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SECTOR HANDBOOK BIOGAS

Prepared by the CrossBorder Bioenergy Working Group on biogas

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The production and use of biogas is seen as one of the most promising bioenergy technologies due to its broad feedstock basis and various forms of application. Several countries worldwide seek to promote the biogas technology as part of the bioenergy market. However, there are significant differences compared to other bioenergy technologies in terms of feedstock, technologies, market requirements and business operators which need well-directed and intrinsic approaches.

This report aims at shedding light on the biogas market structure, its mode of operation and the specific requirements needed by business operators to enter the market. It focuses on the fermentation of agricultural biomass and organic wastes and residues, but – although there is definitely a huge potential in several European countries as well – it doesn’t explicitly consider landfill gas and biogas produced out of sewage sludge. Yet, much information provided in this report will still be of value for related stakeholders.

1.1 Conversion and feedstock

Biogas is a combustible gas which is produced with micro organism assistance during the decay of organic materials like manure, agricultural feedstock or bio-waste in an anaerobic, or oxygen-free, environment. Oxygen-free conditions occur in natural systems such as the bottom layers of wetlands and bogs, but also in artificial systems like landfills, lagoons, and specially designed tanks in biogas plants, then called anaerobic digesters.

In a biogas plant, biomass is fed into a digester for a period of several days, in which archaebacteria under exclusion of light and oxygen decompose the material, with biogas as product. It is a gas mixture, consisting of mainly methane ($\text{CH}_4$, 40 to 75 %), carbon dioxide ($\text{CO}_2$, 25 to 60 %), and other gases (hydrogen, hydrogen sulphide and carbon monoxide). As methane is also the main component of natural gas, the composition of biogas resembles the characteristics of natural gas and therewith provides manifold ways of application.

**Components of a biogas CHP plant**

A typical biogas plant exists in general of three different units: the feedstock storage and loading system, the digester in which the biogas is produced and finally the CHP unit for the utilization of the biogas, resp. the upgrading unit for the biomethane grid injection. The feedstock storage and loading system of an agricultural biogas plant consists usually of a liquid manure store and a store and feed-in unit for solid material, which can be fed into the digester automatically by a conveyor. If solid substrates are used, a suitable metering device is needed, large enough to even out variations in the amount of available substrates. If co-substrates are being
used, additional buildings may be required to receive and treat the feedstock according to their characteristics. Also the removal of contraries is especially important for the process to run without disturbance and to maintain a high quality of the remaining digestate. The digester is the place where the fermentation of the feedstock to biogas takes place. The digester is fed with the feedstock either continuously or discontinuously and can have various designs (steel or concrete, horizontal or vertical, etc.) – depending on the chosen technology and manufacturer. All have to be gas- and watertight as well as completely opaque. A stirring device ensures that the substrate remains homogenous, that the material is equally distributed within the digester and that the produced gas can escape from the substrate. With some feedstock like chicken manure or organic wastes dischargers could be necessary to remove sedimentation layers. Usually the digester is completed with a digestate storage tank for the fermented biomass. The CHP unit is mostly placed in a compact container or a building close to the digester. Here, the biogas is converted to electricity and heat. Depending on the capacity of the biogas plant gas engines and pilot injection engines are most common, reaching an efficiency of approx. 45 % for the electricity generation. The heat is for the most part produced by
the engine cooling water and with even higher temperatures by exhaust gases, recovered by means of a heat exchanger. By the parallel production of electricity and heat the CHP units can reach a total efficiency between 80 and 90 %. While the electricity is fed into the electricity grid, the heat is either used on-site by the operator to satisfy his own heat demand, or it is fed into a district heating grid to supply different customers with heat and therewith gaining an additional income. If there is no meaningful way to use the heat, it is also possible to utilise the heat for a downstream electricity production with an Organic Rankine Cycle (ORC) System.

Different types of biogas plants

In general there are two different types of biogas plants being considered in the CrossBorder Bioenergy project: those using mainly agricultural material as feedstock and those utilizing organic wastes. Depending on the feedstock, the design, technology and other requirements on the biogas plant have to be adopted.

For example: a biogas plant using organic wastes or residues like the wastes from the food industry, food scraps, grease traps or slaughterhouse wastes are required to hygienise the material – meaning to treat them over a defined sector handbook biogas

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period at high temperature, which needs additional technology compared with agricultural plants. Also the composition of the batches can differ from day to day so that an adopted, robust technology is needed capable to handle different feedstock qualities without problems. The feedstock is generally delivered by truck which also requires a well-developed road network, and to avoid odour emissions the receiving unit of the biogas plant is mainly installed in a closed hall leading to extra-costs.

In contrast, a biogas plant using energy crops and manure has a different project design, as the farmer harvests the crops and preserves them on-site as silage, which is then moved to the hopper of the plant by wheel loader. As there is hardly a daily delivery of fresh material, this methodology requires much more space for the storage/silage facilities, but on the other hand the quality of the feedstock remains more or less equal, allowing a better adjusting of the technology to the feedstock’s characteristics. Also, there’s no need for costly buildings to reduce odour emissions at the feedstock receiving unit.

Independent from the type of feedstock or project design, bacteria degrade the biomass feedstock to biogas within the digester. As high value energy carrier this biogas is suited for heat and electricity generation in CHP plants as well as providing gas for cooking, lighting, hot water supply, drying and cooling. In Europe biogas is mainly used on-site for decentralized cogeneration applications.

But in recent years also the upgrading of biogas to biomethane gained more and more significance.

**The refinement of biogas to biomethane**

Biogas can be treated and upgraded to the quality of natural gas (then called biomethane) and fed into the natural gas grid, which opens the door to a whole new range of possibilities. It enables biomethane to be used more centralized at sites with optimal heat demand and achieves maximum efficiency with CHP. An exclusive use in high-efficient gas-condensing boilers for residential space heating is possible, too, but not yet prevalent. Also it can be used as transport fuel in natural gas vehicle at filling stations with an adequate infrastructure.

