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ZEFFIROS

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

DELIVERABLE 3.3

Guidelines for effective bio-waste management

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Sub-Deliverable 3.2.3b – e-Handbook on setting-up a biogas plant

Author: TEKMAP (as subcontractor)

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1. Introduction

To conserve finite fossil fuels and to simultaneously reduce greenhouse gas emissions and mitigation of global warming a gradual switch within renewable energy sources is a necessary task in the next decades. Here bioenergy plays a central role - also for agriculture branch. Bioenergy is a largely CO_2-neutral energy source and it is permanently renewable, as it is produced out of biomass, which is actually a living storage of solar energy through photosynthesis.

The production and utilisation of biogas has a special role within the renewable energies, because it is suitable for the simultaneous production of electricity and heat, useable as fuel for transport and as a substitute for natural gas. In addition, it can be used flexibly and relatively simply stored. And the biogas production is not subject to seasonal, diurnal or weather-related fluctuations and can also be generated from agricultural residues and leftovers. The production and utilization of biogas provides environmental and socioeconomic benefits for the society as a whole as well as for the involved farmers. Utilization of the internal value chain of biogas production enhances local economic capabilities, safeguards jobs in rural areas and increases regional purchasing power. It improves living standards and contributes to economic and social development (Seadi et al 2008).

Also the worship of environmental soundness and sustainability in the agriculture, especially in livestock farming, is becoming more and more important. The carbon footprint of meat, milk and related products is highly compared to vegetable food. One of the main reasons is the emission of methane by cold digestion of the manure produced by the animals. A good solution to reduce the emission of methane is to produce biogas out of the manure in biogas installations. Therefore, more and more farmers are interested in connecting manure utilisation and climate protection intelligently by using biogas technology.

Despite its multiple benefits, small-to-medium scale biogas plants are not yet widely implemented in European livestock farming, or its implementation varies extremely between the European member states. The present handbook for the development and execution of a biogas project, is intended to assist farmers and relevant stakeholders by checking the feasibility of a micro-to-medium-scale digester for localized farm ecosystems. It serves as a guideline presenting the basics of biogas production and utilization and describes the essential steps for developing a biogas project (from the idea to plant operation) in a unified way regardless any intra-country variations in political, financial and legislative frameworks.

1.1. Aim and content of the handbook

Essential for a successful biogas project realization is among others a (practical) long-term view, a good organization and fulfilled technical conditions. To make sure that the anaerobic digestion plant is profitable in long term, the project has to be well planned. This handbook sets its main focus on small-to-medium scale anaerobic digestion plants, running on farm based agricultural side products and residues with a power production capacity from 100 kW_{el} up to about 500 kW_{el}.

The handbook is created to support farmers and interested parties who are interested in using farm related biomass resources for producing a more sustainable renewable energy and are willing to invest in a small-to-medium scale biogas plant in a localized farm ecosystem.

The guideline describes the essential steps for developing a biogas project, beginning with the project idea, over creating a business plan until the final step of plant operation. The handbook starts with a short introduction into the biological biogas production, types of gas utilisation and digestate treatment and gives some general information about realizing a project (Figure 3 gives an overview on the main steps that the farmer/stakeholder has to fulfil to make the project becoming real, profitable and lasting). This is followed by the five main steps of project implementation which are outlined in separate chapters. It makes no claim to be complete. Certain frame conditions may demand modifications from the proceedings presented in this guide.

Annex 1 shows and describes different types of contracts, e.g. for plants construction or external heat supply to purchasers, which might be necessary for realizing a bioenergy project and operating a biogas plant.

Annex 2 provides a checklist for developing the "project idea" and also for the compilation of documents for permit application.

2. Biogas essentials

2.1. Basic knowledge on biogas formation

When organic matter (biomass) is degraded in the absence of oxygen (anaerobic) by microbiological processes, various gases are formed. This gas mixture produced by anaerobic digestion is also referred to as biogas. Digestate is a by-product of the fermentation process. The digestate which results from the anaerobic digestion process is a decomposed substrate, rich in macro and micro nutrients and therefore suitable to be used as plant fertilizer.

Anaerobic digestion is perfectly eligible for agricultural activities since energy crops (e.g. maize, whole grain crops.), organic residues (e.g. manure), side products (e.g. fruit pomace, oil seed leftover) and organic wastes are efficient substrates available or produced on farms.

Biogas consists essentially of methane (CH_4) and carbon dioxide (CO_2) and additionally of hydrogen (H_2), hydrogen sulphide (H_2S), ammonia (NH_3) and other trace gases. The biogas composition is mainly influenced by the substrates used for digestion and the fermentation processes itself. The type of substrate or substrate mixture primarily determined the biogas condition.

The process of biogas formation basically runs in four microbiological steps which are temporally parallel (see Fig. 1). For a smooth process the individual degradation phases have to be optimally balanced to the requirements of the bacteria involved (e.g. pH-value, temperature).

Table 1. Approximate composition of biogas

Component	Formula	Unit	Concentration
Methane	CH_4	Vol.-%	50 - 75
Carbon dioxide	CO_2	Vol.-%	25 - 45
Water	H_20	Vol.-% (20-40 °C)	2 - 7
Hydrogen sulfide	H_2S	ppm	20 – 20.000
Nitrogen	N_2	Vol.-%	< 2
Oxygen	O_2	Vol.-%	< 2
Hydrogen	H_2	Vol.-%	< 1

ppm: parts per million

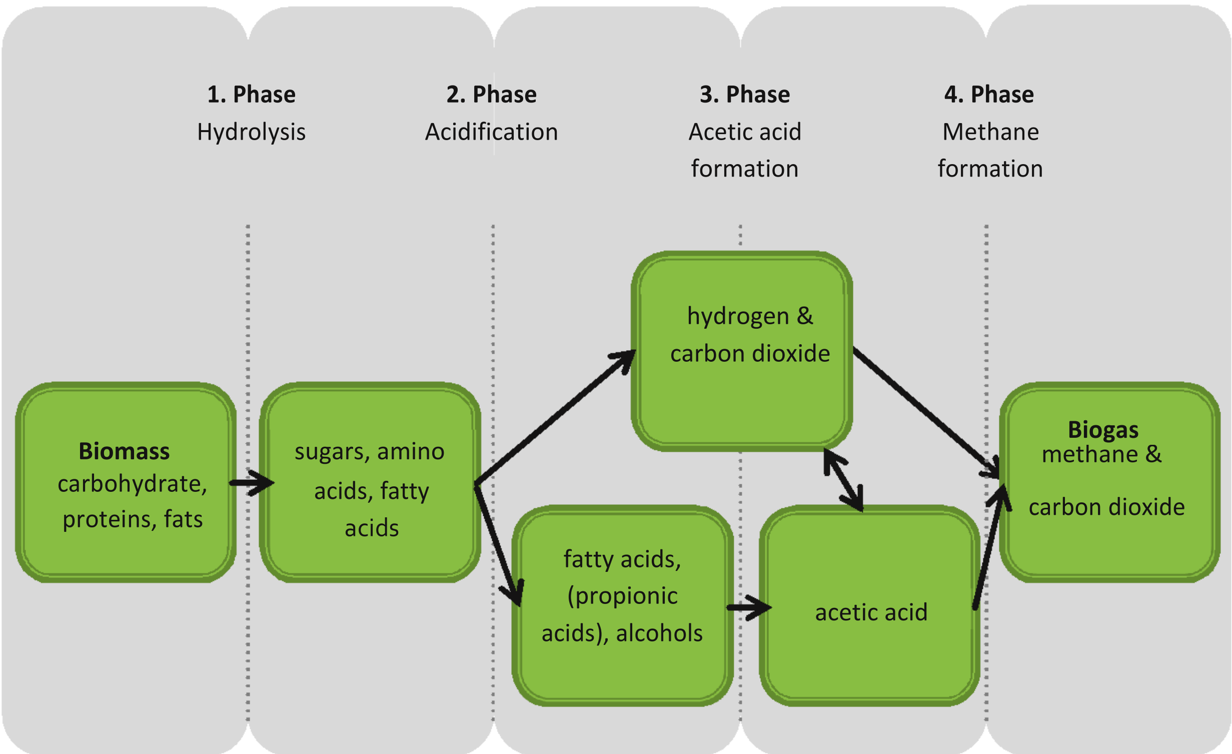

Figure 1. Depicting anaerobic decomposition phases

In the first step the "hydrolysis", the substrate, which is composed of complex compounds (like carbohydrates, proteins and fats), will be cleaved by exo-enzymes in more simple organic compounds (e.g. amino acids, sugars, fatty acids).

The intermediates formed are further broken down in the second step, the so-called "acidification" (acidogenese), through acid-forming bacteria to short-chain fatty acids (acetic, propionic and butyric acid) and carbon dioxide and hydrogen and small amounts of lactic acid and alcohols.

In the third phase, the so-called "acetic acid formation (acetogenesis), the products of acidification will be implemented mainly to acetic acid, hydrogen and carbon dioxide. The acetic acid is formed from organic acids. When this process step is disturbed, an enrichment of acids will occur, because only the methanogens can degrade the acetic acids.

In the last step of biogas generation, the so-called "methanogenesis", bacteria produce biogas over two pathways; from acetic acid and hydrogen and carbon dioxide (KTBL 2013).

Depending on the design and operation of the biogas plant as well as the used biomasses, different environmental conditions are required for optimal activity of the microbes. Therefore, following parameters, among others, should be kept in mind (FNR 2013):

- the oxygen input into the fermenter should not be too high
- the temperature in the digester should be matched to the involved microorganisms (e.g. at mesophilic operation: 37-42 ^{o}C)
- the pH-value of the substrate in the fermenter should range between pH 6.5 and 8 (at single-phase processes) and
- the digester should be balanced in terms of macro and micro nutrients.

In general, the operating conditions of a biogas plant should be kept as constant as possible. Especially important is the feed-in of substrate. Some typical mistakes concerning the plant feeding are:

- feeding substrate continuously over a long period of time substrate is to irregularly supplied
- fast switching of substrates with different composition/quality or
- feeding to much substrate after a "feeding pause" (e.g. due to technical problems).

