D6.4 | Guidance for feasibility analysis covering biomethane investment projects - 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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REGATRACE in a Nutshell

REGATRACE (REnewable GAs TRAde Centre in Europe) aims to create an efficient trade system based on issuing and trading biomethane/renewable gases certificates/Guarantees of Origin (GO) with exclusion of double sale. This objective will be achieved through the following founding pillars:

- European biomethane/renewable gases GO system.
- Set-up of national GO issuing bodies.
- Integration of GO from different renewable gas technologies with electric and hydrogen GO systems.
- Integrated assessment and sustainable feedstock mobilisation strategies and technology synergies
- Support for biomethane market uptake
- Transferability of results beyond the project's countries

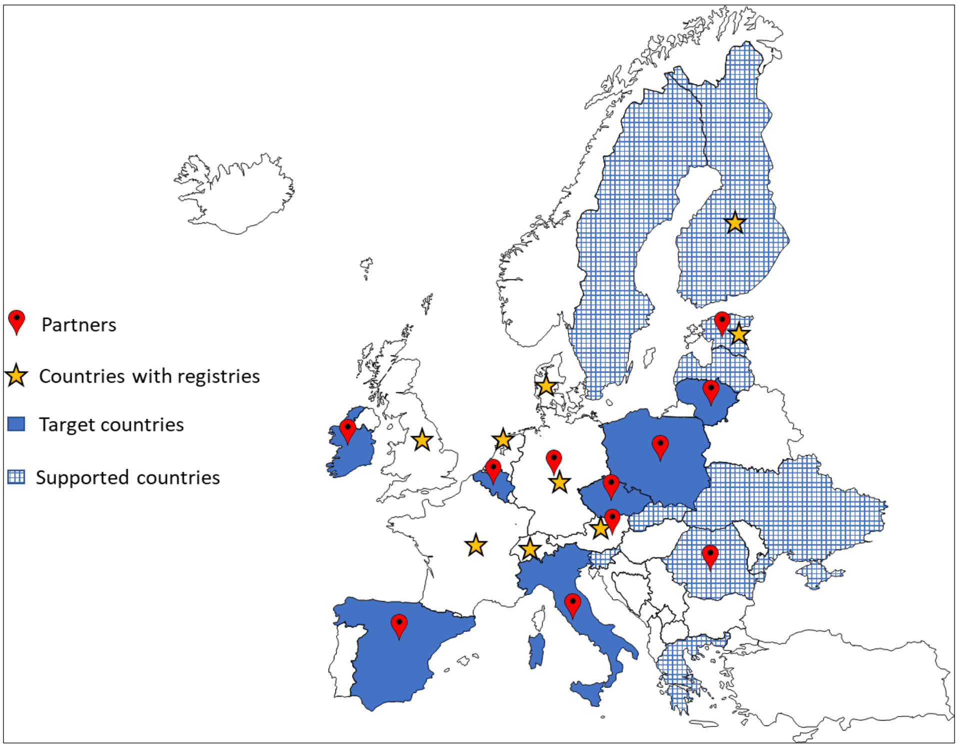

Figure 1: REGATRACE countries and partners

The purpose of this document

This paper has been produced by the European Biogas Assocation in colaboration with AEBIG under the Work Pacakge 6 of the REGATRACE project (www.regatrace.eu). The Guidance for feasibility analysis covering biomethane investment projects is designed to assist project developers in realising 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.

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The document is based on a general guidance on European level and tailored with country specific information by the national biogas association in view of the specific circumstances prevailing in the country. The general guidance has been adapted to local circumstances for enabling direct usage by interested parties in the country. The draft results of the feasibility analysis specific for the country were presented during the third participatory workshop in the REGATRACE project and later – in view of their consolidation – was finally presented during the fourth participatory workshop.

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1 What is a feasibility study?

As the name implies, a feasibility analysis is used to determine the viability of a project idea, ensuring that the project is legally and technically feasible as well as economically justifiable. The feasibility study answers the basic question whether the project is worth the investment. In some cases, a project may not be viable. There can be many reasons for this, including requiring too many resources, which not only prevents those resources from performing other tasks but also may cost more than the investing company/organization would earn by realising a project that is not profitable.

A well-designed feasibility study should offer a comprehensive review of the background of the project, the description of the manufacturing processes the quality and market of the final products, details of operations and management, estimated future market developments, commercialisation of bio fertilisers, monetising of soil carbon sequestration [carbon credits], other bio actives, protein extraction and policies such as Renewable Heat Obligation Scheme, expected financial data, legal requirements, and tax obligations. Generally, the feasibility studies precede technical development, business planning and project implementation.

A feasibility analysis evaluates the project's potential for success, its perceived objectivity is an essential factor in the credibility of the study both for potential investors and lending institutions.

A feasibility study is a study, which is performed by a company/organization to evaluate whether a specific action (investment, acquisition, etc.) makes sense from economic and/or operational standpoint. The objective of the study is to test the feasibility of the specific action and to determine and define any issues that would argue against realising it.

The question a feasibility study should answer is simple: "*Should we proceed with the specific investment project?*" In addition to determining whether the planned project is viable, organizations can use a feasibility study also for understanding the implied risks better.

It is important to remember that a feasibility study is not the same as a business plan. A business plan provides a planning function and defines the actions needed to take a business idea into reality, whereas a feasibility study provides an investigation into a specific investment project under consideration and whether the project is viable.

While it is important to conduct both plans before realising the action, a business plan should only be conducted once the investment project has been deemed viable by a feasibility study.

This Guideline is providing general assistance for conducting feasibility studies for biomethane investment decisions. The main purpose of such feasibility studies is to support/enable.

- taking investment decisions aimed at establishing new biomethane production and
- securing the necessary financing.

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2 Where can the Feasibility study be used?

For investing into new biomethane production facilities two substantially different pathways can be followed:

- expansion of existing anaerobic digestion installation with addition of an upgrading facility (potentially also increasing the raw biogas production),
- investment into new, „green field" complex consisting of anaerobic digestion and biogas upgrading.

This Guidance addressed the issues related to both above mentioned pathways but does not deal with acquisition of already existing and operating biomethane producing installations. The reason for not addressing acquisitions is that in case of existing production the acquisition decision is taken based on actual operational and financial data (cash flow) and not on a general feasibility study.

The primary purpose of a feasibility study is to provide reliable [well-based] data and information to the project developers about the conditions of the project. Subsequently, based upon this analysis the project developers can approach the potential investors and financing institutions.

The feasibility studies assist the project developers also in their communication with the respective authorities, politicians, socio-economic benefits, and impacted communities in securing their support for the project. For this purpose, the study must address in detail the potential risks and the expected concerns by the involved parties.

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*

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    - *Animal byprodcts 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*
    - *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:

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- *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?*

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.

