pollution produced by nitrates from agricultural sources.
		Draft Royal Decree /2020, which establishes standards for sustainable nutrition in agricultural soils
Fertilizer production	**Regulation (EU) 2019/1009** of the European Parliament and of the Council of June 5, 2019, establishing provisions relating to the availability of EU fertilizer products on the market and amending Regulations (EC) No. 1069 /2009 and (CE) nº 1107/2009 and Regulation (CE) nº 2003/2003 is repealed.	**Royal Decree 516/2013,** of June 28, on fertilizer products.
		Royal Decree 999/2017, of November 24, which modifies RD 506/2013, of June 28, on fertilizer products.

Table 8. REGULATIONS APPLICABLE TO BIOGAS PLANTS

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6.3 Uses of the digestate

Digestates will be used as direct application as organic amendment.

Its direct application in the field has the main function of acting in agricultural soils as an organic amendment, that is, improving the properties and structure of the soil by providing organic matter. In turn, its nitrogen, phosphorous and potassium content has the additional benefit of fertilizing farmland.

The agricultural application of the digestate is conditioned both by the characteristics of the digestate itself and by other external factors. The conditions to be taken into account to achieve a successful application are:

- Quality of the digestate (Efficacy, safety, constancy and stability)
- Type of soil and crops where it will be applied (content of organic matter and nitrogen)
- Application logistics (application distance; water content)

7 Commercial feasibility

7.1 Investment costs

The investment costs for a biogas project are:

1. STORAGE OF SUBSTRATES	250.000
2. SOLIDS LOADING SYSTEM	220.000
3. ANAEROBIC DIGESTERS	1.550.000
4. SUBSTRATE PUMPING SYSTEM	210.000
5. BIOGAS PIPING, CONDITIONING AND STORAGE	120.000
6. BIOGAS UPGRADING UNIT	1.700.000
7. HEAT DISTRIBUTION SYSTEM	350.000
8. CONTROL PANEL, AUTOMATION AND ELECTRICAL INSTALLATIONS	300.000
9. STORAGE OF THE DIGEST AND POST-TREATMENT DIGEST	350.000
10. CRANE, DEBRIS CONTAINER, WORK TOOLS	40.000
11. START-UP	30.000
12. SUPERVISION OF THE WORK	325.000
13. HEALTH AND SAFETY ELEMENTS	20.000
14. INTERCONNECTIONS	600.000
15. PLOT	250.000
16. PERMITING AND DEVELOPMENT	250.000
Total price of the biogas plant	6.565.000

Table 9. Costs of the plant

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7.2 Income

The revenues of the biomethane producer related to the sale of the primary product (biomethane) will consist of a contract established as a PPA (Power Purchase Agreement) with an international energy company, based on a fixed value for the certificate + % of natural gas referenced to the TTF market.
The contract will be based on PPA of 10 years duration.
It is a must that carbon footprint is below 20 gr CO2/MJ.
The estimation for the sales of the gas is as follows:

	2024	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*2031*	*2032*	*2033*	*2034*
Estimated value of gas TTF	70	60	40	25	26	28	29	30	32	34	35
Certificate	40	40	40	40	40	40	40	40	40	40	40
Total	75	70	60	53	53	54	54	55	56	57	58
Data in €/MWh											
plant operation	85%	93%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 10. Prize of sale of the biomethane

	2024	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
energy sales (in €)	2.179.815	2.214.009	2.051.591	1.795.142	1.816.513	1.838.952	1.862.513

	2031	*2032*	*2033*	*2034*
energy sales (in €)	1.887.253	1.913.229	1.940.504	1.969.143

Table 11. energy Sales

There will be other incomes expected, associated to the compost produced:

Fertilizers income	t/y	€/t	Total
Compost	9.185	10	91.854
Income			91.854

Table 12. Fertilizer sales

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7.3 Operational expenses

7.3.1 Raw materials

The list and costs of raw materials for biogas production.