The first steps of the biomethane production are usually same than for biogas CHP. The raw biogas is produced in a digester, but instead of utilising the biogas directly e.g. in a CHP unit on-site, it is upgraded to biomethane. Generally it can be said that the upgrading technology replaces the CHP unit on-site of a biogas plant. For the upgrading (and grid injection) of biomethane there are several requirements to be considered.

First of all, the raw biogas has to be
dried, desulphurised, contraries removed and the biogas enriched to approx. 90% methane content. Further on, at the injection station the biomethane has also be compressed and odourised. For this there are several technologies available. Which technology applies best to a planned biomethane purification project is very much dependent on the raw biogas potential of the biogas plant, and the requirement of the natural gas grid into which the biomethane is to be fed in, that is to say whether it is a high-pressure or low-pressure pipeline. The pressurized water washing is the most common technology at the moment, based on experiences from natural gas production. Raw biogas is compressed, sent through an absorption segment and sprayed with water. Carbon dioxide, hydrogen sulphide and ammonia are separated out and remain in the water, while the methane remains as a gas. For this process, no process heat is required, but the compression consumes a good amount of electricity. While a gas quality of 92 to 98 % can be reached, the methane slippage is said to be in a range between 0,5 to 1,2 %. As the biomethane is already compressed during the purification process, the pressurised water washing matches very good to projects, which intend to feed their biomethane into a high-pressure gas grid.

Another applied technology is the amine gas treatment, with which the carbon dioxide is removed from the raw biogas in a chemical reaction. The gas has not to be compressed in this process, reducing power consumption, but the process temperature is 160 degree Celsius, applying therefore for projects where the heat output e.g. of a CHP plant is not fully utilised yet. Other technology providers offer a methodology where the raw biogas is also compressed, but cooled down below 40 degrees. In a bed reactor of solid activated carbon, carbon dioxide and other impurities are removed.

Especially for small scale projects, which may be too small for the natural gas network but suited e.g. for farm-sited gas filling stations, an upgrading process based on membranes is offered on the market. Here, the gas is also compressed up to seven bar and forced through a membrane. Because the carbon dioxide molecules are smaller, they pass through the membrane more quickly. This technology reportedly produces a gas quality between 95 to 97 % biomethane content.
1.2 Markets and prospects

Globally biogas has started to be acknowledged as one of the most upfront technologies for energy production. There are different motivations to start business. Usually, the biogas market development starts within the field of bio-waste digestion as a method to treat and upgrade organic wastes. Especially for companies in the food and other biomass processing industries, where huge amounts of organic wastes (apart of cellulose material like wood, which cannot be processed in biogas plants) accrue, biogas extraction and utilization offers significant benefits, like additional income by selling energy to the markets resp. a substitution of costs for self-needed process energy, while reducing disposal costs for the wastes at the same time. For external plant operators on the other hand the fermentation of bio-wastes from industry promises a low-cost feedstock supply or even a chance of receiving a disposal fee in addition to the income of the energy sells.

It is obvious that there are many different kinds of organic wastes available like separately collected bio-wastes of households, garden and park wastes, waste food, slaughterhouse waste or residual material from food processing. Not all fractions are suited for biogas production in the same way. Each kind of waste must be considered independently. Especially organic wastes from households which are not collected separately are hardly suited as there would be too much foreign, non-biogenous matter in the batch and the efforts for a pre-treatment to costly.

Beneath, the utilization of by-products and energy crops in agriculture is seen to be very promising as an alternative market for farmers. While regulations, which limit the dumping of untreated organic wastes on landfills or which require measures to limit odour emissions, encourage the biogas market as organic waste management method, more and more feedstock from agriculture enter the market solely aiming at producing energy. Hence bio-waste treatment as motivation for the biogas market development is complemented by the conscious production of energy – bio-wastes and biomass in general regain a status as valuable resource instead of costly waste.

It is expected that the development of agricultural energy crops will play a key role in future European biogas markets. The benefits are obvious: Energy crops and agricultural by-products (manure and crop residues) are becoming a highly-sought raw material which creates additional income. And even more, the digestate, which is a mix of water, minerals and not decomposed organic substances, can be used as a high-grade
fertilizer on-site or sold to increase income. Biogas is becoming an integral part of agriculture. Hence, the growth potential, especially of agricultural based biogas plants, is very high, particularly in Europe’s large agricultural countries. An increasing importance of agricultural biogas plants is also reflected in the statistics: in 2007 approximately 6 Mtoe biogas have been produced in Europe, half of which (2.9 Mtoe) as landfill gas, but already 2.1 Mtoe based on agricultural feedstock\(^1\). In fact, the highest increase of biogas production compared to 2006 took place in the field of agricultural plants (plus 20.5\%). Despite this huge variety of different feedstock or stakeholders behind, most biogas plants have one thing in common: the majority of the produced biogas is used for electricity generation so far, although the feeding of biomethane into the natural gas grid gained a great impetus in recent times. In 2008 approximately 30 TWh electricity were produced and therewith 7 % more than the year before, which indicates a strong market growth. The main development took part in OECD countries (especially in Germany, USA, United Kingdom and Italy)\(^2\). Also a number of developing countries have now entered the market, but with 4 GW installed capacity (out of 5 GW installed in total globally) and 24 TWh produced electricity in 2007, Europe covers two third of the global biogas market and is therewith the most advanced market for biogas\(^3\).

Biogas is also being used as biomethane in very limited quantities for transportation, but still this is a niche market so far. To be used in the transport sector in a large scale, biomethane has ideally to be fed into the natural gas grid to benefit from its infrastructure. But despite ambitious voluntary targets e.g. in Germany, which targets to feed bn6 Nm\(^3\) biomethane into the natural gas grid in 2020, several obstacles still have to be removed. But once the framework conditions are set in the right way, the technology of biogas upgrading and feeding into the grid will face a strong growth dynamic throughout Europe. For example, to reach the German voluntary target of feeding bn6 Nm\(^3\) biomethane into the natural gas grid in 2020, approximately 1.500 additional biogas plants with an average thermal capacity of 5 MW will be needed. So far, in 2009, approximately 90 biomethane plants were installed in Europe with a total capacity of 300 MW.