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- 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.
- 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 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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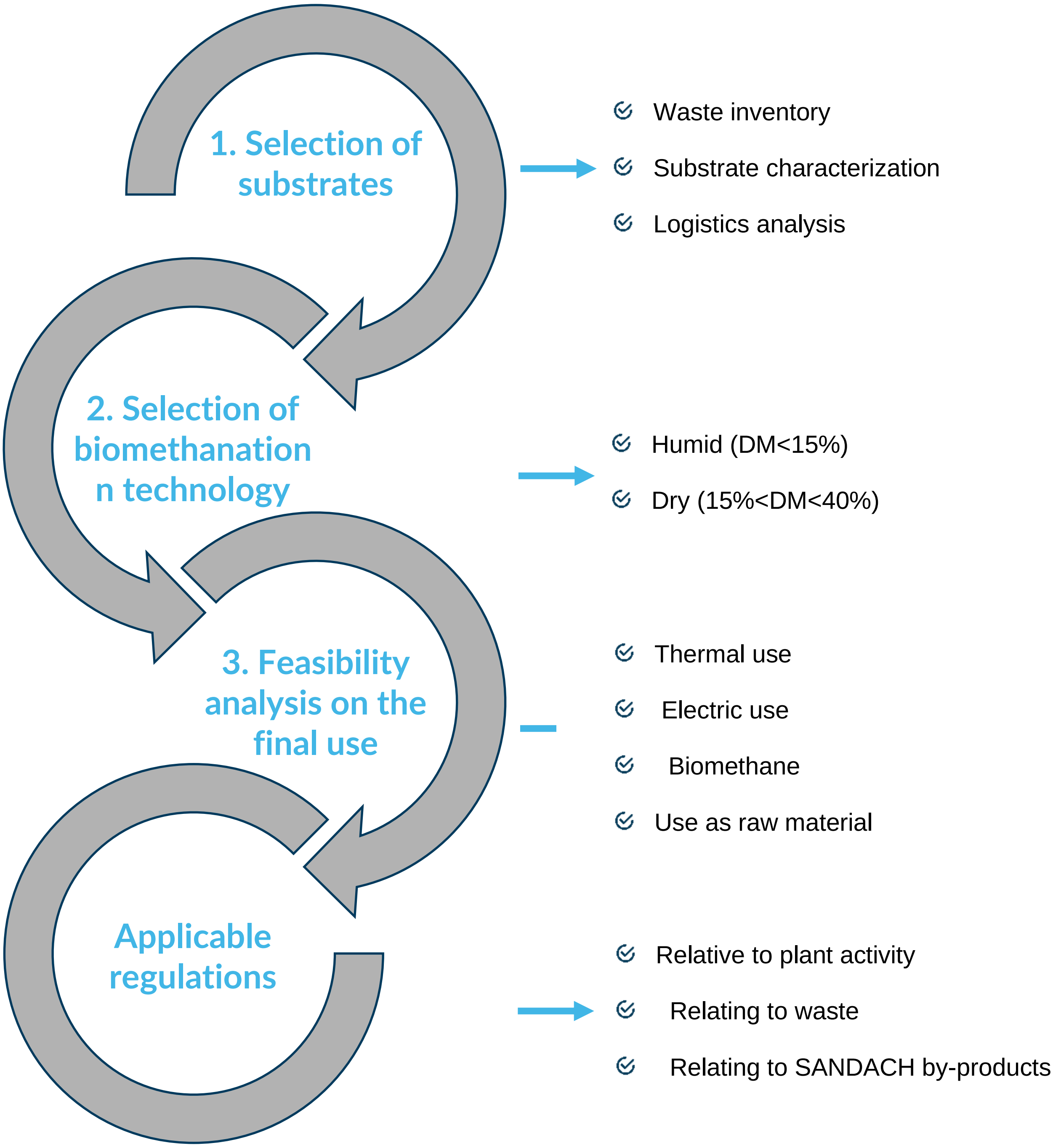
5 Roadmap for the evaluation of biogas projects (Technical and Market feasibility)



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5.1 Selection of wastes

5.1.1 Waste inventory

The waste inventory serves as the basis for evaluating the feasibility of developing a biogas project in a given location.

The producers of waste, the type and quantities of waste generated by these producers must be identified. Once identified, the viability of the waste is evaluated in order to propose the type, quantity and origin of the most appropriate waste that can be recovered in the biogas plant.

To carry out a **feasibility analysis of** the identified waste, the following criteria can be established:

- **Competition:** The identified waste may be being recovered in other processes, such as the production of biogas, fertilizers, feed, etc. It will be easier to reach an agreement to obtain the waste when it is not currently being recovered in other processes.
- **Logistical feasibility:** the cost of transport to the plant will depend on the distance. The greater the distance, the greater the cost. Waste with less interest due to its low biogas potential (eg slurry) will not be viable if it is not located close to the plant.
- **Amount of waste generated:** The volume of waste generated by a company can limit its viability, since, for there to be a stable flow of substrates entering the plant, they must produce a sufficient amount of waste to send at least one vat every two weeks.
- **Income:** the fee for managing each waste. Waste with high management fees will be more interesting for the plant due to the income they represent.
- **Seasonality:** the times of waste production. If a waste presents a very strong seasonality, this will have to be taken into account, since in the periods in which this waste is not generated, it will have to be replaced by others.

5.1.2 Characterization of the substrates

Depending on the type of substrate, biogas projects are divided into 5 categories:

- Agricultural biogas
- Agro-industrial biogas
- Biogas from WWTP
- Biogas from the organic fraction of urban solid waste (FORSU)
- Biogas from landfill

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5.1.2.1 Agricultural waste

Biogas from agricultural waste	These projects generate biogas from agricultural-type substrates, whether they are crop residues, cereal straw or manure-type livestock manure, manure and chicken manure. The main characteristics are: • They are usually small-scale and decentralized projects • They are usually associated with rural areas, so they promote employment, economy and population settlement in rural and less populated areas. • Generally, they are plants where little biogas, and are usually focused on thermal and/or electrical self-consumption to improve the energy efficiency of agricultural facilities. • The management of this waste avoids the emission of pollutants such as methane, nitrous oxide, ammonia, hydrogen sulfide, volatile organic compounds and particles, which can cause serious environmental concerns and health problems. • In the case of field application of livestock manure, anaerobic digestion improves the properties of the product to be used, since it stabilizes and sanitizes them, eliminating possible pathogens that they may contain.

Table 1. Guideline values for biogas production according to the animal that produces the droppings.

Agricultural waste	DM (%)	Potential CH_4 /MO (Nm^3/tMO)	% CH4
Slurry - pig	4,7	447	60,8
Manure - pig	21,0	450	60,0
Manure - equine	35,0	323	60,0
Slurry - rabbit	12,7	410	61,0
Manure - beef	25,0	450	55,0
Slurry - beef	8,5	345	58,0
Manure - chicken manure	36,4	385	51,4

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5.1.2.2 Agro-industrial waste

Biogas from agro-industrial waste	Biogas associated with companies producing waste with a high load of organic material. Includes energy crop residues. The main characteristics are: • When an energy recovery takes place, the energy produced can be used in the facilities themselves to meet the needs of heat and/or electricity, reducing energy dependence and the associated economic cost. • Agro-industrial waste is very diverse, depending on the type of industry that generates them. Among the waste, we can find plant remains, meat and fish by-products, dairy by-products, sludge of various kinds, washing water and water with a high organic load, etc. • The production and quality of biogas depends on the type of company and size. For example, in large paper and sugar mills, where enormous amounts of waste are generated daily, biogas production can exceed 1,000 Nm^3/h, while other smaller ones, such as biogas production, are more modest.