Waste management	t/y	€/t	Total
Alperujo (olive waste)	25.000	2	50.000
pork slurry	12.000	2	24.000
Glycerin	3.000	-20	-60.000
Cow dung	2.000	-10	-20.000
chicken manure	5.000	-15	-75.000
Costo of substrates			-81.000

Table 13. Costs of substrates

7.3.2 Energy consumption

The energy consumption of the combined biogas to biomethane plant consists of 3 elements:

- Electrical energy
- Thermal energy
- Vehicle fuel

An electricity cost of €0.10/kWh has been considered.

	Unit	Anaerobic digestion	Separation SL NF	Separation SL F	Upgrading
electrical costs					
Energy consumption	*kWh/year*	649.648	9.636	25.600	1.765.403
Price	*€/kWh*	€0,10	€0,10	€0,10	€0,10
Cost	***year***	**€64.965**	**€963**	**€2.560**	**€176.540**
Unit cost	*€/m3 treated*	*€1,78*	*€0,16*	*€0,18*	*€9,18/MWh*

Table 14. Electricity costs

The total annual electricity cost is €245.029 per year.

On the other side, the costs associated to thermal energy (burning of orujillo) are expected in 80.000 € per year.

	THERMAL COST	
Heat consumption	2.000.000,00	kWh/year
	80.000,00	**year**

Table 15. Thermal energy expenses

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7.3.3 Personnel costs

The biogas/biomethane plants do not require numerous personnel being present 24 working hours a day. The daily tasks are limited to the loading of the daily volumes of substrates, to checking the installation, to registering the operational parameters and to taking samples from time to time.

The costs associated to this project are:

Plant manager	65.000,00	year
Operators	120.000,00	year

Table 16. Personnel costs

7.3.4 Maintenance

The maintenance of the machinery is the big item among the operation expenses after raw material supply costs. It is obviously important, that the preventive maintenance is carried out according to the respective schedules and the machinery is kept in best operating conditions all the time.

	REPAIRS AND CONSUMABLES	
Anaerobic digestion maintenance and repairs	45.000,00	year
Consumables Upgrading	27.840,00	year
Upgrdaing maintenance	59.300,00	year
Digestate maintenance	8.500,00	year
TOTAL CONSUMABLES	**140.640,00**	year

Table 17. Maintenance costs

7.3.5 Chemicals and other materials

The anaerobic digestion process of may require application of chemicals: desulphurisation agents, anti-foam materials and potentially other chemicals are needed, that is why this factor is considered in the economic calculations of the project in the range of 27.840 EUR/year.

To estimate the consumption of desulfurization reagent and activated carbon, the following has been considered assumption:

- H2S concentration in raw biogas: 800 ppm
- H2S concentration at the digester outlet: 300 ppm

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- H2S concentration at the upgrading inlet: 0 ppm

The proposed mineral desulfurization reagent is a compound of oxy-hydroxides (FeOOH) and iron oxides (Fe2O3) of natural origin, developed to add directly to the digester and has a high affinity for H2S.

The hypotheses considered for the calculation of the amount of desulfurization reagent necessary are the following:

- Substrate flux = 100 Nm3/day
- Biogas generated = 14.247 Nm3/day
- Initial H2S concentration in the biogas = 800 ppm
- Final H2S concentration in the biogas = 300 ppm
- H2S density = 1,36 g/L
- Substrate density = 1 t/m3

Desulfurization reagent

- 19.767 kg/year

7.3.6 Transportation of the liquid fraction of the fermentation residue

The liquid fraction of the fermentation residue should be applied preferably on the cultivated fields surrounding the location of the biogas plant.

The cost of the transportation will be of 7 €/m3:

	DIGESTATE EXPENSE	
Reagents for digestate treatment	93.380,00	year
Digestate Liquid Application	299.440,40	year
TOTAL DIGESTATES	**392.820,40**	**year**

Table 18. Digestate costs

The consumption of polyelectrolyte considered was 10 kg of polyelectrolyte per ton of input dry matter. Polyelectrolyte is only required in the solid-liquid separation stage of the separated non-flocculated liquid fraction. The equipment used in the separation is a screw dehydrator.

With the prior separation of the digestate by means of a vertical screw, it is possible to separate fibers and waste, sending a liquid stream to the separator with flocculant with less dry matter. In this way, it is possible to save on polyelectrolyte.