\(^1\) EurObserv’ER (2008): Biogas Barometer
1.3 Export potential

The principle of biogas production is not a new technology. The first biogas plant known to mankind was documented from ancient Persia as simple covered pit. Especially motivated by last-century’s energy crises, but also triggered by fighting global warming within the last decade, several companies made great efforts in developing the rather simple principle of producing a biogas by digesting organic material to a high efficient and modern, sophisticated technology.

These companies, mainly based in countries with already well-established biogas markets, have consequently a technology advantage compared to those in starting-countries, and therewith the opportunity to sell their products abroad, while the purchasers (investors) of the components will benefit from “leap frogging”, meaning that they can avoid negative experiences due to immature technology and having best-available technology at hand. In combination with the huge feedstock basis, manifold applications and strong political drive behind this provides the biogas technology excellent potentials for export.

But when defining the export potential of a biogas technology, not every component of a biogas plant is suited for export activities. In general, a product to be offered on international markets has to provide clear benefits compared to local competitors in the target country. It can be technological advance (indicated e.g. by better quality or higher efficiency), a lower price at comparable qualities or simply the solution of a problem which hasn’t been solved so far, resp. the service of an unsatisfied demand, meaning: it is simply not available yet. This general rule is also true for biogas technology.

Not all components of a biogas plant require sophisticated technology (like construction works of digesters made of concrete, which can also be build by local craftsmen with local material, but may-be to lower prices) and therewith don’t apply for exports. Other components however are based on longstanding experiences and development processes, e.g. stirrers and loading systems, flares, gas washing units and of course the CHP- or upgrading units, which risk disturbances and wear-out failures of the biogas plant if they are not adapted to the used feedstock and project design.

The technical development in recent years was especially characterized by detailed improvements concerning the enhancement of process reliability and availability of the biogas plant, an increased working life of the system and a significant rise of the electrical efficiency of power generation modules. Which technology is used is very much depending on the kind and available amount of the feedstock, which decides on the size and design of the digester, the amount of produced biogas and consequently the installed capacity of the power generation unit.

For example, practical experiences have shown that combustion engines are sui-
ted best to handle different biogas qualities, which can vary during the fermentation process. They can reach efficiencies of up to 45%. Most common are gas engines and pilot injection engines. Generally spoken, gas engines are used in plants with an installed electric capacity of more than 250 kW, pilot injection engines however are applied more commonly in systems with a electric capacity of up to 350 kW, Also a combination of both technologies has proven to be effective: gas engines for base load operation, and a pilot injection engine for start-up-, peak load and backup operation.

With view on the manifold components and processes of a biogas plant, especially the development of advanced measuring and process equipment, intensive biochemical research experiences and high-level engineering services offer excellent export potential in less developed biogas markets.

Besides technology or hardware, there is also a huge potential for the export of services and know-how. Both, the planning of a biogas plant same than its operation and maintenance need excellent know-how and long lasting expertise. There are many examples known in literature and practice of failed projects because they were wrong dimensioned, based on not to local conditions adopted technologies or simply handled or operated the wrong way – typical mistakes which can be avoided by new actors by reverting to experienced project developers, who can objectively advise on project designs, capacity and adequate technology for the available feedstock. Also maintenance services or regular analyses of the digestate or bacteria can be taken over by specialized companies.

1.4 Target group of the CrossBorder Bioenergy project

The CrossBorder Bioenergy project addresses mainly companies in the biogas business looking for a long-term commitment abroad, e.g. by investments into foreign branches or developing local market sectors to gain a high market share rather than exporting one or just a few units of their products or services to a single project. However, where there is a market with an attractive market volume for foreign investments, there is of course also potential for single projects. Especially providers of turn-key biogas
projects covering all steps of a successful project implementation – from planning and consulting to implementation, operation and maintenance – and project developers are addressed first. These companies will most probably pave the way for many up- and downstream technology providers, component suppliers and service companies, following the pioneering company. But also for companies and institutions in the finance sector like investment funds or even banks are targeted as the information provided by the CrossBorder Bioenergy project will give a clue on favourable investment opportunities, risks and factors to be considered when granting credits. Last but not least the benchmark developed by the project consortium will give policy makers an indicator of the success of the political framework conditions in their country aiming at developing bioenergy markets resp. recommendations on how to improve them to satisfy the requirements of the bioenergy industry as defined during the project.
2. CHARACTERISATION OF MARKET SECTOR
The assessment of the attractiveness of biogas markets has to consider different kind of market sectors and project designs, which have different characteristics and different stakeholders involved and therewith require also different technologies with different chances on international markets.

As the direct use of biogas for lighting and cooking for instance is more relevant in developing countries to serve basic energy needs, it is not common in industrial countries and has no relevance in Europe. The principle behind these very small scale installations is quite simple, for good reason not very sophisticated and doesn’t need highly developed technologies. As it is also the aim of those projects, that they can be easily realized by local people with local material, this sector is not primarily targeted within the market attractiveness assessment of the CrossBorder Bioenergy-project, although of course there may exist companies which develop suited solutions for home based biogas installations as well, but still this is to be seen as exemption.

As described above, the main application for biogas in industrial countries is still the generation of electricity and – to a lower extend – of heat. But again there are many different aspects to consider. Who is the investor or operator and for what reason? Is it to benefit from public subsidies for the production of renewable energy, or is it to treat organic wastes for environmental reasons, to save disposal costs or to reduce external energy needs? Will the biogas plant be operated by a single farmer on-site of the farm, will be in a consortium of several farmers or will it be an industrial plant operated by utilities or other industry stakeholders? The answers to these questions are linked with different requirements on the project design, of financing issues, feedstock supply, the choice of technology etc. and lead to different potentials in relation to the chosen approach.

Thus, the market evaluation for biogas within the CrossBorder Bioenergy-project has to bear different attractiveness in mind – depending on the type of project considered. Generally they can be classified in:

A) Small-scale, farm-sited biogas plants with agricultural feedstock, operated by a single farmer,

B) Medium to large scale biogas plants using agricultural feedstock or bio-wastes, but operated in joint venture of different farmers or stakeholders and

C) The upgrading of biogas to biomethane and its injection into a natural gas grid.