Table 2 shows biogas production relative to raw waste.

Table 2Indicative production values of some organic waste from the agri-food industry.

Substratum	DM (%)	Potential CH_4 /MO (Nm^3/tMO)	% CH4
Viscera and manure	14,6	83,5	58,3
Agro-industrial fats	66,4	100	75,1
fresh whey	7,5	92,3	59,2
barley distillation	21,5	89,9	65,4
apple scraps	30	88	60
pastry waste	87,8	97,1	52,8

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5.1.2.3 WWTP sludge

Biogas from WWTP sludge	Biogas produced from the sludge from wastewater treatment plants (WWTP). Anaerobic digestion is used for the stabilization of the sludge itself. • The size of the projects depends on the size of the WWTP. • Traditionally, they have been self-consumption projects due to the heat needs required by the WWTP, but currently, the trend is redirecting towards biomethane projects in large-scale WWTPs. • In the case of field application of sludge, its stabilization is a requirement according to *Order AAA/1072/2013*. Anaerobic digestion is a form of stabilization, with the benefit of its energy use.

Table 3. Guideline values for biogas production type of sludge.

Substratum	DM (%)	Potential CH_4/MO (Nm^3/tMO)	% CH4
WWTP sludge	18	400	62

5.1.2.4 Organic fraction of urban solid waste (FORSU)

Biogas FORSU	Biogas from the biodegradable organic fraction of MSW. • They are substrates with many impurities. A very thorough pre-treatment is needed to remove them. • The biogas plants from FORSU are usually associated with eco-parks or waste management plants. • Regarding digestate, the Waste Law only considers digestate from the fraction separated at origin (brown container) and not that separated at the plant. If not, the digestate is known as bio-stabilized and its final disposal can be problematic.

Table 4. Guideline values for biogas production from the organic fraction of municipal waste.

Substratum	DM (%)	CH4/MO potential (m3/tMO)	%CH4

Organic urban waste	35	615	60

5.1.2.5 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. Currently, it is the most used method in biogas plants, since it provides various advantages such as:

- Unify waste management methodologies.
- Take advantage of synergies of the different components to increase the production of biogas.
- Optimize the use of treatment facilities.
- Mitigate the seasonality of some residues (mainly agricultural).
- Reduce investment and operating costs.

5.1.3 Logistics analysis

Many aspects must be taken into account when selecting the optimal site for the biogas plant. The cost of logistics is a factor to take into account, since these projects often involve the transport of large quantities of waste. However, just analyzing the distance from the growers to the potential plant can lead to erroneous conclusions. In addition, we must keep in mind:

- The distances from the producers to the plant
- The characteristics of the transport
- who pays for transportation
- The distances from the plant to the point of application of the digestates

5.2 Selection of Bio-methanization technologies

There are two types of anaerobic digestion: wet and dry. In wet digestion, we work with waste with a maximum concentration of 15% of total solids. In dry digestion, we work with waste with a concentration between 15 and 40% of dry matter, so dilution is not necessary.

DRY WAY vs WET WAY

ADVANTAGES DRY WAY	DISADVANTAGES DRY WAY
Lower pre-treatment requirements, being less sensitive to the presence of fines and inert materials, avoiding sedimentation inside the reactor.	Greater mechanical wear, more robust equipment is needed.
Lower losses of organic matter in the pre-treatment because it is less complex.	Less flexibility in terms of admission of waste with high moisture content (slurry, WWTP sludge, etc.).
Reduction of material preparation equipment before digestion, as well as suspension and water transfer equipment.	Higher concentration of COD and BOD in the final effluents and therefore requires a more demanding wastewater treatment system.
Smaller digester volume.	Greater difficulties in achieving adequate agitation/homogenization within the reactor (greater pumping energy consumption).
Less sensitivity to substances that inhibit biological processes.	Less possibility of control in the presence of substances that inhibit biological processes.
Water consumption 10 times less than in wet systems and therefore less need for purification.	
Less liquid output from the plant	

Among the most used reactors for **wet digestion** are:

- Continuous complete mix digester (CSTR)
- Plug flow or plug flow digester
- Discontinuous digester or Batch type
- covered lagoons

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Generally, these digesters tend to be robust and easy to operate, although it costs more to obtain homogeneous mixtures between the substrates and the microorganisms than in other digestion technologies, resulting in lower efficiencies and biogas productions.

Reactors with biomass retention are characterized by increasing the retention time of bacterial biomass above the hydraulic retention time (TRH). With this, it is possible to increase the microbiological activity, thus increasing its efficiency. These digesters are commonly used for the treatment of wastewater with a high organic load. The digestion technologies of biomass retention reactors are:

- anaerobic contact reactor
- Upflow Pelletized Bed Reactor (UASB Bioreactor)
- Expanded Granular Bed Reactor (EGSB)
- Internal Circulation Reactor (IC)

Finally, within the classification we have film or fixed biomass reactors. These reactors are based on the growth of a biofilm, where microorganisms are attached to a surface, thus reducing the loss of microorganisms within the reactor. This technology is applied for the treatment of wastewater with low chemical oxygen demand (COD) and/or low solid content, with the following technologies:

- anaerobic filter
- fluidized bed reactor
- Downflow Fixed Bed Reactor (DSFF)

5.2.1 Other technical aspects of the digestion

There is a big variety of biogas fermentation technologies on the market offered by specialised technology engineering companies, some of them having a proven track record with reference lists and confirmed performance, others at the early stage of development and practical application experiences.

The technological solutions differ from each other in the following key elements:

a) Pre-treatment of substrates
b) Wet/dry fermentation
c) Number of fermentation stages
d) Digestion temperature
e) Digester configuration
f) Mixing equipment (agitators)
g) Desulphurisation
h) Biogas storage

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5.2.1.1 Pre-treatment of substrates

The need from pre-treatment is very much substrate dependent. For example, the biogas plants fermenting animal by-products, animal waste (like slaughterhouse waste) must obey the relevant regulations, must cut the material to prescribed particle size and must carry out thermal hygienisation [pasteurisation]

There are several methods to pre-treat the substrates of vegetable origin also, like ultra-wave treatment, thermodynamic (heat and pressure) treatment, bio extruders, etc. Most of these technical approaches have appeared recently and need to be proven in the practice both in practical and economic terms.

5.2.1.2 Stages in fermentation process

The biogas plants operating on wet fermentation basis differ from each other regarding the number of process stages. There are plants, where the fermentation is realised in a single stage (that means that all substrates enter a single digester, and the fermentation residue is taken out of this digester). Depending on the volume of substrates there might be more than one digester running parallel to each other in one-stage fermentation systems.

In the two-stage solutions the substrates are fed-in into the first stage digester (often called main digester) and the fermentation mass is thereafter forwarded to the second stage digester (often called post-digester). The advantage of such digester configuration is that higher level of biodegradation of organic material (i.e., higher specific biogas yield) can be achieved.