The rate of gas production and the process itself is very sensible and can easily be inhibited. Inhibitors may decrease already in small amounts the degradation rate and gas production or lead to a complete standstill at toxic levels. For example, antibiotics can enter the digester via the manure. Even in small amounts antibiotics, disinfectants or solvents, herbicides or salts of heavy metals can inhibit the degradation process in the digester (KTBL 2013).

2.2. Production of biogas

In agricultural livestock farms cost free substrates like manure, fodder residues and wastes incur. Manure only has a low energy density, because of the high water content and the rather low specific gas yield. This makes it less transport-worthy and economically unattractive at long transportation distances. In order to exploit the potential, inexpensive and easy to operate plants in low (power) capacity range are now available.

Slurry is hydraulically easy to handle. With a high proportion of manure in the digester, also hydraulically challenging substrates, such as grass or solid manure, can be used relatively easy in a small biogas plant (FNR 2013). The adjustment of technology, used substrates and kind of operation thereby decides about the quality of plant operation and the achievable biogas yields. The substrates used ultimately determine the needed appropriate technology and their interpretation, such as cutting units, sizing of pipes, pumps, gas treatment, gas storage and CHP unit (LFU 2007).

Among the general technical requirements for a pure manure digestion, the heat balance can be a critical point – particularly during winter time. Especially at long periods of cold weather, the heat supply for the plant and external heat consumers, such as stables and residential buildings, might be difficult.

The market shows a considerable breadth of different technical solutions for small scale biogas plants, incl. wet fermentation and solid-state fermentation systems. The offered plant concepts range from custom-made systems which include existing facilities on farm (e.g. manure storage and pumps, buildings for the CHP installation or integration of new stable concept into plant construction) to various special concepts, where essential parts have been prefabricated by the manufacturer. Partial existing concepts have been specifically optimized for this type of plant with efforts also to simplify the cost (FNR 2013).

In summary it can be said, that depending on the type of substrate (e.g. fodder leftovers, litter or grass as a co-substrate) and local conditions (e.g. necessary construction for slurry storage), the technical suitability and benefits of each concept should be examined carefully and if possible with support of a neutral consultant.

2.3. Utilization of biogas

The biogas produced is versatile. Mostly it is used in combined heat and power plant-units (CHP) on site. The electricity generated is fed into the public grid or used on site for self-consumption. The internal consumption of the biogas plant can be covered either by the power grid or from the CHP.

In addition to the electricity produced, a CHP also provides heat energy from exhaust and engine cooling. A portion of the generated CHP heat is used to heat up the digester. However, some heat generated is for any other use available (LfU 2007).

Biogas can also be used in boiler for generating low temperature heat for heating and drying equipment or for steam generation. The condition is that the biogas quality meets the requirements of the boiler.

2.3.1. Plant for Combined heat and power (CHP)

As engines for combined heat and power units, spark-ignition or pilot injection gas engines are normally used. Spark-ignition engines (gas engine) are specially designed for gas operation and can be operated with methane content in the biogas from about 45 % and above. They have a gas mixer and a spark ignition ignites the gas mixture.

Pilot injection gas engine work on the diesel engine principle, which are accordingly series engines modified for biogas operation. They are often used for biogas plants with a lower power capacity, because the compressed gas mixture is mixed over injectors with small amounts of ignition oil (biodiesel, vegetable oil). And the engines can be operated with pure ignition oil, if the biogas has low methane content in the biogas or by failure of the biogas production (LFU 2007).

2.3.2. Plant for biogas upgrading

Alternatively, to electricity generation in a CHP directly on site, biogas can also be treated and upgraded into biomethane. Biomethane is a natural gas substitute produced from biogas, which can be injected into the natural gas grid and then be used like normal natural gas.

Physically, biomethane is the same as natural gas and therefor it can easily be used e.g. to generate electricity and heat in CHP or in turbines, boilers or as vehicle fuel.

With the upgrading of (raw) biogas and injecting biomethane into the natural gas grid, a spatial and temporal decoupling between biogas production and use can be realized. This allows a more efficient and demand-driven use of biogas. However, the connection to the natural gas grid is not always possible or economically feasible, as processing and grid connection costs require larger biogas plants (KTBL 2012).

The most common methods for upgrading biogas are pressure washing, pressure swing adsorption, the amine scrubbing and the treatment by membrane technology (KTBL 2012).

A decentralized electricity generation from biogas in plants with combined heat and power units is more attractive when a large part of the generated heat can be used in close proximity of production. In the pre-planning phase of a biogas plant all possibilities of biogas utilization should therefore be included.

2.4. Digestate management

The material terms of the digestate by spreading it on farmland in the immediate surroundings of the biogas plant is still the most (cost) effective variant to deal with the fermentation residues. The project development should clarify the question whether there is sufficient arable land for spreading available or if a guaranteed purchaser for the incurred digestate exists. Only when these options are not given, it makes sense to deal with the processing of the digestate (Fuchs & Drosg 2010).

With processing and treatment of digestate, the pressure on the local rental market for arable land can be reduced, the transportability of the nutrients from the digestate can be increased, a potential excess of nutrients in the region can be defused and storage and application costs might be saved.

In addition, the marketability of liquid and spreadable fertilizers is increased and, not least, reduced environmental impact by avoiding volatile air and atmospheric pollutants.

The digestate treatment methods are divided into the following methods (KTBL 2013):

- partial treatment: separation of solids and production of a nutrient reduced liquid phase or process water
- full treatment: removal of solids and production of an nutrient-rich concentrate; purification of the liquid phase up to a quality that permits a direct discharge into receiving waters.

The dimensioning and the strategy of a digestate treatment plant are primarily based on the following points (Fuchs & Drosg 2010):

- Which digestate amounts inure during plant operation and what's the associated nutrient amount? Which share of digestate can be applied to self-owned or contractual (external)
- Are there other potential purchasers for the digestate in the region?
- What opportunities exist to promote the end products of digestate treatment such as for example compost or liquid nutrient?
- Is unused surplus heat from the operation of a CHP plant or similar available which can be used for the digestate treatment, like drying or evaporation?

2.4.1. Separation of digestate

The digestate processing begins with the separation of liquid and solid fraction in preparation for the subsequent, mostly mechanical or thermal processes.

The separation is performed mechanically using centrifuges or screw presses. For simple applications such as the separation for the production of thin liquid recirculated, no further processing steps of the digestate are required.

2.4.2. Solid fraction treatment

With processing / treatment of the solid phase, a high-quality fertilizer can be produced. The removal of the water allows economically transport of the fraction over longer distances.

Drying process (like belt dryer, thrust reversing dryer, fluid bed dryer) remove the water in the digestate by overflowing it with a hot air stream. As heat source in this case, the surplus heat from CHP can be used. In addition to the removal of water, the digestate will be sanitized and pasteurized by using the CHP heat (KTBL 2013).

2.4.3. Liquid fraction treatment

Beside the direct use of the liquid phase as liquid fertilizer it is possible, to continue the treatment process (full treatment) to achieve a quality of the liquid phase which allows the direct discharge into receiving waters. The effort, requirements and costs for this full treatment process are usually high.

A method to reach this treatment level is the membrane technology. Here, the liquid phase from the separation flows over a membrane which retains solid particles, bacteria, and, in the case of reverse osmosis, dissolved salts in water. The reverse osmosis has due to the large sensitivity of the membranes high demands on the input material: this must usually be first separated and filtered coarse and then pre-treated by ultrafiltration.

3. Fundamental information for a biogas plant set-up

Biogas projects for energy production require a certain amount of investment and structural actions at the farm. That is why it is so important to plan such kind of project very well and specially to proof the economic sustainability of it before checking the technical feasibility. When realising a biogas project, project initiators (e.g. farmers) have the option of carrying out certain phasing of the project themselves, depending on their personal commitment and available financial and personnel resources.

Especially in the early phase of a project the project initiator or else the future plant operators play an important role. In designing a project outline for the first project assessment and for the subsequent development of a feasibility study the future plant operators can or must contribute own information, ideas, desires, expectations and decisions. This ensures that the framework is locally aligned and optimized thus to a long-term sustainable plan.

It is necessary to make project changes at the beginning of the project (as soon as possible) to have bigger positive influences in comparison to make them later in an advanced stage of the project (see Figure 2). Another advantage of doing this early is that costs and time are less than in advanced staged projects. For a successful and expected course of project this means, the sooner you act in an early project stage against wrong decisions, the more influence it has on the general costs of the project and it will cost less to do these changes. For this reasons it is extremely important to do an initial project evaluation even before a sustainability study.

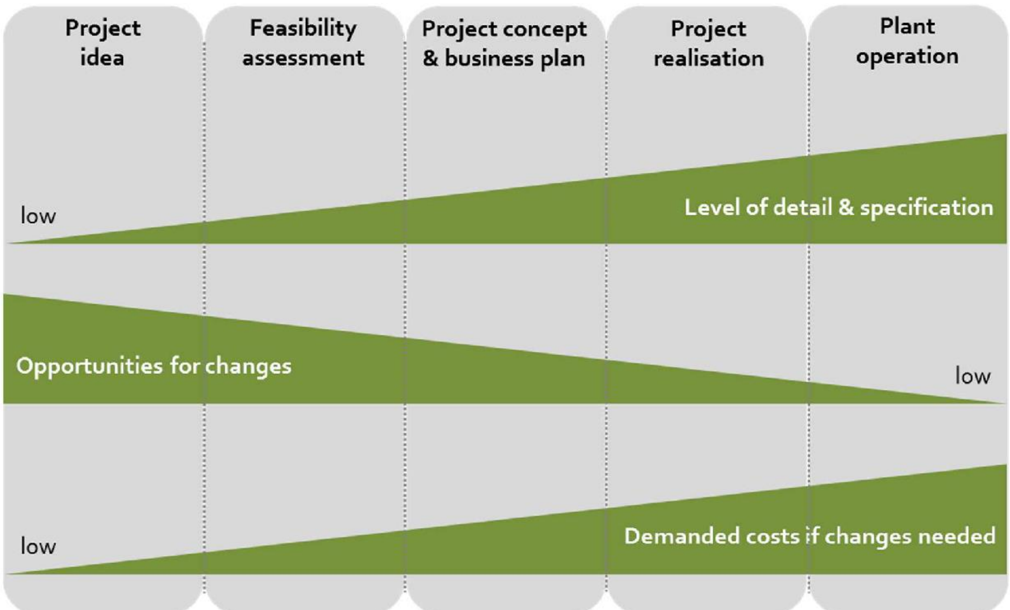

Figure 2. A picture of the overall project & risk management components

The preparation of project idea and feasibility study thus provides a discrete but evolutionary process of project development and realisation. Therefore, the whole chain starting from biomass supply, to power generation and energy loss to digestate management has to be taken into account. And questions that arise along this chain have to be clarified (Eltrop et al 2014). The individual phases of concept formulation, feasibility study, capital expenditure planning, permitting procedure, plant construction and commissioning are presented in this handbook.