The total cost per polyelectrolyte per year is €93.380.

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	Unit	Separation SL F
Polyelectrolyte		
MS	T MS/year	2.668.00
Dosage	kg poly/ T MS	10,00
general consumption	kg poly/year	26,680.00
cost poly	€/kg	€3,50
Total cost	**year**	**€93.380,00**
Unit cost	***€/m3 treated***	***€2,73***

Table 19. Polyelectrolyte costs

7.3.7 Biotechnological service

It is in the elementary interest of the operator of the biogas plant to keep the biological system in the most efficient and balanced condition, otherwise the biogas generation will fluctuate, the biogas production will fall below the potential of the raw materials. The professional biotechnological service includes the following elements:

- Regular laboratory analysis (twice a month) of the composition of the fermentation mass from the digesters (volatile organic acids, etc.).
- Regular laboratory analysis (once a month) of the fermentation residue for remaining biogas potential (to control the efficiency of the degradation of the organic material);
- Laboratory analysis of every new substrate.
- Continuous analysis of process parameters (biogas yield, biogas composition, material balances etc);
- Recommendations on changing process parameters, substrate composition, etc.

For this project, the costs are expected as:

Insurance, analytics, management expenses	20.000,00	year
External technical assistance	30.000,00	year

Table 20. Assistance expenses

7.3.8 Banking expenses

The costs of financing the operation are as follows:

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Senior operating debt		
total debt		5.251.961
years paid		10
debt interest rate		2,5%
Financial expenses	1%	52.520

Table 21. Banking expenses

7.3.9 Cash flow projection

The cash flow projection can be produced for different time durations.

The cash flow scheme must include the following steps:

- Revenues
- Direct and indirect costs
- EBITDA
- Depreciation
- EBIT
- Interest paid on credit.
- Amount subject to profit tax
- Profit tax
- Operational cash flow (interest paid, taxed)
- Investment cash flow
- Operational and investment cash flow
- Financing
- Credit service
- Financing cash flow
- Cash flow (aggregated operational, investment and financial cash flows)
- Feasibility indicators

This is the cash-flow projection of the project:

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	YEAR	-	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Entry																	
	Cost of substrates		(81.000)	(81.810)	(82.628)	(83.454)	(84.289)	(85.132)	(85.983)	(86.843)	(87.711)	(88.589)	(89.474)	(90.369)	(91.273)	(92.186)	(93.107)
	Energy		2.179.815	2.214.009	2.051.591	1.795.142	1.816.513	1.838.952	1.862.513	1.887.253	1.913.229	1.940.504	1.969.143	1.988.834	2.008.723	2.028.810	2.049.098
	Fertilizers income		36.742	41.334	45.927	45.927	45.927	45.927	45.927	45.927	45.927	45.927	45.927	45.927	45.927	45.927	45.927
	Total		2.098.815	2.132.199	1.968.963	1.711.688	1.732.224	1.753.820	1.776.530	1.800.410	1.825.517	1.851.915	1.879.668	1.898.465	1.917.450	1.936.624	1.955.990
Bills																	
	Operating costs		1.093.460	1.107.129	1.120.968	1.134.980	1.149.167	1.163.532	1.178.076	1.192.802	1.207.712	1.222.808	1.238.093	1.253.569	1.269.239	1.285.105	1.301.168
	Total costs		1.093.460	1.107.129	1.120.968	1.134.980	1.149.167	1.163.532	1.178.076	1.192.802	1.207.712	1.222.808	1.238.093	1.253.569	1.269.239	1.285.105	1.301.168
EBITDA			1.005.355	1.025.070	847.995	576.708	583.057	590.289	598.454	607.608	617.806	629.107	641.575	644.896	648.211	651.520	654.822
	Amortization (10 years)		700.261	700.261	700.261	700.261	700.261	700.261	700.261	700.261	700.261	700.261					
	Grants		-														
EBIT			305.094	324.808	147.734	(123.554)	(117.205)	(109.973)	(101.807)	(92.654)	(82.456)	(71.154)	641.575	644.896	648.211	651.520	654.822
	Financial expenses		(131.299)	(118.169)	(105.039)	(91.909)	(78.779)	(65.650)	(52.520)	(39.390)	(26.260)	(13.130)	-	-	-	-	-
Income before taxes			173.795	206.639	42.694	(215.463)	(195.984)	(175.622)	(154.327)	(132.043)	(108.716)	(84.284)	641.575	644.896	648.211	651.520	654.822
	Corporate income taxes		43.449	51.660	10.674	-	-	-	-	-	-	-	160.394	161.224	162.053	162.880	163.706
net result			130.346	154.980	32.021	(215.463)	(195.984)	(175.622)	(154.327)	(132.043)	(108.716)	(84.284)	481.181	483.672	486.158	488.640	491.117
	EBITDA-TAXES	(6.565.000)	961.906	973.410	837.321	576.708	583.057	590.289	598.454	607.608	617.806	629.107	641.575	483.672	486.158	488.640	491.117