5.2.1.3 Fermentation temperature

The biogas plants operated with agricultural feedstocks apply different fermentation temperatures:

- Most of the units are operated at the so called “mesophilic” temperature range, which is 38 +/- 3 °C - the biological system is most stable at this temperature.
- Operating the fermentation at “thermophilic” temperature (54 +/- 2 °C) is more efficient but also more demanding (for example the regulation of the temperature in the digesters must be more precise and reliable);
- There are few biogas plants, which combine a mesophilic stage with a thermophilic stage – this cannot be desirable from the viewpoint of the biological system, while totally different microbes live and “work” at the different temperatures.

One possible approach is to determine the size (active volume) of the digesters calculating with mesophilic fermentation conditions but installing digester heating system and insulation, which would enable to run the plant at thermophilic temperature range in the future. By doing so, a reserve capacity could be established at low cost and with no risk.

5.2.1.4 Digester configuration

The digesters are placed either horizontal or vertical. The horizontal digesters might have a rectangular of a cylinder form, while all vertical digesters are cylinders.

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The digester configuration, the feed-in systems and the mixing equipment are essential parts of proprietary anaerobic fermentation technologies and – as such – are determined by the selected technology partner.

5.2.1.5 Digester dimensions

A key design parameter for any digester system is the overall organic matter loading rate. For any given project, no two digester suppliers will provide a system of the same size. Loading rates are commonly expressed as the average number of days of retention time and/or the quantity of organic matter introduced to a given tank volume per day.

Under "organic load" we understand the quantity of organic dry matter (oDM) loaded into the unit volume of the digester daily expressed in kg oDM/m^3/day.

5.2.1.6 Mixing technique (agitators)

The proper mixing of the fermentation mass is an important pre-condition for efficient biodegradation. There are 3 principal ways of solving this task:

- mechanical agitators,
- circulation of the fermentation mass by means of an outside pump,
- injection of biogas (mixing by the biogas bubbles moving upwards).

5.2.1.7 Desulphurisation of biogas

The most common and cost-effective solution for the desulphurisation of the biogas produced is the biological way, when aerobic microbes convert H_2S into elementary sulphur in the presence of oxygen.

The biological desulphurisation can be carried out either in the biogas area on top of the digesters or in separate desulphurisation columns. The latter is a more efficient solution, which also causes limited dilution of the biogas with nitrogen (and oxygen) but requires additional investment costs.

The biological desulphurisation solution can be extended with adding active-coal filters.

Different biogas upgrading technologies have different requirements towards the sulphur content of the raw biogas. For example, biomethane quality standards and natural gas grid requirements put strict limits on the oxygen content of the product. These requirements must be thoroughly considered at connecting the anaerobic digestion installation with the biogas upgrading facility. No decision can be taken on desulphurisation within the AD unit without knowing the specifics of the subsequent technological step.

5.2.2 Upgrading of biogas

Similarly, to the previous chapter on the anaerobic digestion, this section of the feasibility studies serves the information of addressees (mostly financial people) who may not have detailed knowledge of the technology to be applied in the project.

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Upgrading of biogas to biomethane means

- purification (removing components like water, hydrogen sulphide, ammonia, oxygen, nitrogen, carbon monoxide, halogenated hydrocarbons, siloxanes and particles)
  plus
- separation of carbon dioxide from methane.

Currently, biogas upgrading to biomethane is performed via water scrubbing, chemical scrubbing, physical scrubbing, pressure swing adsorption, and membrane separation. Recent advances have been made in the field of biochemical biogas upgrading using microbial-based systems and also in cryogenic upgrading. The cryogenic technology offers additional benefits, such as production of liquified biomethane (for transport fuel use) and the simultaneous production of high purity, food-grade carbon dioxide.

A comprehensive and up-to-date review of biogas upgrading technologies is provided in the Research review paper „Biogas upgrading and utilization: Status and perspectives” by Irini Angelidakia at all. in Biotechnology Advances.[1]

When selecting the upgrading technology several factors must be looked at, among them:

- expected composition of biogas (for example hydrogen sulphide, ammonia, oxygen, nitrogen content),
- the quality requirements – CEN-EN 16723,
- the natural gas grid technical requirements (for example pressure, oxygen content,
- the intended use (for example intermediary biomethane storage is needed if refuelling stations are supplied directly),
- parasitic load the energy consumption (electricity and thermal) and the available energy sources,
- national regulations on limiting the methane emissions with the CO_2 stream,
- market options and requirements for selling the co-produced CO_2

The feasibility study should reflect that the upgrading technology has been carefully selected and the specific features of the chosen technologies have been taken into consideration when elaborating the material and energy balances.

5.2.3 Storage of biogas

The biogas plants must have a buffer biogas storage capacity, while

- there are interruptions in the operation of the upgrading (and the CHP unit, if installed),
- the volume of biogas production is fluctuating in time.

Biogas can be stored in the gas domes [membranes] installed on top of the digesters. The other solution is the installation of stand-alone ¾ spheres. Both solutions are of equal technical value, the choice is mainly dependent on the configuration of the digesters.

1 *journal homepage: www.elsevier.com/locate/biotechadv*

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The necessary minimum size of biogas storage capacity is to be determined considering the coupling with the upgrading unit. Installing big biogas storage capacity provides important operational flexibility but results in additional capital and operational costs.

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. There are several technical and organization measures to reduce the emissions from biomethane plants. Technical mitigation measures are real interventions on the plant, e.g., the installation of specific components and are mostly in connection with costs. Organizational measures describe the action sequences during plant operation. A non-exhaustive list of mitigation measures is listed below.

Technical mitigation measures:

- Gas-tight covering thanks, e.g., storing or mixing tanks.
- Installing an exhaust gas treatment
- Correct 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 feasibility studies for biomethane investment projects must contain the estimated material balances of the processes foreseen. The respective data can and should be obtained from the technical offers of the respective technology suppliers. Only preliminary opinions can be formulated but no decisions should be made based on data from literature.

In case of converting an existing biogas plant to biomethane production the material balance of the anaerobic digestion unit will be composed from actual operational data.

5.2.6 Energy supplies

Both the anaerobic digestion and upgrading units consume electrical and thermal energy.

The level of energy consumption related to the biomethane production depends on

- the volumes and composition of substrates,

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- the selection of technology (for example mesophilic or thermophilic digestion, membrane, chemical absorption, or any other upgrading technology),
- the energy demand of the necessary technological equipment,
- the energy consumption of digestate processing (for example drying).

Correspondingly, the feasibility study can address the issue of energy supplies only based on data available from the basic engineering of the AD and upgrading units.

5.3 Feasibility analysis on end use

It is critical aspect is to encourage the purification of biogas to biomethane and enable the connection of biomethane plants to the network, facilitating access to the network.

In line with the "Biomethane Action Plan" of the REPowerEU of the European Commission: "The content of existing promotion schemes at national level for electricity production from biogas should also be reviewed to focus on support for biogas upgrading" and "Carry out regional assessment of network development and matching it with the potential of sustainable biomethane production"; respectively.