The following Figure 3 shows the different essential steps or phases of the project development and some aspects which should be considered by implementing a biogas plant.

Figure 3. Project development phases and fundamental questions for setting-up a biogas plant

4. Project's idea phase

The project idea begins with the questions e.g., if a biogas plant will fit into the agricultural business, will the project be helpful to enhance the farm in its development and what information's are needed to answer these questions and to develop a precise project idea.

This first step of the project embraces all the basic questions the farmer should have during his first reflection to decide, if he wants to go on planning a biogas project. As it is the first step of action, mainly general data collection, qualitative assessments and rough quantitative calculations can be done by the farmer itself.

When considering a biogas project, it is important to see the whole picture, including the availability of substrate, the actual biogas plant and the supply of energy to purchasers. The three aspects presented in Figure 2 must be considered from the outset in the same degree of detail, the objective being to carry out a well-founded initial evaluation of the project concept.

The farmer/stakeholder has to care about subjects like the availability of substrates for biogas use and the options for transport and storage, first settings on plant type and on categories of production capacity on the options for energy use so as information on plant location and implementation into the existing farm (see Table 2).

Table 2. Thematics to be addressed during the ''project idea'' phase

Substrates	• Quantity • Availability & Logistics • Quality
Biogas plant	• Type of Anaerobic Digestion concept • Size of plant • Location
Energy output & residues	• Energy production & use • Use of residues
Investment & benefits	• Costs of the plant • Benefits of the biogas project
Type of company	• Legal form of the biogas project
Field reports	• Visiting comparable plants • Experiences from farmers

An initial evaluation of the project does not require definite decisions on the above-mentioned aspects (this will take place in the subsequent planning phase). Rather, the aim is to ensure that there are at least one or, if possible, several options for successful realisation of the project (FNR 2013).

At the end of the first step "project idea", the farmer/stakeholder will have a clearer idea of his project thanks to first qualitative and rough quantitative calculations regarding the substrate provision, the plant capacity and the produced energy. The farmer will decide to stop the project or to go on and specify his project idea in more detail.

The following aspects for the first project overview will be described in more detail. The Annex I provides a checklist on the main aspects introduced below.

4.1. Availability of feedstock

The farmer has to specify and pre-estimate the substrates available on his farm for running a biogas plant. This starts from the different kinds of feedstock / substrate available on the farm and also when the substrates will be available during the year (continuous, seasonal, once a year) in long term. But this only counts for fermentable substrates. Biomasses with high cellulose content or "bulky" substrates like horse dung with straw may need a pre-treatment before use. Woody biomasses are not suitable for anaerobic digestion. Additionally, the substrate provision from nearby farmers or industries should be considered.

The following questions are of relevance:

- ✓ Which kind of self-produced substrates (e.g. livestock manure or dung, clover-grass, energy crops and/or residues from agricultural production like potato peelings) are available in the long term?
- ✓ Do I have medium-term/long-term plans to change my farm?
- ✓ Will the farm-produced substrate be enough in long term for running a biogas plant?
- ✓ Will there be some suppliers nearby who can provide substrates regularly, in long term and to which costs?
- ✓ Is the use of these substrates worthwhile in view of the statutory requirements (question of proportionality, e.g. by using hygienic risky wastes)?
- ✓ Are the substrates suitable for the anaerobic digestion? Do I might need a pre-treatment for some biomasses?
- ✓ How much tonnes will be available every year and when?
- ✓ Which pre-estimated qualities will the biomasses have (biogas yield per tonne)?
- ✓ How is the surrounding infrastructure - will the farmer and/or supplier will be able to transport the substrates easily and cheap to the plant?

4.2. Size and capacity of the plant

The substrate potential of the farm and the resulting biogas potential are decisive for the dimensioning and design of the biogas plant and producing energy quantity. Based on the pre-estimated substrate data the plants type, the category of the plant size and the plant capacity can firstly be estimated.

Plant technology for biogas recovery covers a very wide spectrum. There are virtually no limits in terms of component and equipment combinations. It must be noted, however, that expert analysis of plant and system suitability and capacity adaptation on a case-to-case basis are invariably required. There are several variant processes for generating biogas and many different concepts for small-scale anaerobic digestion on the market [KTBL 2013].

One question is what method or concept might be the right one for the substrate mix that will be gained from the farm. The classification of the processes for generating biogas according to different criteria (Eder 2012, KTBL 2013) like

- dry matter content of the substrate (wet digestion or solid-state fermentation)
  type of feed (plant runs continuously, quasi-continuously or intermittent (batch))
- type of concept (plant with stirred vessel, compact plant, tower systems / high fermenter)
  process temperature (mesophilic or thermophilic operation).

The plant size results significantly from the farm-produced substrate mix and its specific gas and methane yield, from which the producible biogas quantity can roughly be determined. Based on standard biogas yield values for each type of biomass used, the possible annual biogas-and methane yield can be estimated. This can be used for the dimensioning of the biogas plant and to estimate the producible energy amount. The capacity of the plant can be indicated in produced electricity (kWh_{el}), produced heat (kWh_{th}) or produced (raw) biogas or biomethane (m^3/h).

With the online calculation tool on www.bioenergyfarm.eu, the first assessment on biogas production and size of the biogas plant can be checked.

The information on the plant size will also contribute to think about the adequate and acceptable location for the biogas plant and to about the question how will operate the plant.

4.3. Energy output and residues

Based on the gas formation potential of the annual substrate for the plant, the expected amount of energy can be roughly estimated. The farmer should think about how he will use the produced energy. Depending on the conversion-process (CHP, boiler or biomethane production) different types of energy or products will be produced.

For biogas typically electricity and heat will be produced in a combined heat and power plant (CHP) on the farm. The electricity can be fed into the electricity grid or used to reduce the electrical purchase of the business. The produced heat is firstly needed to hold the process temperature of the plants. Depending on the plant size, the substrate mixture (high manure content has a high heating demand) and weather conditions, a varying amount of surplus can be used on the farm for heating and warm water production. It also might be possible to deliver external heat customers (e.g. greenhouses, pig farms, neighbouring houses and enterprises).

Biogas can also be used in a boiler for heat production only or, as an alternative option to CHP, be upgraded to biomethane (natural gas quality level) and fed into the national gas grid to be delivered to the customers directly.

In addition, the fermentation produces digestate as a by-product that can be used as fertilizer and therefore partially replace mineral fertilizer.

The properties of the digestate or their ingredients are essentially determined by the materials going into the fermentation process and the anaerobic digestion itself. The positive effects on the properties of the digestate are:

- reduction of odour by degradation of volatile organic compounds
- extensive degradation of short-chain organic acids and thus minimizing the risk for leaf burn,
- improving the (flow) properties and consequently reduction of leaf contamination of fodder crops and less effort during homogenization,
- improvement in short-term nitrogen effect by increasing the content of fast-acting nitrogen and
- destruction or inactivation of weed seeds and pathogens (human-, zoological and phytopathogenic).

Since the carbon fraction is changed by the fermentation of substrates, in essence the nutrients remain unchanged. The nutrients in the digestate are more soluble and therefore more available to plants after the anaerobic digestion process [KTBL 1999].

In addition, the digestate also carries a certain value, which can be calculated on the basis of current fertilizer prices. The value of 1 m³ manure digestate is (country specific) about 10 € per ton. Related to the value is also the transportability. At a distance of more than approx. 18 km the transport costs for digestate exceed the price for mineral fertilisers [EDER 2012] and transport is no longer feasible in economic terms.

The following main questions are of relevance:

- ✓ Which form(s) of energy do I want to produce (electricity/ heat, heat or gas)?
- ✓ Is the energy production only for farm-based (own) consumption?
- ✓ Who will buy the energy?
- ✓ Are there potential heat purchasers close to my farm? Do I have to invest in a local destitution network?
- ✓ How much heat needs to be supplied every month?
- ✓ Will there be enough surplus heat from a small-scale biogas plant, to ensure constant delivery to external heat customers?
- ✓ How much digestate will I produce?
- ✓ What opportunities of post-fermentation waste management are available?

- ✓ Will the post-fermentation waste management be an additional cost or income position?

4.4. Expected investments and benefits

Based on the rough estimation of the annual biogas yield from the available biomass and the resulting plant sizes, a first assessment of the necessary investment for the biogas plant can be done. In addition, first predications on the potential benefits and revenues can be made.

4.5. Type of company for the relevant biogas business

The question of the legal form for the construction and operation of a biogas plant must be clarified early in advance of the project. The choice of the legal form is not just a question of tax burden, but there is a significant interaction between National Corporation and fiscal law, because the taxation law has normally different consequences depending on the legal form.

In many countries, individual enterprises are very common in agriculture. With the inclusion of an agricultural activity, either through the establishment of a company or from the transfer of a business, the owner becomes an individual enterprise who scores income for tax purposes. The advantages of a legal form for the establishment or acquisition of a biogas plant often depends on the size of the biogas plant and the way in raising capital. For small scale biogas plants it may be preferable in some countries, to operate them as a side business to the farm. Thus, the legal form of the farm business is also critical for the companion business. The legal form can be individual enterprise or a business partnership, like a partnership organised under the civil code (FNR 2013, FNR 2013 B).