2.1 Small-scale, farm-sited biogas plants

This type of biogas plants is characterised by a rather low electric capacity of 50 – 100 kWel, installed on the premises of the investing farmer and is both financed and operated by the farmer. In most cases it is financed with equity capital of
the farmer and credits, which makes the creditworthiness of the farmer decisive for bank credits. The farmer is liable for the payment of the instalments with his farm property meaning a high personal risk for the farmer.

This makes the integration of a biogas plant into the daily processes on a farm utmost important, although the farmer usually acts in multiple functions: as feedstock supplier by using manure, residues or energy crops from his own farm, as plant operator in charge of loading, monitoring and maintaining the biogas plant and as “craftsmen” keen to take care for as many tasks as possible for cost reasons. Nevertheless, the efforts linked even with a small-scale, farm-sited biogas plant mustn’t be underestimated – especially in terms of time needed for the operation and maintenance, but also in view of know-how needed to sustain a continuous fermentation process and to minimize deadlock time.

The motivation for the farmer lies in gaining an additional income to his daily farm business, based on the conditions/potential on his farm. Thus, usually farm-owned residues, manure and/or energy crops are utilized, the biogas plant planned accordingly. This means for example, that a farm with 100 cattle would have a potential for a 30 kW power unit. Usually livestock farming and dairies can be found in regions with a high share of grassland, making those regions potentially peculiar attractive for technology providers and project developers, focused on rather small capacities and agricultural residues and manure. Thus, profound consultancy in planning and designing a biogas plant, which is adapted to the conditions on-site and integrated best into the daily business of the farm, can become a well-demanded service. In terms of technology it is not only important to find the best technology for the utilised feedstock and offered in the required scale/capacity, but also to have a sturdy technology which can be managed by a rather inexperienced farmer, too.

2.2 Medium to large scale biogas plants with agricultural feedstock or bio-wastes

In comparison with small agricultural biogas plants, medium to large scaled projects (> 350 kWel) are – amongst others – characterized by a much larger investment volume of € 1 million and even higher. This makes them usually too expensive to be financed by a single farmer. Hence, projects like this are operated by a project consortium of two or several stakeholders having a legitimate interest in developing a biogas plant. By doing so, more equity capital is available and risks can be shared. Most commonly these stakeholders are farmers, waste disposers, municipalities, utilities or plant manufacturers, all bringing-in their specific know-how and strength: feedstock supply, construction and operation of the biogas plant, sales and marketing of the produced energy.
The portfolio of suitable feedstock provides a bright range, but an economic operation of a biogas plant with a capacity of 350 kWel or bigger requires in general a higher share of feedstock with a high energy density, like energy crops, to avoid a long and costly transportation of the biomass. This makes larger biogas projects particularly interesting in regions with a good potential of available, energy-rich bio-wastes or with farm land for energy crop cultivation. Though energy generation costs are lower due to scale effects and higher energy yields of the feedstock, it mustn’t be forgotten that there are also higher risks in terms of feedstock supply (and prices), higher efforts for the acquisition of farmers and farm land, and higher costs for conditioning and storage facilities. Another crucial difference to small scale projects is the fact, that medium scaled biogas plants are often project financed. This means that banks (or investment funds) are not so much interested in the creditworthiness of the investor itself, but in the expected cash-flow of the project. This in turn requires a solid, long-term planning security for the project, which makes, with view on the strong dependency of biogas projects on public support, the design and maturity of these support schemes a key factor in the bank’s financing decision process and therewith of a successful market development.

2.3 Biomethane upgrading

As biomethane is one of the most flexible RES energy carriers, it can be used for electricity in CHP on-site or transported via pipeline to remote generators, for heat on-site, by district heating grids or directly as natural gas substitute in domestic space heating systems, or even for transportation in natural gas vehicles. The criteria to assess the attractiveness for upgrading biogas to biomethane follow the same principles in the beginning of the process.

The core process of the production of the raw biogas is the same than for biogas CHP plants. It is based on the same feedstock and technology. But instead of utilizing the biogas immediately in a CHP unit, it is subject to several refinement processes before it is most commonly fed into a natural gas pipeline. The locations of biogas/biomethane production and use are separated. The similarities in the raw biogas production same than the flexibility of its end-use is why most of the criteria,
which trigger the development of on-site biogas CHP plants, also apply for biomethane projects. Still, the attractiveness of a market for biomethane projects is much more complex compared with biogas CHP plants for several reasons:

- The upgrading and grid injection of biomethane is linked with much higher costs, although costs for the CHP unit can be saved if the biomethane is just sold to a gas CHP operator. So far it is still not profitable for small scale biogas projects. To become profitable, it is of great importance to develop scale effects and to utilize energy-rich energy carriers for a high biomethane yield. For this reason, medium to large scale capacities apply best, utilizing energy crops or energy-rich bio-wastes rather than animal manure.

- In contrast to on-site biogas CHP, the injection of biomethane into a natural gas grid is of course dependent of the existence of such, which is not the case in all European regions. In addition, there are many different requirements e.g. on the gas quality to be considered, which also can vary from region to region. Same is true for administrative procedures and costs for the grid connection.

- Also the sales of biomethane are much more than on-site biogas CHP in direct competition with natural gas in the market. Biomethane is first of all a substitute energy carrier for natural gas applications, hence, for the sales of biomethane on the gas markets, the price difference between natural gas and biomethane is crucial. Therewith, questions of the natural gas price development, existing support schemes both for biomethane and natural gas or national dependencies on natural gas imports play an important role for the attractiveness assessment of biomethane markets.

- To be used as transport fuel, a sound infrastructure is needed (like the availability of filling stations offering natural gas fuels, adopted engines in cars etc. and an adequate policy support (e.g. blending quotas, investment subsidies for gas vehicle etc.) to become an option for the biogas industry.
3. CRITERIA AND INDICATORS FOR MARKET ATTRACTIVENESS
The evaluation of market attractiveness for biogas is a complex issue, various aspects have to be considered and information collected. For SME which have decided to expand on international markets but haven’t identified a suited country yet, this selection process can be very time and cost intensive and moreover, if these companies haven’t gained any experienced in market assessments so far, important key factors can easily be ignored.