There are other possible uses for the biogas:

5.3.1 Biogas for thermal use.

It is the simplest, most economical (low investment), immediate and efficient option, but it requires that the facilities where the substrates and consumption points are concentrated be very close. This situation can occur in some industries of the agri-food sector (preserves, vegetables, slaughterhouses, among others) and certain farms or livestock operations, presenting in these cases a favorable environmental and economic balance. It is also currently carried out in numerous urban wastewater treatment plants that use part of the biogas they generate to cover their own thermal needs.

5.3.2 Biogas for electrical use or cogeneration.

This is the most widespread option in Spain. These facilities produce biogas mainly from organic waste (through capture in landfills and also through digesters) and urban wastewater. Electricity generation/cogeneration with agro-industrial biogas is currently less developed.

5.3.3 Biogas and biomethane for use in transportation.

Decarbonization in the transport sector is complex, given that it presents cases of difficult electrification, such as heavy road transport and maritime transport, for which the use of biomethane is a technologically mature opportunity. In addition, the Renewable Energy Directive (RED II) establishes objectives for the consumption of renewable energies in transport, as well as a specific sub-objective for advanced biofuels. Biomethane for use in transport is used compressed at 200-250 bars or liquefied as explained below:

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Compressed Natural Gas (CNG)

- Stored at high pressure, between 200 and 250 bar in cylinders.
- Less autonomy than LNG, generally about 400 km for a car.

Liquefied Natural Gas (LNG)

- Stored in liquid phase in cryogenic tanks, at atmospheric pressure and approximately –160 °C.
- It has traditionally been used to transport natural gas reserves in methane tankers.
- It has great potential for use in heavy transport since it has more autonomy than CNG.

5.3.4 Biogas for use as raw material.

Biogas can be used as a resource to obtain other energy vectors, such as renewable hydrogen, through processes such as steam reforming (SMR), partial oxidation (POX) or autothermal reforming (ATM). This alternative makes it possible to value waste even more, expanding the range of uses to which biogas can be put and favoring the opportunities offered by its management in certain rural areas.

5.4 Applicable regulations

a) Food/feed crops

Food/feed crops are defined in the RED II as follows:

”Food and feed crops” means starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land.

Article 26 of the RED II contains specific rules for biomass fuels (including biogas) produced from food and feed crops.

In several European countries regulatory limitations are in force in relation to the share of food/feed crops which can be processed in a biogas installation.

b) Animal by-products

Animal by-products (ABPs) are materials of animal origin that people do not consume. ABPs include among others:

- Animal feed - e.g., based on fishmeal and processed animal protein,

- Animal slurries/manures - Organic fertilisers and soil improvers - e.g., manure, guano, etc
- Technical products - e.g., commercial food waste, by produces from food and drinks processing plants, pet food, hides and skins for leather, wool, blood for producing diagnostic tools.

ABPs emerge – for example - from slaughterhouses, plants producing food for human consumption, dairies and as fallen stock from farms.

ABPs can spread animal diseases (e.g., BSE) or chemical contaminants (e.g., dioxins) and can be dangerous to animal and human health if not properly disposed of. EU rules regulate their movement, processing, and disposal. In Ireland pasteurisation is standard requirement to mitigate the risks associated, the Department of Agriculture have categorised three types of AD plants, and application for licence is required to operate an AD plant.

ABPs are categorised according to their risk using the basic principles in Regulation (EC) 1069/2009.[2] and Commission Regulation 142/2011[3] These regulation also contain the rules for processing ABSs in anaerobic digesters of the biogas plant.

Regulation (EC) 1069/2009 has been transposed to the domestic legislations of the EU member states.

c) Substrates accepted for “advanced fuel” production.

RED II contains specified targets for the share of “advanced fuels” in the total fuel consumption in transport. In case the transport fuel use of biomethane is targeted focusing on this list of Annex IX Part A is much desirable.

d) Sustainability requirements

The sustainability requirements must also be taken into consideration. Among the sustainability related requirements (detailed in Article 29 of the RED II) the data on greenhouse gas emission intensity are the most important. In Ireland, the Green Gas Certification Scheme measure and monitors the sustainability of biomethane produces in compliance with REDII criteria.

According to Article 29. para 10. of RED II the greenhouse gas emission savings from the use of biofuels, bioliquids and biomass fuels shall be:

- at least 65 % for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021.
- at least 70 % for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021 until 31 December 2025, and 80 % for installations starting operation from 1 January 2026.

2 REGULATION (EC) No 1069/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009

3 COMMISSION REGULATION (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive

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The GHG emission savings are to be demonstrated in comparison with the relevant fossil fuel comparators. RED II imposes different GHG emission reduction thresholds depending on the field of application. For example:

- for biomass fuels used as transport fuels the fossil fuel comparator shall be 94 g CO_2eq/MJ,
- for biomass fuels used for the production of electricity the fossil fuel comparator shall be 183 g CO_2eq/MJ electricity,
- for biomass fuels used for the production of useful heat, as well as for the production of heating and/or cooling, the fossil fuel comparator shall be 80 g CO_2eq/MJ heat.

Annex VI of RED II contains the „Rules for calculating the greenhouse gas impact of biomass fuels and their fossil fuel comparators". In the Annex default values are also provided for some biogas substrates (manure, maize whole plant, biowaste). In lack of default values, the GHG emission is to be calculated, the methodology is detailed in Annex VI. Preference is for actual figures calculated, more robust and reliable data/information on GoO for gas consumers. Sustainability criteria has proposed 40% animal slurries with 60% agri-feedstock, substrate of grass silage/mixed species pasture.

When planning the biomethane investment the GHG emission caused by the production and transportation of biomass (processed in the AD unit) must be considered. BIOSURF Deliverable 5.3. Methodology for the calculation and certification of GHG emission caused by the production of biomethane (in the whole Life Cycle) [4] provides assistance. The GGCS for Ireland already factors the logistics of feedstock into LCA.

4 http://www.biosurf.eu/en_GB/downloads-and-deliverables/deliverables/

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	European	National
plant activity		Royal Decree 475/2007, of April 13, approving the National Classification of Economic Activities 2009
		Law 34/2007, of November 15, on air quality and protection of the atmosphere.
		Royal Legislative Decree 1/2016, of December 16, approving the consolidated text of the Law on Integrated Pollution Prevention and Control.
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.	
SANDACH	REGULATION (EC) No 1069/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of October 21, 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).	RD 1528/2012, of November 8, which establishes the rules applicable to animal by-products and derived products not intended for human consumption.
	Regulation (EU) No. 142/2011 of the Commission, of February 25, 2011, which establishes the provisions for the application of Regulation (EC) No. 1069/2009 of the European Parliament and of the Council	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.