The summary of the expense (total costs) is as follows:

	ELECTRICAL COST	
Anaerobic digestion	649.000,00	kWh/year
Upgrading	1.765.000,00	kWh/year
Digestates	36.000,00	kWh/year
TOTAL ELECTRICAL CONSUMPTION	**2.450.000,00**	**kWh/year**
TOTAL ELECTRICAL COST	**245.000,00**	**year**

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	THERMAL COST	
anaerobic digestion	2.000.000,00	kWh/year
	80.000,00	**year**

	REPAIRS AND CONSUMABLES	
DA maintenance and repairs	45.000,00	year
Consumables Upgrading	27.840,00	year
Upgrdaing maintenance	59.300,00	year
Digestate maintenance	8.500,00	year
TOTAL CONSUMABLES	**140.640,00**	**year**

	EXPLOITATION OF PLANTS	
Insurance, analytics, management expenses	20.000,00	year
External technical assistance	30.000,00	year
Plant manager	65.000,00	year
Operators	120.000,00	year
TOTAL OPERATING COSTS	**235.000,00**	**year**

	DIGESTATE EXPENSE	
Reagents for digestate treatment	93.380,00	year
Digestate Liquid Application	299.440,40	year
TOTAL DIGESTATES	**392.820,40**	**year**

TOTAL	**1.093.460,40**	

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7.4 Financing

As a matter of fact, feasibility studies are crucial in securing financing for a project while they must secure the necessary trust of the investors and financing institutions. The financing chapter of a feasibility study must be tailor-made to the project it covers.
The expected financing payments are as follows:

mortization	Year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
Financial costs	52.520	-	-	-	-	-	-	-	-	-
loan installment 1	656.495	643.365	630.235	617.105	603.975	590.846	577.716	564.586	551.456	538.326
Total cost	709.015	643.365	630.235	617.105	603.975	590.846	577.716	564.586	551.456	538.326
outstanding debt	5.251.961	4.726.765	4.201.569	3.676.372	3.151.176	2.625.980	2.100.784	1.575.588	1.050.392	525.196

7.5 Feasibility indicators

7.5.1 IRR

IRR 15 years	5,85%
IRR 10 years	1,23%

7.5.2 NPV

NPV 15 years	3.001.827
NPV 10 years	410.666

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8 Overall risk assessment

PREVENTIVE AND CORRECTIVE MEASURES

Below is a list of the measures taken in the processes listed in the previous section that are sources of polluting particle emissions into the atmosphere, such as odours, particles and exhaust gases.

The purpose of these measures is that the action to improve the decentralization of energy production with the start-up of the biogas plant does not pose a risk to the environment and/or human health.

Digestate storage

The recovery of manure, cattle manure and poultry manure prior to being applied in the field can be considered as an improvement of activities linked to farms. It is not directly an emission reduction measure linked to the activity of the biogas plant, but it can be considered if the activity of the farm and the biogas plant are viewed as a whole. Analysing the existing situation now and the situation once the project has been carried out, an improvement in the reduction of odour emissions associated with the storage of manure is clearly observed. The established design for receiving the slurry at the biogas plant and subjecting the slurry to anaerobic digestion ensures the reduction of odour emissions. The discharge into the tank is carried out through a pipe with a hose coupling without producing emissions due to discharge.