Biogas plants which will be run as a separate business, beside the initially farm business, might have a limited partnership or possibly a private limited company as legal forms. Differences between the individual legal forms are, for example, the liability, allocation of profits, publication requirements, capital raising and administration of a business (FNR 2013, FNR 2013 B).

The farmer/stakeholder should think in parallel about the nature/structure he'd like to give to his enterprise.

In addition to the technical aspects of the biogas project, the fiscal aspect has to be kept in mind. This applies for example income tax, business tax or sales tax. Tax law related issues are not covered in this handbook, but they should be discussed in each case with a tax consultant or the taxation authorities.

4.6. Inspect existing plants

For the development of a biogas project it is always beneficial to visit some existing plants as a way of acquiring experience and information. Therefore, it is very helpful to get in contact with other farmers, biogas plant operator or plant builders to get information e.g. about

- experience of existing plant operators with various components and substrate combinations

- structural options available on the market
- practical information about realising a biogas project as well as about the bottlenecks
- structural/process-related problems and maybe how to solve them
- what kind of technical solutions where found
- experience in the planning and approval of the plant
- assessment of the needed project run-time from planning till energy production.

5. Feasibility study

Objective of the feasibility study is to analyse among other things the technical solutions and alternative concepts and to assess the level of risk. For this purpose, it is advisable to consult a specialist. The assessment leads to an overall impression and allows a specific recommendation for a specific concept, which can be further substantiated.

The implementation of a new operating branch in the existing agricultural business by a new biogas plant can substantially be attributed on the following arguments:

- ✓ to broaden the production base
- ✓ risk protection of the income by the use of the biogas power (new earnings)
- ✓ provision of liquid funds throughout the financial year
- ✓ energetic utilization of waste materials and by-products
- ✓ Reduction of emissions and odours from manure storage and application of fertilizers
- ✓ Improvement of plant availability of nutrients and enhancement of fertilizer application from manure
- ✓ autonomous energy supply and
- ✓ improved image.

Before the decision is made for biogas, the different possibilities of biogas production and utilization should be checked for the conditions set by the farm and possible risks should be assessed.

Table 3. Specifics to be addressed within the feasibility study

Substrates	• Quantity & Logistics • Quality (e.g. biogas yield)
Biogas plant	• AD Technology • Parameters • Location
Energy output	• Annual Energy production • Annual Energy utilization
Economy	• Detailed costs on annual basis • Detailed revenues on annual basis
Type of company	• Legal form of the biogas project • Role of the farmere/stakeholder
Obstacles	• Identify bottlenecks • Describe solutions

If the farmer wants to go further in his biogas project, he must define his project in a more precise way, analysing the different technical options and details for substrate provision, bioenergy production and utilisation. Additionally, he will study them to know if they are profitable in long-term and environmentally and socially acceptable.

Chapter 3 shows that with growing level of project detail and establishment, the opportunities for technical and structural changes decrease. At the same time, the costs are increasing if changes are necessary. Thus, a well-structured and thorough planning is essential for (economically) successfully realizing a biogas plant.

For this purpose, the farmer/stakeholder may ask a suitable association or a professional biogas consultant to give him support. They will ask the farmer for detailed information on the purpose of his project, his farm (agricultural production, livestock), the surrounding area, etc. They will provide the farmer with technical and practical information and will give him good advices to optimize his biogas project. They will make detailed calculations on the substrate potentials, plant size, energy output and utilization as well as of the demanded yearly costs and yearly income.

Together with an expert or consultant, the farmer/stakeholder can make relevant calculations to get further in his biogas project by creating a feasibility assessment.

Different project options have to be studied deeply during this step. Those options are all well-described and feasible (profitable and respectful of social/ecological aspects in the long-term). At this time the farmer should be very aware about everything which deals with realizing and running an anaerobic digestion plant – such as the fermentation biology, the substrates, the different types of companies he can create for the plant, how to make a detailed overview on costs and incomes, the required building conditions regarding environmental and social aspects, demands for the plant operation, etc.

5.1. Potential offered by substrates

Starting points for the establishment of an agricultural biogas plant should be among others the available manure and residues on farm, the worthwhile local heat sink and exploitation potential for the digestate.

Specifically, it is this necessary to determine the available amount of manure and its properties (like dry matter and organic dry matter content), which are depending on the kind of livestock and the type of animal husbandry (a reference value is 0.15 till 0.2 kW/livestock unit (500 kg live weight)). To determine the amount of manure e.g. agricultural advisory services or technical literature can be used. It should be noted a single slurry sample often provides only an uncertain value - this applies to the determination of the process flow as well as for the biogas yield determination in the laboratory.

In addition, the amount of agricultural residues (such as fodder leftover, Silo topcoats, etc.) and, if available, by-products have to be detected as possible cost-neutral substrates (in temporal and quantitative amount in observance of availability and transport distances).

The dimension of the project (plant) is mainly determined from the biogas-production rate of the substrate mix. The standard biogas yield values for each type of biomass used (see Table 4) allows to predict the annual biogas-and methane yield and therefore the energetic capacity of the plant (which is baseline for the economic feasibility of the project).

The achievable biogas yield is influenced by the composition and storage of the substrate and by the process technology itself. The storage time of liquid manure before the digestion process for example affects noticeably the biogas potential. Thus, the biogas yield can be reduced after one week of storage by up to about 50%.

The estimation of the expected yield of gas, which is necessary for the construction of biogas plants as part of the planning, will be based on individual experience. This leads to very different dimensions of the equipment under otherwise identical initial conditions. Since biogas plants are characterized by high capital requirements and longevity, errors appearing in the system design are often serious, because later correction of design defects is usually not possible. For these reasons, (uniform) standard values for estimating the gas yield of agricultural biogas plants are used on the basis of existing knowledge (KTBL 2015).

Table 4. Standard biogas properties of some commonly met substrates

Substrate	Characteristics	Dry Matter (% of fresh)	Organic Dry Matter (% of DM)	Biogas yield (l_N/kg oDM)	Methane share (%)
Poultry dung	depending on the straw-feces ratio, short-stored	40	75	500	55
Cattle dung		25	85	450	55
Cattle manure	Incl.fodder residues	8,5	80	380	55
Pig manure		6	80	420	60
Maize silage		35	95	650	52
Grain silage	Medium grain fraction	35	95	620	53
Fodder beet silage	oDM acidily corrected	16	90	700	52
Clover grass silage		30	90	580	55
Grain litter		88	85	650	56

The farmer/stakeholder, e. g. together with an expert or consultant, has to quantify and specify the substrates available for the biogas production on the farm. Additionally, substrates available on neighbouring farms will be considered in the quantification if willingness on participation has been expressed by other parties. Information is necessary on which substrates are available regularly and which substrates are available seasonally, on transport distances and means as well as on storage facilities.

5.2. Biogas technology

The technical details of the biogas plant need to be specified (e.g. plant concept, size/capacity, compounds, material of the digester, type of gas utilisation (CHP-Unit, boiler, biomethane production etc.) and eventually options for heat utilization.

In this context, different technical options/solutions for substrate provision and bioenergy production and utilization have to be elaborated. Additionally, an appropriate location for the biogas plant (including storage, additional rooms or installations, etc.) has to be identified (see next chapter).

Moreover, in addition to choose the right plant concept some conditions should be noted, such as:

- existing storage capacity (for silage, digestate)
- heat requirement of the operation or the surrounding customers (volumes, annual load profile)
- entry points for electricity
- integration into the heat supply net
- if necessary, a redundant source of heat (in case of failure of the CHP during winter)
- usable buildings substance (e.g. for CHP or gas storage) or storage vessel as a new digestate storage
- workload of the plants suitable for labour available on-farm
- arable land for application of digestate.

5.3. The choice of location

With increasing plant size and technology, the importance of the right plant location increases. The possibilities for distribution and use of the produced energy are particular important here. It has to be kept in mind that the transport of heat is only economically sensible over a short distance and the transmission of electricity in the low voltage range might also result in a reduction of the economic yield because of significant line losses.

For the site search it is relevant, how the distribution of the substrate and the digestate will be realized. Furthermore, it must be determined whether the necessary substrate quantities and qualities on site are available in the longer term.

These are some influences on the choice of the site location for a biogas plant:

- ✓ legal requirements (distance regulations (emissions, noise, hygiene), water protection)

- ✓ infrastructure (roads, logistics)
- ✓ minimal pumping distances, minimal driving distances for front loader, use of gravitation instead of pumping
- ✓ distribution of energy products (entry points of electricity (transformer), heat sink location, micro gas line, entry point to gas grid (biomethane) or location filling station)
- ✓ distribution areas of the fermentation products (digestate)
- ✓ geological settings (water protection area, construction ground)
- ✓ expansion capabilities of the plant
- ✓ funding (funding opportunities related to the location).

5.4. Energy production and utilization

The farmer/stakeholder together with the expert or consultant will calculate the yearly amount of electricity, heat or gas resulting from the different solutions identified above.

The energy demand of the anaerobic digestion plant as well as the one from the farm incl. associated building and other (external) customers will be identified.

5.5. Economics

Starting points for the establishment of an agricultural biogas plant should be the available manure and residues, the useful utilization of the produced heat and the exploitation potential for the digestate. The decisive aspect in the decision to build a biogas plant is the question of whether the inserted factors capital and labour can be adequately remunerated. In other words, can the proposed biogas plant be operated economically?

For the so far identified farm-based (plant) concepts, the total investment costs have to be identified as well as the probable cost of operation including all variable and overhead costs for the whole biogas plant and additional relevant buildings and installations. The farmer/stakeholder can, with support of the expert, determine the economic situations of the concepts analysed so far. Relevant information refers to demanded total investment costs, the upcoming annual costs (also for operation, maintenance capital allowance, replacement investment, personnel, insurance etc.) and yearly income from selling the produced energy. So the farmer/stakeholder will get an overview of the costs and income of the biogas plant on a yearly basis. Additionally, he/she can match the data with his/her personal and operative financial situation which is essential for the decision making process. With the help of a balance sheet, an overview on life time basis of the plant and information on the payback period of the project should be concluded.