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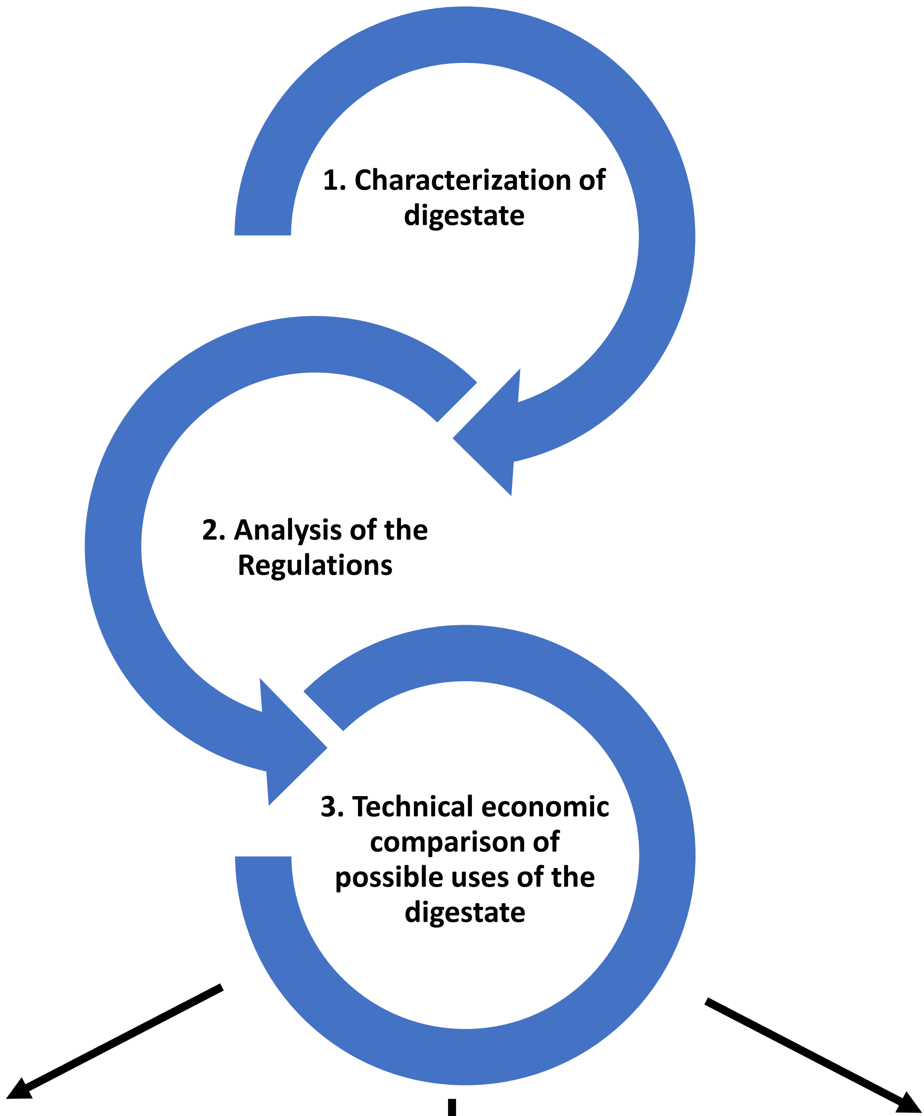
6 Roadmap for the evaluation of digestate handling



Direct land applicatioon:

- Cost
- Typology of soils and crops where it will be applied
- Logistics

Production of fertilizers

- Selection of technology fo separation, solid and liqui fraction
- Applicable regulations
- Fertilizer Market Assessme

Other applications

- Construction material
- Fuel production
- Use as livestock bedding
- Production of biopesticides
- Algae production
- Hydrothermal carbonization

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6.1 Characterization of the digestate

6.1.1 Typology of digestates based on input waste and by-products:

- Agricultural waste
- livestock waste
- Agricultural residuals
- Food waste
- WWTP sludge
- Organic fraction of urban waste s
- Organic fraction from selective collection (FORS)
- Organic fraction of urban solid waste (FORSU)

6.1.2 Characterization of the digestate

The most important parameters to take into account, among others, for the characterization of the substrates are:

- Total solids (TS)
- pH
- Nitrogen and ammonium concentration
- Phosphorus and potassium concentration

Below is a summary table with the evolution of the parameters between the fresh substrate and the digestate:

Table 5. Evolution of digestate characterization between fresh substrate and digestate.

Parameter	Dry material	pH	Nitrogen	Ammonium	Match	Potassium
Substratum	↑	↓	↑/=	↓	=	=
digestate	↓	↑	↓/=	↑	=	=

6.2 Applicable regulations

Below is a summary table with the applicable regulations:

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	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 6. REGULATIONS APPLICABLE TO BIOGAS PLANTS

6.3 Possible uses of the digestate

6.3.1 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. Despite this, the use of digestate as a fertilizer has numerous limitations such as the low nutrient content (entails the use of large amounts), the quality and possible contamination with pathogens, which means that many countries currently do not legally consider it as a fertilizer.

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 considered to achieve a successful application are:

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- 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)

6.3.2 Separation technologies

The main digestate separation technologies are:

- sieving
- band press
- Screw Dehydrator
- decanter centrifuge

Screens (both static and vibrating) are mainly used in slurry treatment, their cost is low but the level of separation is lower than other separators. They are generally used as pretreatment to reduce energy costs.

screw presses they tend to have lower efficiency for the separation of minerals (N, P, K) and are only efficient with digestates with lower moisture content (> 4% DM) that have large particles such as manure (Guilayn, F., et al, 2018). However, coarse particles are mainly degraded during anaerobic digestion and thus are not retained, resulting in low separation efficiency for the digestate. The main advantages are low investment and energy consumption.

decanter centrifuges they recover the N-org generated, but can be damaged by separating larger particles and are more effective in removing small particles in suspension. Higher investment costs (more cost in energy and maintenance) make the economic viability of centrifuges necessitate much higher flows. The advantage of the centrifuge lies in the fact that it combines high efficiency with automation with lower overall operating and maintenance costs than belt presses. Additionally, they require a small amount of space relative to their capacity, are easy to clean, and parts are easy to replace.

The band presses they are relatively expensive and therefore more suitable for collective or regional applications. The disadvantages of the belt press are the use of wash water for the belt and the use of coagulants and flocculants to obtain a sufficiently high separation efficiency, as well as the generation of odours. However, the personnel requirements are low and they have less associated noise compared to centrifuges.

6.3.3 Solid fraction recovery technologies

Once dehydrated, the solid fraction of the digestate can be subjected to different treatments:

- composting
  - open systems
    - static stacking
    - Flip stacking

        - Combined forced aeration and turning system
    - closed systems
        - vertical reactors
        - Horizontal reactors
- thermal drying
    - direct drying
        - Fluidized Bed Dryer
        - belt dryer
        - rotary drum dryer
    - indirect drying
        - tray dryer

The belt dryer is a commonly used post-treatment technique for the digestate solid fraction and several suppliers are available (Eriksson, L., et al, 2016). The technology is set at high maturity and low technical complexity. Operating costs are estimated to be lower than other technologies due to lower energy consumption. Its main disadvantage is the generation of a large amount of air that needs treatment.

For the rotary drum dryer, an average technical maturity is estimated. It has investment costs and energy demand higher than those of the belt dryer, assumed to be high. It also generates a lot of polluted air to be treated and can cause safety problems and the risk of explosions.