From there, within the CrossBorder Bio-energy project relevant categories and criteria have been elaborated with support of market established industry stakeholders which will give guidance on what to consider and to look for in the market evaluation process:

**The political framework conditions**

Political regulations play an important role for the accelerated development of RES. First of all, clear and binding targets for the RES sector or even single technologies are a strong driver for investments. But of course these targets have neither to be undemanding, nor exaggerated or unrealistic. They have to go hand in hand with the actors’ capability to reach the targets and a sound implementation concept. Hence, the existence of an ambitious, but realistic development target – either specifically for biogas or biomethane, or at least for RES in total – which is also combined with a sound action plan, is an important indicator for the wholeheartedness of the political will. In addition, if the implementation requires a national budget, it has to have the necessary capital which is detached from annual budget negotiations to provide important planning security.

Though many policy makers wish to develop the biogas sector, the production costs of biogas are still higher compared to fossil competitors, investments into the biogas market therewith linked with a significant higher risk. These risks wouldn’t be accepted without a minimum security for the investment, e.g. in form of a support scheme which covers these extra costs or provides a long-term calculable cash flow within the pay-back period of the investment. So another important fact is whether or not the targets and action plans were transposed into adopted support schemes or regulations, that is to say: Is there a sufficient support scheme implemented, or not? Last but not least existing support schemes or their conditions mustn’t change too often along a minimum period of time, as this again wouldn’t contribute to the investors’ confidence and hampers the investment security. Steady and reliable support schemes are of utmost importance to evaluate and accept the risk, otherwise the potential would remain untapped.

**The feedstock supply**

It is obvious that the availability of biomass in a sufficient amount is crucial. Nevertheless it is worth to have a closer
look at the kind, amount and regional dissemination of the feedstock. Biogas plants differ significantly in their designs, technologies and capacities according to the utilized feedstock. Or, to say it the other way round, the available feedstock determines which kind of biogas project can be realized. So the different kind of feedstock potentials should be raised separately.

In addition, to be attractive for foreign investments, the biomass potential has to allow a critical market volume for the investor. To justify the costs, efforts and risks of investing into a foreign market, there has to be potential to sell numerous biogas plants rather than just one. The feedstock potential of a region has to correspond with this requirement accordingly which demands that the biomass already used for existing biogas plants or other applications has to be deducted from the theoretical potential as well. Very attractive is the development of energy-rich, but low-cost bio-wastes, which can be found as leftovers in restaurants, as municipal organic wastes or as wastes and residues in biomass processing industries, although there could be different requirements on hygienisation, pretreatment and transportation causing additional costs.

For agricultural biogas plants animal manure is a valuable energy carrier, but manure has a low energy density. For that, it is not only important to know, how many livestock is needed to provide a sufficient amount of manure to operate a small scale biogas plant, but also – again to assess the market volume – how many farms in the region keep sufficient livestock in stables instead of on pasture to be able to collect the biomass.

One of the biggest potentials definitely arises from agricultural energy crops, as they have a high energy density and therewith allow the operation of medium- to large scale biogas plants resp. the production and grid-injection of biomethane. Although it mustn’t be forgotten, that with a rising capacity of the biogas plant, the radius of the catchment area for the feedstock rises, too, which requires again a sound logistical infrastructure. But the more decisive question is, if there is at all farm land available to grow energy crops on, and how much. This question can only be answered theoretically as it is too much dependent on short-term and highly volatile developments on agricultural markets like price developments of competing products made out of the biomass (food, feed) or varying harvest results. As an approach it is suggested – neglecting trans-border trade – to raise the amount of farm land which is not needed for the food production of the inhabitants of the examined region. Further on, the available farm land per capita can be compared with the corresponding farm land needed (theoretically) to feed a person in the region. Both results can give a clue of how much farm land could be utilized for the biogas production without competing with the food sector, although, in reality trade and price effects will of course influence the farm land potential.
distinctly. In addition, present abandoned land suited and allowed for agricultural expansion should be considered. And as described already above, also the structure of the agriculture plays an important role. Is the farm land disseminated homogeneously among the farms, or are there just some owners of large estates while the bulk of farms own only small amounts of cultivable land? How many farms can provide a sufficient amount of farm land to grow energy crops for a small- to medium scale biogas plant? How many to operate a medium- to large scale one?

Last but not least, if the biomass has to be transported to the biogas plant, a dense infrastructure suited for related means of transportation like truck roads, railway lines or waterways is needed.

The energy market

Beneath the feedstock supply and the structure of agriculture, the quality of the energy market is a decisive criterion for an investment decision, too. Due to the high flexibility of biogas in the energy markets, there are many issues which can be considered, but there are generally spoken three aspects which are important to analyse: the available energy infrastructure and its rules, the development of the fossil competitor and competition with other biogas stakeholders already active in the market.

If the main target of the biogas production is the generation of electricity, it is first of all good to know how the electricity market has developed in recent years and – even more important – how it is expected to develop. Is the electricity market growing or shrinking? Are there already new power plants announced, or are existing plants already out-dated and due for replacement? Maybe in association with a decision to phase out nuclear energy? As usually it is not foreseen to sell just one, but plenty of biogas plants, the market volume theoretically available for additional electricity production is relevant to justify a long-term commitment in the target country.

But even if the market volume seems to be attractive enough to enter the market, the electricity still has to be sold to the markets. That means that the biogas plant usually has to be connected to an electricity grid and the electricity to be fed-in and transported. So there has to be an electricity grid available close to the biogas plant to avoid costly grid connection costs. And as experience has shown, if there aren’t clear rules defined for biogas plant owners and grid operators on the costs, rights and duties of grid injection and transportation, the denial of the grid access has often proven to be the bottleneck for a successful development of the RES electricity market.