Both the solid fraction and the liquid fraction resulting from the separation of the digestate have better characteristics compared to fresh slurry. The energy recovery of livestock manure manages to reduce the organic load and eliminate odours. In this way, in addition to being valued energetically, it is possible to improve the properties as fertilizers. As for the liquid fraction, its acidification, in addition to producing a very positive effect on its fertilizing characteristics, will reduce the risk of ammonia emissions and other volatile organic compounds that have not been reduced in biodigestion, almost to zero. This reduction in emissions covers both storage and the natural evaporation that occurs during storage in the existing pond.

Finally, the pool volume of 2,331 m3 allows storage in periods when the land does not require nutrients due to the type of crop. In addition, by allowing a balance of total annual evaporation of the digestate of 17%, so that a more concentrated product with a high level of nitrogen and sulphur of great quality as fertilizer will be obtained.

Warehouse and entry of raw materials

As a preventive measure, raw materials are stored separately.

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In the case of liquid substrates, there is an aerial GRP tank for glycerine and an underground slurry storage tank with their respective concrete filling stations to collect any spillage during the unloading of the substrate through a hose. At no time does the liquid circulate through open conduction, and in this way, there is no emission of odours into the atmosphere.

As a measure to reduce the emission of odours from the storage of cattle manure and chicken manure, these are stored in silos that are covered with a tarpaulin to prevent them from being a point of attraction for animals and to avoid the emission of odours as much as possible. smells. As a measure to reduce odours, a plan is also made for the storage time of co-substrates in the silo so that it does not exceed four days. In this way, the putrefaction that causes bad odours practically does not take place.

With the purpose of minimizing the odours given off by the solid substrate loading and unloading operations, the separation distance between the solids loader where the solid substrates are unloaded and the storage silo has been reduced to the maximum. In addition, the trips of the shovel tractor that transports the solid substrates with shovel dimensions of 2,780 kg are optimized to the maximum in order to minimize the emission of odours related to their handling, as well as taking the exact load to prevent the residue does not remain uncovered for a long time. Therefore, the journey is made six times a day and the distance to travel from the silo to the solids feeding system is 30 m (five minutes long). For this reason, the emission of odours due to the handling of solid waste occurs in a timely manner approximately 30 minutes daily.

Fermentation and biogas production at the plant

As a preventive measure to reduce the emission of polluting gases into the atmosphere in the event that the upgrading unit is offline for any reason, a safety torch is placed that would be responsible for preventing biogas from being emitted into the atmosphere without combustion.

In addition, the oversizing of the gas holder allows for a greater storage capacity of biogas and thus, a greater margin of time to repair the upgrading unit.

In case of interruption of gas production, there are corrective safety measures constituted by an overpressure valve, which relieves the conditions of excess gas in the gas holder.

Likewise, there is a low-pressure sensor to cut off the supply to the upgrading unit in the event of an excessive decrease in stored biogas.

Use of biogas in the upgrading unit

To reduce emissions at source of polluting gases from the upgrading unit, the following corrective and preventive measures will be applied:

- Biogas cooling to remove the NH3 that may be present in the biogas. In this way, it is ensured that it is not present in the CO2 off gas stream emitted by the upgrading unit.

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- Use of activated carbon filters for the elimination of H2S and siloxanes in the biogas. The emissions of these pollutants are practically reduced to zero (less than 5 ppm) and consequently, they are not present in the CO2 off gas stream. These filters are regularly replaced to ensure their operability. In the same way, with the elimination of H2S, the associated odours are eliminated, constituting a measure to minimize emissions.
- Use of a safety torch for burning biogas and for burning biomethane, in order to avoid the direct emission of methane into the atmosphere.
- Supervision of CO2 and CH4 concentration online in the off-gas stream using an analyzer.
- Protection in case of a flammable source, which can cause an explosion, with the consequent release of polluting gases. All electrical installations are equipped with protection against flammable sources. As an additional preventive measure to avoid any flammable source (fire, smoke, light...) prohibition signs are installed.
- Preventive maintenance of the installation, to avoid any possible breakdown that could generate a gas leak.