The fluidized bed dryer is an attractive method for digestate treatment. One of the advantages is that it can work with a closed air circuit, in addition to its reduced maintenance and the absence of moving parts. The main disadvantage is the high electrical consumption by blowers and the need for uniformity in their supply.

Within composting technologies, static pile systems with forced aeration are adaptable to the production rates that are needed. This technology is mechanically simple, therefore low maintenance. Conversely, this configuration can be labor intensive and can produce nuisance odors and dust. Covering, negative aeration, chemical scrubbing, or use of a well-maintained biofilter may be required to minimize odor migration off-site. The popularity of the forced aeration static pile method is based on ease of design and operation and the lower capital costs associated with building the facilities.

Manual turning composting is adaptable, flexible and mechanically simple. However, it requires a large area and may result in the release of foul odor, dust and other airborne particles into the environment during turning.

Closed systems are less adaptable and flexible. However, they require a smaller area and generate relatively little dust outside the facility. Due to the increased complexity of mechanical systems, breakdowns are more frequent, and repairs are more difficult and costly.

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6.3.4 Nutrient concentration technologies in the liquid fraction

The liquid fraction can be subjected to the following treatments

- Nutrient Concentration Technologies
  - membranes
    - microfiltration
    - ultrafiltration
    - nanofiltration
    - Inverse osmosis
      - coiled membranes
      - vibrating membranes
  - Evaporation
- Nutrient recovery technologies
  - stripping
  - Struvite recovery
  - biological oxidation

Membrane filtration can be used for partial or complete processing of the digestate by physical separation. Normally three steps of reverse osmosis are needed to reach discharge levels of ammonia, before that solid liquid separation and filtration is needed. Particles that block or clog the membrane are a challenge when applied to digestate treatment. To solve the problem of clogging caused by membrane technology, vibratory membranes were developed. Although it requires high investments, it is an attractive technology due to its low OPEX, since it requires fewer chemicals than conventional membranes.

Evaporation can lead to high operating costs due to the use of chemical products to acidify and prevent foam formation. Acidification is used to retain ammonia in the concentrate. Furthermore, the high energy demands of 300-670 kWh per ton of water make evaporation only interesting when excess heat is available in sufficient quantities (Drosg et al., 2015). However, the cost of thermal energy could be greatly influenced by the application of low pressure, which allows heat to be used below 90 °C (Drosg et al., 2015).

In the case of ammonia extraction, an efficient separation of the liquid and solid fraction of the crude digestate is required before treatment, which can still require a high maintenance and cleaning effort (Drosg et al., 2015). It has a high separation efficiency (greater than 80%) but its main limitation is the organic matter carried along with the ammonia. Therefore, anaerobic digestion favors the production of good quality fertilizers. Also, ammonia stripping can only remove nitrogen.

On the other hand, the recovery of struvite produces a salt with good fertilizer characteristics. By removing ammonia and phosphorus, the nutrients can be concentrated into a product

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separate from the digestate. The digestate can then be handled more easily. However, the high operating cost due to the consumption of chemicals makes the technique less attractive.

Biological processes represent an unattractive option due to their significant operating expenses and high investment costs (Drosg et al., 2015). The NdN is generally used to treat the recirculation stream to the digester of the liquid fraction of the digestate. In this way, inhibitions by ammoniacal nitrogen are avoided.

6.4 Fertilizer market.

Having the digestate as a raw material would be an economic benefit for the fertilizer industry, since it is a local product, reducing the consumption of exported raw materials for the production of fertilizers, translating this into lower logistics costs.

The main component of the digestate is nitrogen, therefore, following the guidelines of *RD 506/2013* and *EU Regulation 1009/2019* , the following fertilizer products may be formulated:

- From the concentrate obtained from the evaporation and membrane processes:
    - Liquid organo-minerals of nitrogenous base
    - Complex liquid organo-minerals of the NPK, NK or NP type
    - Liquid organic EC fertilizers with nitrogenous base, NPK, NK or NP
- In the case of stripping with the liquid fraction
    - Ammonium nitrate solutions.
- From the composting of the solid fraction:
    - compost organic amendment
- When the solid fraction is subjected to thermal drying:
    - humic organic amendment

Finally, another group of fertilizers that can be formulated are phosphate or struvite salts, which are not currently covered by *RD 503/2016*, but have just been incorporated into *EU Regulation 1009/2019* through *DELEGATED REGULATION (EU) 2021/2086 DE THE COMMISSION of July 5, 2021 that modifies annexes II and IV of Regulation (EU) 2019/1009 of the European Parliament and of the Council in order to add precipitated phosphate salts and their derivatives.*

6.5 Possible applications of the digestate

In addition to its primary use as an agricultural feedstock, according to the Waste & Resources Action Program (WRAP), alternative uses for digestate include:

- Construction material
- Fuel production
- Use as livestock bedding
- Production of biopesticides
- algae production

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In addition to these alternative uses, it can be used to cover landfills and energy recovery through pyrolysis or gasification of the digestate and treatment by hydrothermal carbonization.

7 Commercial feasibility

7.1 Biomethane revenues

7.1.1 Revenue sources

The revenues of the biomethane producer related to the sale of the primary product (biomethane) may consist of several components:

- sales price of the molecules (corresponding to the prevailing prices on the market segment where the physical product is being delivered),
- feed-in-premium (FIP) from a financial support scheme of the national government, if any,
- price premium paid voluntarily by the customer in respect of the „green" value (environment friendly, renewable, sustainable, etc.) of the product, if any,
- price premium paid by the customer in respect of the tax benefits the consumer is granted for purchasing renewable gas,
- income from the sale of Guarantees of Origin, if any,
- income from the sale of biofuel certificates, if any,
- income from the sale of ETS certificates, if any.

7.2 Investment costs

The investment costs for a biogas unit are greatly influenced by the local conditions, among them the following non-technological factors may have a substantial impact:

- Availability of storage facilities for raw materials and fermentation residue, resp. the necessity of constructing new storage capacities for these purposes,
- Conditions for establishing both the electricity and natural gas network connections (voltage, pressure, distance, etc.)
- Magnitude of costs of earth works, road construction, etc.
- Logistics for substrate supplies and digestate placement.

No final feasibility study should be produced without having the site of the installation identified. The impact of site selection can be quantified in the pre-feasibility study phase through comparing the preliminary cash-flow calculations for different alternatives.

The capital budget is composed of the investment costs of the anaerobic digestion and upgrading units together with the auxiliary investments (like grid connection, utilities, etc.). Realistic and final feasibility study should be performed only based on the budget offers by the technology suppliers or EPC contractor(s). The preliminary cash-flow calculations provide a necessary and useful guidance for selecting the technology supplier(s) or EPC contractors. For

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example, comparing IRR for different technology solutions with regard to differences in prices, material and energy balances, utility consumptions, payment terms, etc. will facilitate the selection of the most feasible technology.

All relevant cost elements must be considered, among them the costs of

- the acquisition of the site,
- earth works,
- establishing the export and import network connections (electricity and natural gas),
- detailed engineering,
- permitting,
- construction, equipment, pipes etc. (including transportation to the site, potential customs clearance),
- instrumentation, control, and automation,
- first set of spare parts,
- gas analysis, local laboratory,
- internal roads,
- fencing,
- fire alarm and fire protection,
- lightning protection,
- energy and material costs for start-up,
- technical documentation, handbook for operation, etc.