The combination of biogas production and animal husbandry are clear synergies in terms of economy and often also in terms of work-based economy. It is important that the size of the biogas plant and thus the labour requirement is adapted to the operating conditions of the farm.

In this phase, the farmer/stakeholder must ask himself/herself the questions, e.g.:

- how can I manage the investment (commitment periods up to e.g. 20 years)?
- how much time will be required every day for routine inspection/maintenance work?
- is this workload compatible with the situation on my farm (do I need extra staff)?
- what working time model is possible for my family (e.g. who will take over the farm after me)?

Although the economic analysis of the feasibility study on an economically promising result comes, it is necessary to continue to question the economics of the project critically. If a lack of profitability emerges, nevertheless the possibility of terminating the project should be also taken into consideration.

5.6. Operating company & the founders' roles

The expert will help the farmer/stakeholder (and possible partners) to evaluate the pros and cons of the different types of companies and to decide for the best options. Additionally, the farmer/stakeholder and the expert will evaluate the impact of the different biogas solutions on the farmer's current activities.

It is important that the size of the biogas plant and thus the labour requirement is adapted to the operating conditions of the farm. The required workload for the biogas plant operation can mainly assign to following process steps:

- biomass management
- plant operation incl. substrate preparation and feeding process
- monitoring, maintenance and troubleshooting
- administrative tasks and
- digestate application.

All parts of the process are necessary for operation, but they can be linked to very different labour requirements depending on the mode of operation and substrate. The work schedule must be included in the considerations to avoid surprises at the stage of pre-planning in any case (FNR 2013).

Before starting to operate an anaerobic digestion plant, it is advisable that operators and staff will have a certain qualification to run a plant, so that they have basic knowledge about the biological process (helpful for trouble shooting). The qualifying measure raises also the awareness of the operator for potential hazards on site and helps to safely operate the plant (professional cooperatives and some insurance companies require this for the system operation).

5.7. Bottlenecks

For successfully realizing a biogas project bottlenecks have to be identified in an early projects stage and solutions have to be discussed.

In this context, it is helpful to meet the local authorities in an early project stage to check if it is realistic to build a biogas plant in the chosen area etc.

Moreover, it is necessary to evaluate the risks of each possible biogas concept, i.e. the effects of lower plant availability, higher yearly costs, lower income, spare parts availability, emission and noise sources, occurring problems with the neighbourhood, logistics, grid connection etc.

6. Concluding to concept & business planning

Based on the conceptual work which was done in the previous steps, different solutions for the on farm biogas project could be identified and the feasibility assessment has also examine the economic, environmental and social aspects. With this preliminary work and the feedback of the supporting expert, the farmer has to choose the most feasible concept for his situation in the long term and write a business plan.

The farmer has to decide which biogas solution is the most promising one - and which concept will be realized. This project developing step is the most important and difficult to do, as it contains the final decision on the biogas plant project concept detailing each aspect of the selected project.

The business plan will allow the farmer to present his on-farm biogas project efficiently, especially to authorities and banks.

Table 5. Considerations within concept's conclusion and business planning

Comparison	➢ Compare candidate plant concepts
Project concept	➢ Decision for most feasible solution
Business plan	➢ For the selected project concept

6.1. SWOT Analysis

The farmer/stakeholder and the expert will make comparisons between the different concepts and plant solutions by evaluating the pros and cons of each of them. They are related to technical aspects, environmental, economic and social conditions, the role of the farmer and expected bottlenecks.

The comparison can be carried out with the help of a SWOT analysis. It is an important part of the business plan. The strengths and weaknesses analysis is used for systematic observation of products, processes, enterprises and other objects to be analysed. The analysis can easily and relatively quickly identify existing problems and show opportunities of the project.

The farmer/stakeholder will answer the following questions which can be summed up in a short table for each biogas solution/concept:

"**S**trengths": What strengths are characteristic for the project?

"**W**eaknesses": Are there any weaknesses which have to be taken into account?

"**O**pportunities": Which special opportunities are offered by project realization?

"**T**hreats" of a project: Are there any threats, especially from the economic, legal or technical point of view?

An exemplary overview of a SWOT-Analysis for a biogas plant project can be seen in Table 6. In the first step of the SWOT analysis, the four areas are to be filled with content.

The internal influences are factors, which can be influenced by the farmer or person / institution that belongs to the project. Opportunities and threats, however, describe the business environment. Thus could be, for example, new markets or increasing heating costs. Threats may be, for example, political developments or declining demand.

The external influences are factors, that can`t be influenced by the farmer or person / institution that belongs to the project. The strengths can e.g. be market positions or successful / useful products. The weaknesses can be, e.g. inefficient processes or upcoming dependencies. The gathering and analysis of own strengths and weaknesses return the internal point of view.

The analysis start ideally with the aspects strength and weakness - this involves an objective consideration of the project. Subsequently trends of the respective strengths and weaknesses are created which determine whether the particular trend can be used as an opportunity or pose a risk for the project. With the strengths / weaknesses profile and the resulting opportunities and risks, an essential element of the business plan is developed.

Table 6. The SWOT table

SWOT	Positive	Negative
	Strengths	**Weaknesses**
Internal influence	• new source of income • new markets (for digestate) • increasing heating costs by customers • substitute mineral fertilizer • low payback time • self supply • …	• inefficient process • upcoming dependencies (substrate supply) • lack of labour • biomass purchase • …
	Opportunities	**Threats**
External influence	• inefficient operation • lack of knowledge • finding new market • …	• increasing biomass costs • political developments • declining demand • high inflation • …

6.2. Business planning

The farmer/stakeholder, supported by the expert, has to make a decision on the biogas project concept he wants to realize on his farm. The decision will be based on the SWOT analysis results but also on e.g. financial or personal preferences.

The elaboration of the business plan will be the following step of the concept development. The business plan is prepared and formulated to summarise the project idea and the new agricultural branch operation. The business plan describes in detail how this would work for the project, to whom it is directed, where the opportunities and risks lie and whether the project is worth it.

It serves not only the future plant operators but is an important decision document for banks, authorities and possibly for business partners. The business plan will sum up all the details of the selected project concept. It refers to all the details elaborated within “the feasibility assessment study”.

The business plan comprises about 15-18 pages and should contain:

- ✓ Purpose of the investment (general reason to invest, reasons to invest for farmer)

- ✓ description of non-technical aspects (e.g. form and legal status of company, location, market analysis, subsidies, social and ecological aspects)
- ✓ overview on technical aspects and dimensioning of the biogas plant (technical description of the plant, demand on amount, transport and storage of substrates, demand on manpower for operation etc.)
- ✓ economic viability incl. tables with economic data (investment plan; annually cost plan, plan on yearly revenues and plan on profitability, etc.)
- ✓ SWOT analysis
- ✓ additional explanations by the external expert.

In a well-written business plan, the critical points of the project are discussed and checked. As a result, the project stands before the realization on solid ground which prevents risks by planning deficiencies. Further, the business plan has several important functions, such as:

- ✓ during preparation of the business plan, the farmer shall be critical to the project in order to check its feasibility (can the plant be implemented?) and its cost-effectiveness (will it be profitable?)
- ✓ it is also an informative document for banks or lenders, potential funding bodies and / or investors. Funding bodies will demand for such a business plan, but also for business partners it is an important document and guideline during the implementation of the project and for operating the new branch of the farm.

7. Project realization

This project development step comprises all activities from getting permits for building and operation, organising the financing and funding for the bioenergy project till the fundamental planning of the plant construction and bringing it into service. The farmer has to get into contact with different authorities and institutions, as e.g. consultancy firms for detailed planning, banks, local communities or companies which will be needed for building the biogas plant. Additionally, the farmer has to provide all the data and plans relevant for successful project realization.

The complexity and time frame of this step among others is depending on type and size of the biogas plant and especially in which country the plant will be erected. Also the proceedings and effort for e.g. getting permits may also differ for each country and also within the various provinces.

Apart from the technical parts, aspects of acceptance are also very important for realizing a bioenergy project. It must be considered to involve the public in an early stage to avoid unpleasant delays later in the project realization.

Table 7. Tasks within the realization phase

Permits	• Providing needed documents, plans and information
Funding	• Providing documents and reports for banks • Providing documents for funding programme
Acceptance	• Neighbourhood should accept/approve biogas project
Contracts	• Conclude contracts with e.g. external heat costumer
Ask for tender	• Request for offers • Placement of orders
Building the plant	• Schedule the project • Controlling • Start plant operation

7.1. Permits

Agricultural biogas plants are often built close to agricultural sites (farms) and are often, depending on national legal framework, seen as a “building structure” and therefore needs at least a building permission by national construction law.

Some plants need approval according to Emission Control Regulations, also depending on national legal framework. These approval processes are normally more complex as well as more demanding and requires higher efforts in terms of time, organization and finances than the permission by construction law.

In principle (in many countries), there is a right to a plant authorization, if public regulations and concerns of occupational health and safety are not indicating otherwise. The regulations relating to the construction and operation include, for example [EDER 2012]:

- construction planning act
- occupational health and safety law
- water protection legislation
- nature conservation law
- waste legislation
- fertilizer act
- hygiene legislation.

The farmer has to get the required permits for building and operating the biogas plant from the local authorities and maybe other relevant institutions. It may be necessary to realize a detailed technical plan of the plant location and construction to receive those permits.

Some requirements to be considered by the manufacturer and/or farmer for construction of a biogas plant:

- noise and odour report for operation near residential areas, if necessary
- sufficient storage capacity for digestate (no land-spreading during winter time) landscape conservation plans
- fire protection design
- structural engineering (statics) for tank construction observe the requirements for concrete quality
- technical and operational safety acceptance of the facilities for starting operation

The applicant should contact the responsible approval authorities early in the process. The first discussion, in which the designer of the plant should be present, is to introduce the project to the authority. It is not only to make personal contact with the authorised person, but it will illustrate the framework of the project clarifies what conditions are imposed and what documents are required.