Same is true for the processing and grid injection of biomethane. The biggest potential arises from the distribution of biomethane via the natural gas grid to offer biomethane in the heat, electricity or transportation sector, although the marketing of biomethane as transport
fuel on-site of the biogas plant has proven to be successful in many cases as well, as long as the natural gas vehicle infrastructure is well developed. Yet, the existing and regulated access to the natural gas grid is one of the key drivers to expand biomethane applications. In addition, for direct sales of biomethane in the heat sector the connection density and consumption of natural gas customers is a good indicator.

The heat market can generally be an attractive market for biogas plants as well, as they are keen to operate the plant in CHP to increase income and lower risks. Therewith, countries with a rising heat demand or a defined high target for RES heat can provide very attractive framework conditions for biogas CHP plants, respectively decentralized CHP projects based on biomethane taken out of the gas grid.

Nevertheless competition with fossil fuels in the energy market mustn’t get lost out of sight, of course, which indicator is its price development over the recent years and into the future. A good investment climate exists, where prices for fossil fuels, especially for the direct competitor natural gas, have risen steadily and are expected to grow further on. If then these fuels are in addition to that also based to a large extend on imports, the economic pressure arising out of it paves the way for investments into biogas technologies. On the other hand, a high share of available domestic fossil fuels or their low prices, maybe even due to financial support to lower social impacts, can be seen as an intense market barrier for biomethane in particular, but also for biogas CHP projects.

If both the energy infrastructure and the competition with fossil fuels look favourable for the biogas sector, it is not unlikely that there are already market competitors active in the country. Therewith, their number and economic power in terms of sold biogas plants or their sold cumulated capacities has thoroughly to be analysed. A low number of competitors in a market with high volume can usually be seen as good opportunity. On the other hand, a strong competition in the sector already indicates favourable framework conditions and a running market. Therewith, the interpretation of the market analysis depends very much on the existing market volume and the investor’s strategy.

**Profitability and support**

Without financial or regulative support the operation of a biogas CHP- or biomethane plant wouldn’t be profitable in most cases. Due to the higher energy production costs, the economic risk for investments into biogas projects is fairly higher compared to already market introduced, fossil energy carriers. With view on the long-term payback-period for the investments, potential investors will feel a delicacy about spending their money without having a minimum of planning security. Same is true for the financing of projects by banks which won’t dare to grant credits to risky projects or will
demand unfeasible charges to cover the risk.
Consequently, a country which has successfully implemented a support scheme addressing this fundamental disadvantage is very attractive for investors resp. technology providers. There can be many ways to overcome this market barrier, one of the most successful is the introduction of a feed-in system (FIS), which provides a cost-oriented remuneration of the electricity production. But it is not only the amount of the fee which decides about the success or failure of this market incentive, but also the duration of the payment, regulations on the grid access and whether the available budget is limited or not. Also mandatory quotas for RES electricity or heat can be an incentive, if designed in the right way, though they are less common. Some countries gained great success with taxes on CO₂-emissions, therewith developing the environmental benefits of RES installations.
If there isn’t a support scheme for the operation of a biogas plant implemented, also the availability of investment subsidies could be an attractive incentive to lower the total costs of a biogas project. Sometimes, there are also special support programmes effective to attract in general investments into remote areas or to create jobs, which could possibly be utilized for biogas and biomethane projects.
But as mentioned above, also banks and their attitude to RES project play an important role in the market development of the biogas sector. Although it is of
course possible to finance a biogas or biomethane project in cooperation with a domestic bank in the home country or with an international financial institution, local banks in the target country are in many cases first address for local investors intending to buy a biogas plant from a foreign technology provider. Consequently, these banks should be well-informed about biogas technology and their functioning and open to grant related credits to a feasible price. It is beneficial for a market development, if a bank is already committed to the biogas technology, which can be derived e.g. from advertisements or highlights within annual reports up to special programmes offering low interest rates or beneficial conditions for loans.

In addition, to manage the risk of volatile prices, for many investors the price transparency of markets is an important factor, too. Is there a market place where prices both for feedstock and energy are published? And are there means to modulate the price risk, e.g. by hedging or trade with futures?

**Administrative issues**

As different the market potentials of the European countries are for the biogas sector, as different are the administrative challenges to be solved when entering a market. For example, there are different regulations to be considered concerning the planning permission and building approval for a biogas plant in municipalities or rural areas. Sometimes, the best biogas potential cannot be developed due to constraints in the building code. Also requirements on minimum efficiencies of biogas plants, which usually can only be fulfilled by also selling the produced heat to external customers, can prove to be a market barrier, if at the planned – or allowed – location of the biogas plant no heat customer can be acquired and consequently a rather meaningful project cannot be realized.

Environmental restraints can hamper a successful market growth, if there are excessive thresholds defined, e.g. for emissions of pollutants into the air or of noise. Legal requirements for the reduction of odour emissions can for example also rapidly put the profitability of a bio-waste processing biogas plant on the edge. On the other hand, regulations e.g. prescribing the treatment of wastes of biomass processing industries can be a great market driver and motivation for those companies to invest into biogas technologies.

Due to the variety of different regulations and requirements, but also because of the various state of knowledge at the authorities, the duration and efforts of the approval procedure can be very different from country to country. For planning a biogas plant it is naturally important to get the allowance as soon as possible to avoid running costs and the risk of changing framework conditions during the time between application and approval. It can be helpful for a market entry if there is a dedicated industry association for biogas and biomethane...
which can consult and assist with the procedure.

**The individual country risk**

Apart from specific decision factors for biogas related investments, there are also many aspects to be regarded on a macro-level, out of which the profile of the country itself in terms of Gross Domestic Product, economic development and wealth of the society. Higher costs linked with RES in general are usually only accepted by the public in a period of welfare and positive development expectations, while in times of economic slowdown or depression short-term cost savings and social safeguard are put in the foreground. This is true both for the private or commercial customers’ financial capability than for public budgets with which support schemes for RES are financed.

Linked to that is the question of credibility and reliability of a country, respectively its industry stakeholders as partners for international business cooperation. How secure are investments into a foreign country, how likely is a payment failure? There exist already highly professional and approved country assessments like the ratings of Standard & Poor’s or Moody’s which should be called in to minimize financial losses due to political crisis or economic turbulences. Also export credit insurance companies often provide own assessments of the export risk into foreign countries, which are especially suited for the export of technologies and services.