Mobile emission sources

With regard to mobile emission sources, the following corrective and preventive measures will be established:

- Covering of the materials transported in trucks by means of hoods, tarpaulins or other systems.
- Cleaning of vehicles, paying special attention to the wheels and underbody of the vehicle, installing a disinfection speed bump.
- Adequate conditioning and maintenance of the access routes and circulation of vehicles and machinery, to avoid puddles, mud and dust emissions.
- Compaction or paving of the surface of access and circulation roads.
- Addition of suitable material (gravel, gravel) in the dustiest soils.
- Cleaning of accumulated material to clear steps.
- Optimization of work plans and minimization of routes in the installation.
- Establishment of operating criteria according to weather conditions.
- Limitation of the speed of movement of vehicles and machinery within the facility and its signage.

Other preventive and corrective measures

Plant screens will be available for dust retention and will also help minimize the visual impact generated by the project. Around the entire perimeter of the farm, a plant screen with native species will be placed in a staggered distribution separated by 7 m to be placed in two rows and will be installed outside the fenced area.

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Digestate management

In the biogas plant, the organic matter contained in the input substrates is degraded, and some elements and nutrients are transformed. The rest of the matter leaves the biogas plant, in the form of a liquid, homogeneous, stable and odourless digestate.

The amount and characterization of the digestate can vary greatly depending on the input substrates. According to the diet of alperujo, pig slurry, cattle manure, chicken manure and glycerine described above, 42.913 t of digestate are estimated annually, with 88.7% moisture. Subsequently, it is subjected to a separation process to obtain two streams: solid and liquid.

Currently, with regard to livestock manure, they are being used as mineral organic fertilizer, for which the farms that generate this waste have sufficient land, as evidenced in the corresponding Manure Management Technical Projects that they presented for legalization. from their farms. Specifically, there are plots in the municipalities of XXXX, which allow a total annual application of 71,868 kg of Nitrogen. Further on, the nutrient balance associated with the anaerobic digestion process is shown.

In addition, the bio-methanation plant will have a storage pond with a volume of 2,331 m3, fenced and waterproofed, with sufficient capacity to store the digestate produced during periods when it is not advisable to apply it to the land. In total, there is a storage buffer capacity for the liquid fraction of 69 days.

With the biogas plant, no substantial modifications are made to the process of agronomic recovery of livestock manure. The digestate from the biogas plant will be separated. The solid fraction is stored in a granary with a capacity of 413 m3 and is used as solid fertilizer, while 50% of the liquid fraction (12,172 t/a) is stored in the existing fenced and waterproofed pond. The remaining half is returned to the anaerobic digestion process to dilute the input substrates. It is previously subjected to acidification to prevent the ammoniacal nitrogen from evaporating. During the months of storage, a natural evaporation will take place. In total, it is expected that 2,089 t/y of water will evaporate into the atmosphere, reducing the output volume of the liquid digestate fraction.

The advantage of the agronomic application of the digestate is that in the anaerobic digestion process the biodegradable organic load present in the input substrates, which causes bad odours and the emission of methane and carbon dioxide into the atmosphere, is eliminated.

Taking into account that nitrogen is an inhibitor of methanogenic bacteria, and that livestock manure is the substrate with a high content of this element, co-substrates, glycerine, poor in nitrogen have been chosen so that a high concentration of nitrogen is not produced. at the biogas plant. In this way, the nitrogen load of the digestate does not increase and therefore, the land required for its application as fertilizer will be sufficient with the land annexed in the Manure Management Technical Projects associated with the authorizations of the farms from which the manure comes.

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With the biogas plant, the total amount of fertilizer applied to the field is not significantly affected, but its quality as an organic amendment is greatly improved. The emission of bad odours and greenhouse gases is eliminated, and nitrogen and other trace elements are transformed into forms that are more easily assimilated by plants and crops, thus also minimizing the leaching process in the soil.

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