For producing and injecting of biomethane (biogas upgraded to natural gas quality) into the gas grid, special regulations have to be observed.

The approval of planning should be done in close contact with the plant manufacturer or delegated plant planner themselves and the agricultural advisor. Depending on the type of the required permit and the approval authority the amount of documents that have to be handed in may vary strongly (FNR 2013). A Checklist for the compilation of the approval documents can be found in Annex II.

Chapter 2.2 of Annex II gives an overview on the proceedings for permit for biogas plants.

7.2. Financing - Funding

Bioenergy projects are generally financed through own funds and / or borrowings or loans. Under certain circumstances, the project can be financially supported through funding from promotion programs (public funds).

An essential prerequisite for a project financing is basically the appraisal in a feasibility study (see chapter 0). The content and results of the feasibility study can, among other things, convince potential lenders and investors from the technical feasibility, economic viability and creditworthiness of the project.

Basically a credit institution and / or a qualified financial advisor should be involved early in the preparation of a financial plan to get the feedback on affordability in an early stage of the project (e.g. at the end of the feasibility study). The requirements of the bank concerning project information, documentation and collateral should also be clarified in time, which then form the basis for the comprehensive appraisal. The funding can be tightly coupled to the operator model and the legal form of the company.

The provision of equity capital is usually essential for lending by banks. Normally, a minimum ratio of equity capital in form of a self-financing or a quasi-equity loan has to be provided to receive state financial assistance or standard bank loans. The equity capital includes also cash assets and contributions in kind (e.g. operationally necessary goods). The capital requirement depends on the ownership structure (existing or newly established companies), the specific investment costs and the economics of the project (Eltrop et al 2014).

In the case of partial financing through a credit, the early contact with a credit institution is important for a successful financing. The bank is the first and crucial point in this way. It offers free consultations to be informed about various financing and funding opportunities, ranging requests for financial assistance to the relevant institutions. For borrowing the provision of adequate guarantees is absolutely necessary. The presence of sufficient collateral is thus a crucial part of project financing. The protection of the loans by the bank might be guaranteed e.g. by:

- mortgages (charge on the land)
- collateral assignments (e.g. the entire plant or individual machinery)
- guarantees or
- purchase guarantees for produced power and heat.

Form and scope of standard collateral should be agreed as part of the loan negotiations between the borrower and the bank (Eltrop et al 2014).

The framework of project funding differs from country to country and is also regional in its nature, scope and objectives. Basically, the promotion can be distinguished in subsidies in investment and development loans (interest-subsidized loans).

7.3. Improving acceptance

The biogas technology has so many positive aspects. It is a e.g. a renewable energy source, has versatile utilisation forms (electricity, heat and fuel), can be used flexible (bioenergy which is storable and allows energy production on demand) and generates additional income for agriculture and rural areas. Despite all this, in some countries the biogas technology is treated negatively in the media and biogas investors have to deal increasingly with citizens' groups and neighbours who are against the biogas plant (NIMBY-Effect - not in my backyard).

Social barriers or poor acceptance are often related to the increasing traffic for transporting and harvesting energy crops (too many vehicles, too noisy and too many exhaust emissions). In addition, there is often the opinion in public that biogas plants are smelly and also dangerous (danger of explosions) so that the plants are not tolerated near residential areas. Also, in some regions the cultivation of energy crop is seen problematically. Opponents claim that intensive energy crop cultivation has negative effects on the beauty of the landscape, decreases biodiversity and causes over-fertilisation of soils plus excessive use of pesticides and herbicides.

Therefore, the farmer should get into contact with his neighbours to present them the biogas project and discuss it together (visiting existing biogas plants would be an idea). Experience proves that it is always better to involve the public in an early stage to make them understand the benefits of the project, so they don't feel disregarded and complain at the end.

Apart from the technical planning a number of aspects of acceptance are relevant, which must be considered in advance of the plant building, if necessary. This is in the first place the early information of the public or neighbours. Essential criteria of a good acceptance are e.g. (Ehrenstein et al 2012):

- creating an open communication atmosphere and the responsiveness for insecure neighbours,
- name potential impact of the biogas plant, such e.g. odour development, increasing transport traffic, in a realistic way – don't whitewash the issues (e.g. it "never stinks")
- involve (local) proponents of the project in the public relations
- clarify the question of plant location early and if possible amicably appoint benefits of the project for the community
- offer opportunities for participation
- where appropriate involve mediators for conflict prevention and resolution
- residents should be given the possibility to get to know the biogas plant, for example by arranging an "open day" presentation
- a good and responsible plant management is indispensable and requires expertise.

Events for interested citizens for presenting information and allow discussions about the project are an essential part of the planning procedure. External experts may be invited to discuss certain issues (e.g. legal framework, health, etc.) and thus to increase the level of information and understanding to the local people (Ehrenstein et al 2012).

7.4. Contracting for realization

For realising and operating a biogas plant it may be necessary to clarify certain trade relations in bilateral treaties. The number and legal nature vary depending on the business model.

Essential for every project is usually a plant construction contract. Also the substrate supply and digestate delivery must often be contractually regulated. In addition, a plant management contract can also be completed, if necessary. By selling surplus heat of the own CHP or (raw) biogas to external customers, delivery contracts may be required. Also concession agreements with private landowners and easement agreements with the municipality might be of importance for the plant operator.

All contracts should be tailored to the individual needs of the contractors to offset their own best interests. The contracts with energy customers (e.g. for heat delivery) have to be updated regularly.

In Annex I (Information on contracts) different types of contract are presented and essential aspects are described in detail.

7.5. Tendering

The farmer/stakeholder should do a tendering process to choose the best plant manufacturers for building the biogas plant. Therefore the future plant operators must inquire the manufacturer, which will be considered to build the plant, to create and submit offers which are comparable and allow a thorough evaluation. For a good comparison some offers should be sought.

When comparing the offers, it is important to look beyond the mere price. Equally important is the quality and expected/guaranteed output offered, the experience of the manufacturer and the services they propose when it comes to support, repair or maintenance of the biogas plant. It is also important to decide, whether it should be a turnkey construction by a plant manufacturer (low work load and project planning time required) or if it should be planned and realized by an engineering company (larger share of own (farmer's/stakeholder's) work on construction possible).

As mentioned before (see 4.6) it's always beneficial to visit existing plants of the manufacturers or engineering company and get in contact with the plant operators in order to benefit from their experiences.

7.6. Construction and commissioning

A good project management needs a good organization. Therefore, it is important that the farmer/stakeholder has a good overview on the plant construction phase. Unexpected events and costs must be avoided to ensure that the project will be finished successfully.

The farmer/stakeholder has to make a detailed schedule with the plant builder / manufacturer to have an overview on the whole process of plant building and installation. It enables the various parties to deal with bottlenecks and avoid interruptions at an early stage. Each step must be presented in terms of resource requirements, budget and duration and they must follow a logical order. Regular reports on construction process help to keep this schedule updated.

During the construction, farmer/stakeholder and expert have to check scrupulously three points:

- ✓ **Quality:** Is the job under control and professionally executed? Does the farmer really receive what he expected/ordered? Do plant parts have failures? The security of a biogas plant is a very important aspect.
- ✓ **Financial aspects:** are there any unexpected expenditures? If yes, why weren't they anticipated?
- ✓ **Deadline:** is the building operation on time regarding the time-schedule (sometimes, start of operation has an effect on amount of feeding-in tariffs)?

After building and installation of the biogas plant has been finished, the facility starts operation. For that, it will be tested and approved (failures will be reported) by the plant manufacturer and/or authorised experts. After successful testing and commissioning the biogas plant is ready to produce biogas.

8. Plant operation

The project realization ends when the anaerobic digestion plant has been built. The next and essential step of the project starts when all structural and technical components of the plant are installed and the operating license has been granted: the start of operation.

8.1. Ramp-up to steady operational state

For the staring-up various tests and inspections must be organized and carried out. Initial operation of a biogas plant is made up of the technical (duration a few days) and the biological part (duration some weeks).

Before starting up the biogas plant, the plant owner must check if all the obligations included in the building permission are fulfilled. The entire gas system should been tested for tightness. The documentation for the technical units as well as for the entire biogas plant must be present, which also includes instructions for initial operation, a risk assessment and an explosion protection document (Eder 2012).

Starting up a biogas plant should always be done by the company who designed and built the plant. During the start-up phase, the farmer and the staff who will operate the plant, will be advised in running and maintaining the biogas plant.

From a technical perspective the start-up of the biogas plant is only acceptable, if the safety devices are functioning and in compliance with the regulations information about safety listed in the operating instructions of the manufacturer (Eder 2012).

Biological initial operation is often referred to as "start-up", depending on the used biomass the process needs minimum some few weeks' time and can last up to 6 months. The biological start of a biogas plant should be thoroughly planned and organized in advance and already possible before the technical start-up (FZ 2013).

The Table 8 shows and describes the different steps for starting the biological operation.

Table 8. Organization of the ramp-up of the plant

Ramp-up stage		Specifications and sources of errors
1	Creating a stat-up schedule in cooperation with an expert	Starting the process of the anaerobic digester is from the biological, economic and safety point of view a critical phase. The frame conditions (substrate input, biological activity and DM content of the inoculum) of each start-up are different.
2	Fill 50-60% of the digester with manure or fermentation product, possibly diluted with water	Level should be high enough so that all inflow and outflow openings are sealed and no air can enter the digester / gas storage (explosion protection). Alternatively, all inflow and outflow openings need to be closed (also applies to gas pipes).
3	Slow heating up of the digester to operating temperature (max. 1°C/d)	The microorganisms must be able to adapt to the rising temperatures
4	Inoculation of the fermenter with fresh digestate; amount approximately 20% of the reactor contents mentioned under step 2	Fermentation starts with increasing gas production and CH4 content. The gas is discharged via the overpressure protection. Aspects of explosion protection must be observed. The biogas can be used in the CHP, as soon as the gas has reached a CH4 level of >45%
5	For CH4 contents > 50%: initial charge with fresh substrate and gradually increasing the load (weekly about 0.3-0.4 kg oDM / ($m^3 \cdot d$))	Rapid increase in load increases the risk of instability in the biogas process. Too slow increase leads to economic losses through delayed achievement of full load operation.
6	Process analysis at least once weekly needed	Allows a customized increase of the load by occurring instabilities.
7	Comparison of targeted and actual analysis results (substrate input, acid level, gas or electricity production) with the start-up schedule	Adjustment of the substrate feed-in to meet the intended power output, so that an economical operation is possible.