With view on the financial risk of investments into foreign markets, the currency exchange risk has to be highlighted as well. A beneficial exchange rate which makes the domestic currency cheaper compared with the foreign currency is a good driver for exports as the buyer therewith gets also the product cheaper than on the domestic market. But volatile exchange rates don’t provide a reliable basis for investment decisions as ordered products or services can quickly become more expensive than calculated and putting any profitability calculations at risk. For this reason, the membership of both countries, the home country of the exporting company and the target country, in the European Monetary Union (“euro zone”) is seen to be a great advantage in Europe.

Another financial risk arises with steadily growing inflation rates, which not only reduces the purchase power of potential customers, but also abate the value of the company’s assets, once acquired with the market entry process. A stable or even declining inflation rate over a period of time is accordingly another valuable indicator to avoid negative financial impacts on the investment.
4. LIST OF CONSIDERED CRITERIA AND INDICATORS

To evaluate and compare the attractiveness of biogas markets in different countries common assessment criteria translated into measurable and therewith comparable indicators have to be defined. This was done during the CrossBorder Bioenergy project with great support of industry stakeholders of the target groups, who identified the key information needed by them and consulted with the implementation of the data into a practicable tool.

The following list is the result of the intense industry consultation process and should give an overview on the criteria and indicators considered within the assessment of the European biogas markets within the CrossBorder Bioenergy project. In addition, this list can also be applied by companies as checklist for an individual market evaluation, offering guidance in the bulk of criteria to be considered and assistance in the assessment of the received results.
1. Country profile (geography, demographics, logistics, etc.)

1.1 Geography and Climate
- Total land area
- What is the average summer temperature across regions in target country over the last 10 years?

1.2 Population
- Total number of inhabitants
- Total number of households in the country
- Population density
- Household density
- Total number of personal transport vehicles

1.3 Wealth/economic status of population
- What was the average GDP real growth rate between 2008 - 2010?
- GDP per capita for 2010

1.4 Logistics - road and rail network
- What is the density of road-network? (for goods/biomass transportation)
- What is the density of the electricity transmission and distribution networks?
- What is the density of the gas transmission and distribution networks?

2. Energy Policy (political will, nREAP, etc.)

2.1 The nREAP is ambitious and proposes appropriate measures
- There are high-volume targets for RES (Difference in ktoe 2010 - 2020)
- There are high-volume targets for biogas (Difference in ktoe 2010 - 2020)
- There are high-volume targets for electricity from CHP (Difference in ktoe 2010 - 2020)
- Proposed measures for bio-methane and biogas in nREAP are appropriate and convincing
- Proposed measures for biogas CHP in nREAP are appropriate and convincing

2.2 A political will to develop the RES-sector is clearly recognisable and stable
- Does the government provide an appropriate budget for the targeted market growth for biogas, biomethane?
- Have the support schemes/framework conditions for investments in
biomethane changed within the last 2-4 years?
• Is a revision of the framework conditions announced, which could affect biomethane market development?
• Is a revision of the framework conditions announced, which could affect the electricity market development?
• What is the period of time before the next general (national) elections.

3. Feedstocks

3.1 The biomass potential is sufficient to enable biogas CHP projects
• How many cattle-equivalent units are in the region? (to identify potential based on feedstock)
• How large is the (municipal + commercial) bio-waste potential in the region?
• What is the amount of biogas already produced in the region?

3.2 The biomass potential is sufficient to enable biomethane projects
• How many cattle-equivalent units are in the region?
• How large is the (municipal + commercial) bio-waste potential in the region?
• What is the amount of already produced bio-methane in the region (to identify the remaining technical potential)?

3.3 The agricultural structure is beneficial for biogas and/or biofuel projects
• How many farms have at least 150 cattle in stables, which could enable small biogas CHP projects?
• How many farms have at least 500 cattle in stables, which could enable larger biogas CHP projects?
• How many farms have at least 125 ha crop land, which could enable larger biogas CHP projects?
• What is the available farmland per inhabitant?

3.4 Feedstocks are available for biofuel production
• Amount of domestic demand for cereal for biofuels in 2010
• Did the cereal production of 2010 exceed the domestic demand?
• Did the oil seed production of 2010 exceed the domestic demand?
• Area of fallow/abandoned land available for agricultural expansion

4. Economic instruments (prices, support schemes/guarantee, subsidies, etc.)

4.1 Financial support schemes can be claimed for investments
• What portion of the investment in biogas plants can be claimed in subsidies (cumulative, including tax advantages)?
• When does the scheme end granting funding for biogas plants?
• Subsidies for investments in logistic/Infrastructure for high blend / pure biofuels are in place
• Investment subsidies for green vehicles procurements are in place

4.2 Financial support schemes can be claimed for operation
• 150 kW biogas plants: How high is the legally guaranteed price for electricity (either feed in system, green certificate or other) in 2010?
• 500 kW biogas plants: How high is the legally guaranteed price for electricity (either through feed in system, green certificate or other) in 2010?
• >500 kW biogas plants: How high is the legally guaranteed price for electricity (either through feed in system, green certificate or other) in 2010?
• How long is the guaranteed duration of the biogas support scheme?
• Is the support scheme limited by a maximum public spending budget?
• Is there a financial incentive to support the operation of biomethane or gas vehicles?

4.3 Prices of fossil fuels are high and heavily taxed
• What is the price per kWh of gas for households?
• What is the price per kWh of gas for large scale consumers (average over the last year)?
• What is the commodity price development of natural gas over the last 4 years?
• What is the tax on gas (CO2, energy, excluding VAT or ‘normal’ taxes)?
• Is the use of fossil gas supported e.g. by tax incentives, obligations, free delivery of CO2-allowances etc.?
• What is the price development of electricity of the last 4 years?
• What is the average end customers price for gas for transport over the last year (2010)?