7.3 Operational expenses

7.3.1 Raw materials

The list and costs of raw materials for biogas production.

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

It is to be noted that the actual electricity consumption depends on

- the selected fermentation technology, first on the consumption of the applied feed-in and mixing equipment and
- on the actual substrate qualities and composition.

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.

Usually, the local personnel do not include technicians trained for full service and maintenance of the machinery (CHP unit, agitators, mixers, etc.), the local staff does only daily routine checks and small caretaking tasks and calls the service company when needed.

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.

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 Example** in the range of 10.000 EUR/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.

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.

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7.3.8 Insurance

The costs of insurance must be included in the cash flow calculations of the feasibility study.

7.3.9 Banking expenses

The banking expenses must be included in the cash flow calculations of the feasibility study.

7.3.10 Administration and overhead expenses

Administration and overhead expenses must be included in the cash flow calculations of the feasibility study.

7.3.11 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

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. To enable fulfilling this role key issues must be studied and cleared in the pre-feasibility study phase, the most important among them:

- is there a non-repayable investment subsidy available and – if yes – under which conditions?
- is the project qualified for receiving an investment subsidy?

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- what is the level of private capital which could be invested into the project and what is the expectation of private investors for repayment and profitability?
- are banks/financing institutions ready to provide credit in form of direct project finance or securities are required from the stakeholders in the project?
- which are the basic requirements of banks/financing institutions for providing project finance (necessary Debt Service Coverage Ratio (DSCR), offered credit terms, such as interest rate, repayment period, grace period, supporting documentation).

Having collected the information on the above issues the feasibility study will determine whether the financing of the project under the given circumstances is possible.

The cash-flow calculation of the feasibility study applies the above listed information collected in the preparatory phase and supposed to confirm that the

- the project has acceptable feasibility indicators under the available conditions of financing,
- the credit service is guaranteed,
- the expectations of the private investors can be fulfilled.

7.5 Feasibility indicators

7.5.1 IRR

As one of the key indicators for feasibility usually the Internal Rate of Return (IRR) is selected. IRR is the discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. The higher a project's internal rate of return, the more desirable it is to undertake the project. As such, IRR can be used to rank several prospective projects or potential alternatives an investor is considering. Assuming all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best. One can think of IRR as the rate of growth a project is expected to generate. While the actual rate of return that a given project will in practice generate often differs from its estimated IRR rate, a project with a substantially higher IRR value (than other available options) would still provide a much better chance of good return on the investment.

7.5.2 NPV

Another feasibility indicator is the Net Present Value (NPV). The Net Present Value is the difference between the present value of cash inflows and the present value of cash outflows. By other words: the Net Present Value (NPV) of a project is the return on the investment (the sum of the discounted cash flows) less the cost of the investment.

NPV is used in capital budgeting to analyse the profitability of an investment or a project.

NPV compares the value of money (EUR) today to the value of that same money (EUR) in the future, taking a discount factor (for inflation and returns) into account.

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8 Overall risk assessment

The fourth element focuses on the major risks the proposed plan can entail. The overall risk assessment part of a feasibility study examines the different ways your organization can reduce the risk of embarking on the new action.

The overall risk assessment should answer the following questions:

- *What are the major risks associated with the construction and operation?*
- *What is the survival outlook for each of the above risks?*
- *How sensitive are the profits on different risk scenarios?*
- *What are the best ways to minimize these risks?*

The aim is to try to cover all the possibilities and create a risk assessment checklist, 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.

In addition, at launching a new project, the overall risk assessment should also consider one final question. Answering the question "*When can the project be able to support itself without extra financing?*" is an important part of a feasibility study. Self-sufficiency is crucial for business success, as having to borrow can hinder the long-term survivability of the activity.

The construction and operation of a biogas/biomethane plant involves environmental, health, safety, commercial and other risks. With the accumulated experience in the industry these risks are well understood and can be managed if not eliminated. The objective of risk management is to identify all potential risks and put in place suitable measures that will reduce these risks to acceptable levels.

Ensuring the health and safety of employees and the public, and the protection of the environment should be a priority when undertaking any activity, including the construction and operation of a biomethane producing installation.

The failure to identify and manage risks can result in a disproportionate number of accidents and incidents that have a negative impact on the environment, or on the health and safety of site employees and the public. This leads to a negative perception of the industry, and as a result leads to increased wariness of insurers and investors who work with the sector.

The effective risk management should result in:

- Prevention and/or management of pollution incidents and therefore avoidance or reduction of remediation costs.
- Prevention of accidents that could result in harm to employees, prosecution, and business disruption.

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- Better staff retention, by demonstrating commitment to their safety and wellbeing.
- Reduced cost of insurance premiums and better insurance policies.
- Improved operational performance, delivering higher quality outputs.
- Better overall financial performance.

The ADBA Best Practice Checklist Risk Management[5] provides a comprehensive description of different risks related to the anaerobic digestion technology and the content can be applied to the biogas-biomethane complex directly. The risk categories detailed on the ADBA paper are:

- catastrophic failure
- environmental risks
- health and safety risks
- commercial and reputational risks.

For project developers it is recommended to study the referred ADBA document.

In relation to a biomethane development project the risk management checklist can be specified to include the following items:

Collateral/bankability requirements

- How Is the off take of biomethane and by-products secured?
- Are there long-term substrate supply agreements with sufficient penalties imposed upon default of feedstock supply to cover the losses that would be suffered?
- Is there sufficient insurance over the project risks?
- Is there a long-term land lease agreement if the property is not owned by the project developer?

Permitting and licensing requirements

- Has a basic assessment or full Environmental Impact Assessment been completed?
- Has a waste management licence been obtained?
- Has an air emissions licence been obtained?
- Is there a natural gas grid connection agreement?
- Does the project have a licence for biomethane production (if needed under the domestic legislation)?
- Does the project have a construction permit?

Technical considerations

- Does the EPC contractor have sufficient experience/references?
- Is there a guaranteed performance ratio for the plant? Is this guarantee financially secured?

5 http://adbioresources.org/our-work/best-practice-scheme/best-practice-checklists

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- Does the EPC contract provide for O&M training, has sufficient handover period been allocated?
- Is there a base warrantee on equipment of at least 2 years?
- Has the technical design been reviewed by a qualified independent party?

Contracting requirements

- Have the rights of project properly secured in the respective contracts (land lease, permitting, licences, offtake agreements)?
- Have the construction, O&M, off-take, and feedstock agreements been compiled by parties experienced in biogas/biomethane projects?
- Have the EPC, O&M, off-take, and feedstock contracts been validated by qualified external parties, ideally experienced in biogas/biomethane projects?

Additional considerations

- Has the business model included at least 12 months commissioning time at zero revenue?
- Is there an environmentally responsible digestate management and placement plan?

All in all, a critical aspect is the involvement of the Public Administration developing economic and financial mechanisms formulated in a specific and dedicated program to support and promote renewable gas production projects.

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