8.2. Operational phase

When the biogas plant has started its operation, which daily, monthly or yearly measures are necessary for control, maintenance and for securing substrate and fuel provision? From now on the farmer has to do regular controls and maintenance to assure security, safety (especially concerning emission standards) and efficiency.

For a farm scale biogas plant, with an electrical power capacity (equivalent) of up to 75 kW_{el}, the labour time (net) for operating and maintenance is usually approx. 1.8 hours per day (KTBL 2013).

Table 9. Operational aspects of the plant

Control	• Quality • Safety • Emissions
Maintenance	• Repairs • Service
Documentation	• Self-control, troubles diagnostics • Officially reporting requirements

Process control

The required measures/tests (either on a day to day basis or in case of problems) should have been listed and detailed in the plant instructions of the manufacturer who built and installed the facility.

An analysis of practice data from operations diaries of 31 German biogas plants showed that within a year a total number of 1,168 operational disturbances were documented by the operators (KTBL 2009). It was found that the plant component CHP-Unit, solid substrate feeder, pumps and agitators were the most susceptible parts. The qualitative evaluation of this disturbances showed, that the biological process has been the fifth most frequent reason (see Figure 4) of malfunctions.

For this example, 4,282 working hours were necessary to solve all the malfunctions. This corresponds to an average of 138 working hours per biogas plant and year. On average for every 10 kW of installed electrical power 1.2 malfunctions occurred per biogas plant and year.

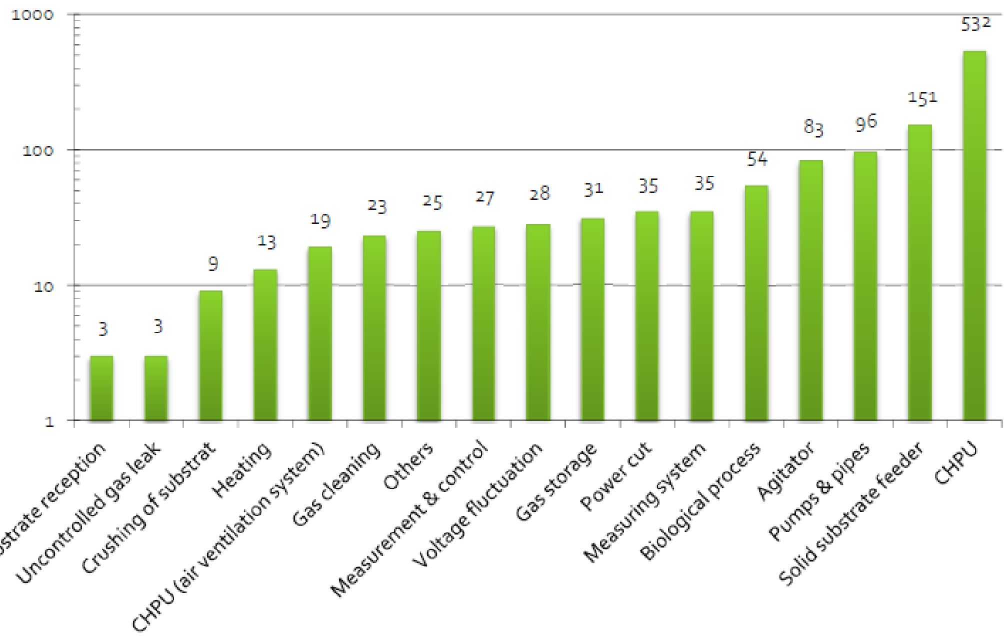

Figure 4. Most frequently met malfunctions over a year in 31 German plants

These results point out the importance of consequent process control. Most significant indication for a process disturbance is a noticeable decrease of biogas yield respectively methane concentration. In contrast to technical problems – which can regularly be solved quite fast – process disturbance are more difficult to correct and require a basic understanding of the farmer for the biological processes and inhibition of the anaerobic fermentation.

Maintenance

Most of the controls may be done continuously by control and monitoring systems (like temperature of the reaction, the amount of substrates, the quantity of gas/electricity/heat produced, etc.) but others might require expert support or can be done by the farmer himself (e.g. resolve liquid leakage at pumps, oil changing at CHP, small repairs etc.).

The farmer has to ensure maintenance and observe the maintenance intervals (important for warranty of plant parts) of the biogas plant and the downstream equipment. Some maintenance can be done by the famers himself (e.g. scheduled replacement of wear parts as filters, seals and replacing or replenishing supplies or consumables like engine oil or water) or by certain service providers (e.g. general overhaul of CHP unit).

Measuring is the precondition for process control and optimisation. But the necessary measurement equipment creates costs, which often – especially on small scale installations – tried to be avoided during implementation.

Documentation

Consequent documentation is the only way to get reliable information on status and efficiency of the biogas production process. The collection of data over a longer period is not only necessary for self-control, but also relevant in case of troubles diagnostics and consultancy by external experts.

As a very simple, effective and less laborious method is the so called „input or operations diary". Furthermore, in some countries (for example Germany) data on input of the plant must be available due to legal requirements.

Advantages of an input diary are (Gomez 2008):

- traceability of quantity and quality of input substrates (also supplier where needed)
- control and optimisation of volume load
- economic efficiency calculations (supplier, gas demand, electricity demand, operation hours)
- process control
- gas leakage detection

The input diary should include the following information:

- ✓ amount of every substrate or substance fed into the process

- ✓ process temperature
- ✓ gas quality (CH_4, CO_2, H_2S)
- ✓ gas yield
- ✓ amount of gas utilized
- ✓ power production
- ✓ (net) operating hours
- ✓ fuel demand (in case of pilot injection gas engine)
- ✓ electricity injected to the grid
- ✓ services, disturbances

8.3. Safety issues

Construction and operation of a biogas plant is related to a number of important safety issues, potential risks and hazards for humans, animals and the environment. Taking proper precautions and safety aim at avoiding any risks and hazardous situations, and contribute to ensuring a safe operation of the plant.

Fulfilment of important safety issues and stipulating clear preventive and damage control measures is a condition for obtaining the building permit (this may differ depending on country):

- fire & explosion prevention
- mechanical dangers
- sound static construction
- electrical safety
- lightning protection
- thermal safety
- noise emissions protection
- asphyxiation, poisoning prevention
- hygienic and veterinary safety
- avoidance of air polluting emissions

- prevention of ground and surface water leakages
- avoidance of pollutants release during waste disposal
- flooding safety
- collision and tear-off protection.

Apart from poisoning and asphyxiation, there are other potential dangers related to the activity on a biogas production site. In order to avoid these types of accidents, clear warnings must be placed on the respective parts of the plant and the operating personnel must be trained [SEADI ET AL 2008]:

- Other potential sources of accidents include danger of falling from ladders or uncovered areas (e.g. feed-funnels, maintenance shafts) or to be injured by movable parts of the plant (e.g. agitators).
- Equipment like agitators, pumps, feeding equipment is operated with high electrical voltage. Improper operation or defects of the CHP unit can result in fatal electric shocks.
- Risks of skin burning through unprotected contact with the heating or cooling systems of the biogas plant (e.g. motor coolers, digester heating, and heat pumps) must be considered. This also applies to parts of the CHP unit and to the gas flare.

For these reasons, it is advisable that operators and staff of a biogas plant are trained on plant safety. This qualifying measure raises the awareness of the operator for potential hazards on site, it helps to safely operate the plant and to establish safe procedures if external companies need to work on the biogas plant.

Annex I: Contracting info

I.1 Constuction contract

The plant building contract regulates the structural condition and is the centrepiece for the construction of the biogas plant. The main regulation points are significantly depending on the concept and the size of the plant. From the perspective of the plant operator, in particular the following points are in need of regulation (FNR 2013):

- ✓ whether the project is realised by an engineering company or as turnkey construction, the contract should possibly including all trades/crafts, agreement of specific performance and should contain detailed service specifications
- ✓ coordinated technical requirements of the plant are observed (e.g. minimum hydraulic retention time)
- ✓ bank guarantees or other valuable collateral can reduce the cost risk in construction as well in the warranty period
- ✓ a specific completion date should be agreed, also rules in terms of delays to compensate for revenue losses (penalty)
- ✓ clear rules for the test operation (scope, duration, power values, retries, etc.) and acceptance should be made
- ✓ agreements to "whether and how" of subsequent changes of the scope of work (reduction and / or extension) increase the flexibility, even if a request of change was not clear included in the contract
- ✓ a reduction of the statutory warranty circumference should be avoided. The aim of the plant operator is instead the longest possible warranty period
- ✓ a forward-looking planning covers a contractual right to supply spare parts to fixed or at least determinable prices (price adjustment clauses) for as long as possible
- ✓ usually, the payment will be agreed on progress of construction work. The amount of progress payments based on the economic value of the trades/craft or partial performance, the maturity date results from the project schedule / construction schedule. The payment of the last rate should not take place before the end of the express warranty, but in any case not before lodgement appropriate securities (warranty bond).

I.2 Management and maintenance contract

The biogas plant must be regularly serviced and maintained. Plant operators normally negotiate maintenance contracts for their biogas plant, occasionally supplemented by management contracts. If the plant manufacturer or constructors don't offer maintenance services, the operator should demand written maintenance requirements. Intervals and amount of maintenance should be defined as detailed as possible in written form (FNR 2013).