5. Market aspects (volume, access to grid, etc.)

5.1 The energy sector is large and expected to grow
• Amount of gas used in medium and large scale consumers (2010)?
• Expected growth in large and medium-scale use of gas from 2009 to 2020
• Amount of gas used by small scale consumers (2010)?
• Amount of total national electricity consumption
• Expected growth in national electricity consumption from 2009 to 2020
• What is the average age of the stock of power plants (coal, natural gas, nuclear)
• What is the share of natural gas in the electricity sector?
• Has the region decided to phase out nuclear energy (providing potential for RES)?

5.2 Access to the electricity grid is guaranteed
• Is there in general an electricity grid available with sufficient capacity?
• Is there in general an electricity grid available with regulated grid access?
• Is there in general an electricity grid available with regulated costs for grid connection?
• Is there in general an electricity grid available with priority for RES?
• Is the grid operator obliged to connect all renewable energy installations?

5.3 The heat market offers good opportunities
• What is the total amount of energy consumed by the small heating sector?
• What is the proportion of customers connected to a district heating grid?
• What is the amount of coal in the district heating sector?
• What is the average age of the stock of domestic heating appliances
• Is the connection of a biomethane plant to a natural gas grid regulated?
• Are the costs for grid connection regulated?
• Is there a natural gas grid for biomethane feeding available with priority for biomethane?

5.4 Produced energy can freely be marketed
• Is the electricity market liberalised and private firms are free to participate in any part of the supply chain?
• Is the heat market liberalised and private firms are free to participate in any part of the supply chain?
• Is the gas market liberalised and private firms are free to participate in any part of the supply chain?

5.5 The electricity market in the target country provides promising growth perspectives
• What is the rate of additional electricity demand until 2020 (overall, not only RES)? ((2020-2009)/2009)
• What is the growth rate of electricity from biogas over the last 4 years?
• What is the cumulative amount of electricity produced from biogas in the last available year?
5.6 The heat market in the target country provides promising growth perspectives
- What is the rate of the additional heat demand until 2020 (overall, not only RES)?
- What is the growth rate of biogas in the heat market over the last 4 years?
- What is the cumulative amount of heat produced by biogas in the last available year?

5.7 The gas market enables the use of biomethane
- What is the rate of the additional gas demand until 2020 (overall, not biomethane only)
- What is the additional gas demand until 2020 in absolute terms?
- What is the cumulative amount of biomethane consumed in the last available year compared with biomethane target?
- What is the growth rate of biomethane in the gas market of the last 4 years (CAGR)?
- What is the growth rate of biomethane in the transport sector of the last 4 years (CAGR)?
- What is the total amount of biomethane used as vehicle fuel?
- Amount of all gaseous fuels used in transport

5.8 The Framework conditions for fossil fuels do not impair market development
- What is the contribution of imported natural gas on the primary energy supply in real terms?
- What is the percentage contribution of imported natural gas on the primary energy supply?
- What is the contribution of imported oil to primary energy supply in real terms?
- What is the percentage contribution of imported oil to primary energy supply?
- What is the contribution of imported coal to primary energy supply in real terms?
- What is the percentage contribution of imported coal to primary energy supply?

5.9 Bioenergy is already implemented with a strong growth
- What is the total biogas production quantity irrespective of final use
- What is the biogas production growth rate in the last 4 years (CAGR)

5.10 An intense competition is not recognisable
- Number of competitors providing (manufacture or sale) turn-key biogas plants
- Total amount of biogas/biomethane plant capacity sold (by existing competitors) over the last 4 years
6. Regulations (laws/mandatory targets for bioenergy, permitting, emission thresholds, etc.)

6.1 Regulatory instruments to support bioenergy markets have successfully been introduced
   • How large is the quota for RES electricity in absolute terms?
   • How large is the quota for RES heat in absolute terms?

6.2 The approval procedure by the authorities is adequate in terms of time
   • How long does the approval process last in average for a biogas plant < 500 kWel installed capacity?
   • How long does the approval process last in average for a biogas plant > 500 kWel installed capacity?

6.3 Specific regulations are favourable for bioenergy market developments
   • Is there a hygiene regulation for the treatment of bio wastes, which could incite its utilisation in biogas plants?

6.4 Are criteria for efficiency required?
   • Is there an obligation for CHP-operation of a biogas plant, if so, what is the required heat percentage?

6.5 Existing emission thresholds can be fulfilled with the applied technology
   • Are there limits to emissions to air from biogas plants and, if so, how severe are they?
   • Are there limits for noise emissions from biogas plants and, if so, how severe are they?
   • Are there any regulations to mitigate odour emissions from biogas plants?

7. Project financing context (economic situation, loan, banks, etc.)

7.1 The country has a solid financial position
   • Standard and poors rating

7.2 Export friendliness
   • Euler Hermes rating
   • Corruption perception index
   • Country risk as reflected by the @rating country of COFACE
   • Ranking of feasibility of “starting a business” in the IFC-World Bank Doing Business Index
7.3 The banks are familiar with bioenergy technology and support its development
  • Is the support of bioenergy projects highlighted in official papers of the banks, like annual reports etc.?
  • Are Governmental guarantees for loans for bioenergy investments in place?

7.4 Foreign investments are supported in the target country
  • Are there any programmes implemented in the region to attract foreign investments?

7.5 The banks in the target country provide attractive conditions for bioenergy projects
  • Can bioenergy plants benefit from interest rates for credits lower than usual in the market?
  • Are the support conditions feasible in an adequate scope?

7.6 The market is liquid and transparent
  • Biomethane prices are published on market place
  • Financial market instruments (e.g. hedging, futures) are available to mitigate the bio-methane price risk

7.7 The value of the investment is stable due to a low currency exchange risk
  • Is the market part of the Euro Zone?
  • Was the inflation rate of the country more or less stable within the last 4 years (CAGR)?

8. Readiness for uptake (public acceptance, stakeholder networks, etc.)

8.1 Efficient networks and information are accessible
  • Is there a Biogas association (with a minimum of 10 company members) assisting the market?
  • Public web sites/information/market reports on bioenergy

8.2 Public acceptance/knowledge of technology
  • Is biogas known to and well-regarded by general public?

8.3 No public opposition to bioenergy technology and projects
  • Have any biogas project permissions been declined due to public opposition in the last four years?
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