The following points should be taken:

- in addition to the plant construction contract a maintenance contract with the plants manufacturer or builder is recommend (negotiated at the same time)
- the term of the maintenance contract should not be less than the warranty period from the plant construction contract
- to obtain warranty claims, a maintenance contract is useful for the plant operators who has not the technical skills for maintenance.

I.3 Substrates supply and digestate delivery contracts

In addition to the initial investment, the operating costs of the plant (e.g. for substrates and their delivery) determine in particular on the cost efficiency of the plant. Costs and arrangements for substrate supply are at an early stage to be considered in the calculation of profitability with an appropriate risk surcharge.

In substrate supply contracts, delivery volumes of renewable resources (energy crops) are usually defined on area basis, because the harvest is not fixed from the outset. In good harvest years, it may therefore come to an over-supply of substrates in poor to a shortage.

The exploitation of the digestate can also be negotiated in a contract after completion of the fermentation process and the corresponding storage of the digestate volume. In practice, it has been proven many times that the substrate supplier takes back the digestate to use it as fertilizer on his agricultural land [FNR 2013].

In substrate supply and digestate collection contracts can be found - in addition to the usual rules on liability etc. - regulations on the following points [FNR 2013]:

- term of the contract, including rules on termination and contract renewal
- delivery quantities or information on cultivated area stating the expected yields and any minimum quantities delivered, including where appropriate options
- price adjustment mechanisms, usually based on an index or several indices (e.g. consumer price index, diesel fuel index or substrate price index), depending on the term of the contract
- harvesting business service and delivery logistics, i.e. agreements on whether the operator or the substrate supplier harvest, the chopping, the removal, silage plus compression of the substrates takes over where they are stored and how long they have to be stored / may as well
- digestate collection (volume, responsibilities, dates, periods, deadlines, prices) including logistics (in particular transport, storage, distribution) under consideration of the requirements for the application of digestate as fertilizer.

I.4 Heat supply contract

Upon conclusion of a heat supply contract similar points have to be considered as for a biogas supply contract, such as arrangements to the quantities delivered, run time or remuneration. In addition, further regulation is needed for the following points.

Depending on the type of heat utilization (cooling buildings, feeding into a heat network, process heat, etc.) different requirements are to be observed and the fulfilment of which has to be ensured in the heat supply contract. It is important from the perspective of the CHP plant operator, to agree on a total purchase obligation or minimum purchase obligation of the heat customer (FNR 2013).

I.5 Biogas supply contract

The produced biogas is normally converted into electricity in one or more of CHP-units on site or its surroundings (satellite CHP) owned by the plant operator. However, this is not mandatory. The plant owner may also sell all or part of the raw biogas produced. The buyer then provides the utilization, such as electricity and heat production in his own CHP, heat production in a boiler or the upgrading into natural gas quality (biomethane) in a separate biogas upgrading plant.

A supply contract for raw-biogas is not subject of particularly energy law requirements. Mostly the raw biogas is transported in own piping systems or networks.

The contract for delivery should consider the technical, economical and legal interests of both parties reasonably.

Usually, a biogas supply contract contains the following regulations [FNR 2013]:

- ✓ a sectional regulation of the supply volume by minimum or maximum quantities (number of kilowatt hoursof biogas per hour / day, etc.). Such delivery quantities corridor takes the natural fluctuations in biogas production into account, without neglecting the interests of both parties on reasonable predictability
- ✓ the contractual (minimum) term and clearly defined mechanisms for termination and renewal of the contract are of importance for both parties. The longer the contract term is, the more important the price adjustment clauses are
- ✓ price adjustment clauses can be tied onto neutral indexes like e.g. electricity prices or prices for substrate on the stock market or consumer price index, etc.. Price adjustment clauses should reflect the respective cost risks in the first place, specifically in relation to the fixed duration of the contract agreed. The agreement should explicitly regulate, whether and how changes affect the purchase price for the raw biogas
- ✓ depending on the intended use of the raw biogas by the buyer, the definition of certain desired properties of the raw biogas is recommended. According to the functionality and technical requirements of the power generation unit, the buyer will set certain quality needs for the raw

biogas (minimum methane content, etc.). The gas quality is also important for those buyers who upgrade the raw biogas into biomethane. In this case, the criteria shall also be in accordance with the technical requirements of the biogas upgrading plant At which point the ownership of the raw biogas shall pass on to the buyer, is also needed for reasons of risk assumption. For this purpose, the local conditions and ownership are noted for example at the piping system or the gas storage(s)

- ✓ The contractual obligation to supply includes the transfer of ownership of a certain amount of raw biogas in a certain quality. It is therefore necessary to make arrangements for the measurement of the quantity and the quality of the raw biogas and to regulate the corresponding bearing of the costs.

I.6 Concession agreement with land owners

The construction and operation of a biogas plant on the property of the plant owner represents the rule. However, if e.g. an operated satellite-CHP – in own operation or by a third party –, or the produced raw biogas fully or partly supplied by pipelines or the generated heat transported via heat pipes, the consent of adjacent property owners may be required. For this purpose, concession agreements concerning law of obligations are concluded. The duration of such a concession agreement should correspond to the expected need.

The compensation schemes should, due to the long term nature of such a project, contain price adjustment mechanisms. The protection of the rights of use of land owned by others should necessarily be done by appropriate easements entry in the land register. This will ensure that the rights are not lost in the case of sale of land or in the event of the insolvency of the other party (FNR 2013).

I.7 Path easement agreement with the community

If pipelines for a district heating network or (raw) biogas network laid along public roads, it may be required that the operator of the biogas plant and the operator of the heating network enters into an easement agreement with the responsible road authority. This one-time or annual access fees are agreed in most cases (FNR 2013).

Annex II: Checklists

II.1 Project idea checklist

Table 10. Project preparations checklist

Phase	Item/ Subject	Checked	Specific comments
1. Evaluation of the agricultural resources			
	Your fields and farms: Clearly identify the available substrates and estimate the quantity in tons per month/year for each of them		
	Animal waste (manure, dung, slurry, etc.)		
	Agricultural residues (like fodder leftover, grain litter etc.)		
	Household waste (like food/kitchen wastes)		
	Other		
	Schools or company kitchen (food/kitchen waste)		
	Agro-industrial company (organic industrial waste)		
	Others		
	How much will it cost		
	First (preliminary) calculations of the farm's biomass potential and the annual costs for the plan		
	Make calculations for a first assessment of the economic feasibility of your planned project		
	Check the results which will describe the different costs (investment, substrate cost, logistic costs, operational costs, etc.) and the net incomes		
	Get in contact with a national biogas experts for consultancy and advice.		
2. Evaluation of logistics			
	What is the quality level of the surrounding infrastructure?		

Phase	Item/ Subject	Checked	Specific comments
	Can trucks freely use those roads?		
	Which substrates have to be transported (tons/year)?		
	How much will the logistics be (€/year) and is it worthy for it (normally less than ca. 20 km distances ensures profitability)?		
3. Project purpose			
	Determine the energy consumption of farm and private housing.		
	Determine the nature (gas, heat, electricity) and the quantity of energy which is required.		
	Are there selling opportunities (e.g. surplus heat, Biomethane as transportation fuel) nearby?		
	Inform yourself about the prices and the conditions (period, gas quality, quantity of energy that can be sold, etc.).		
	Determine with the clients their needs (quantity and nature of the produced energy). Check that it’s about a long-term bond.		
	Think about how the energy will be transported (heat net, filling station etc.).		
4. Kind/structure of the plant management company			
	Inform yourself about the most common forms of company and their specificities.		
	Identify the persons who may take part in your project. Discuss with them about their involvement and their responsibilities.		

II.2 Checklist for approval documentation

Table 11. Documents for approval

Building application forms / application forms on emission control regulatory approval	Request the forms at the responsible authorities for the approval process
Qualified location map/drawing	This has to be acquired at the municipal cadastral and land surveying office
Land Registry abstract	Information about the ownership, commercial type and location of the site
Plant and Operations description	Forms with plant data, type of processes (incl. material utilization overview) as well as plant and operation description created by the designer
Emission / immission	Presentation / description of the emission-causing processes / operations of the plant
Noise certificates, odour surveys and/or emission source plan	If the licensing authority decides due to special conditions of the location that a report must be created, a certified expert (authority on the subject) has to be assigned.
Waste management / utilisation	If necessary (based on the used substrates), presentation of the application and disposal methods of the used waste and used plant parts.
Plant Safety	Description of the plant under fire safety point of view, depicting a fire protection plan by the planner, possibly creating a fire safety report produced by an approved expert. Description of measures to ensure safety requirements, location plan with possibly explosion zones on site.
Intervention in nature and landscape	Compatibility of the project on the basis of existing planning conditions (e.g. land use plan, development plan). Representation of compensation or reparation measures for intervention relevant projects components.
Authorization under EU-regulation for animal by-products	Request for approval of the biogas plant according to EU regulation for animal by-products (EC No. 1069/2009) e.g. by the use of manure or dung.
Site plan with distance space	Create accordance with the requirements of the safety regulations for agricultural biogas plants of the agricultural professional associations
Structural calculations for major components of the biogas plant	The statics of the large components are created and supplied by the plant or component manufacturer
Installation plan	This is created by the designer/planner
Detail drawings	This is created by the designer/planner: - piping plans (for substrate, gas, heating media) incl. slope, flow direction, dimensions and material properties

	- consideration of the explosion zones areas (ex-zone plan) - type and design of reloading points for manure, silage and other pourable substrates - engine building / room with the necessary installations - heating pipe plan incl. connection with the heat producers and consumers - basic flow diagram with operating units - current flow diagram for the integration of CHP in the operation - gas storage, gas-safety valve unit - substrate storage
Flow diagrams for process plants	Creating a basic flow diagram with operating units by the planner.
Digestate utilization	Presentation / documentation of the necessary areas for agricultural application of digestate
Asset retirement obligation Statement	Undertaking by the applicant on decommissioning and dismantling of the plant and soil sealing after permanent termination of the permitted use.

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Authors: Ioannis Agnantiaris

Contact details: tekmarteam@gmail.com, +30 23210 024270

Organisation: TEKMAR O.E.