FABbiogas

BIOGAS PRODUCTION
IN THE FOOD & BEVERAGE INDUSTRY

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Content

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Foreword

This handbook is addressed to everyone interested in the topic of biogas production from residues of the Food & Beverage Industry (FAB industry). Especially it is interesting for persons from the FAB industry, waste management companies, biogas plant operators and policy makers. It was created within the EU project FABbiogas. Project partners from 6 countries are working on this project with the aim to promote residues from FAB industry as a new and renewable source for biogas production (www.fabbiogas.eu).

The European FAB industry is the second largest manufacturing sector in the EU 27 with a market share of 12.2 % in value added terms. This sector generates a turnover of €917 billion (14.5 % of total manufacturing turnover) and employs 4.5 million workers (European Commission, 2009). The amount of residues generated in the manufacturing sector (FAB industry) is 5 % of total food production (EUROSTAT 2006).

Organic residues from production processes harbor a widely untapped potential for energy generation. Anaerobic digestion provides a promising alternative to standard waste treatment. A number of good practice examples show that by implementing biogas technology into the FAB industry, substantial economic and ecological savings are possible.

The basic aim of this handbook is awareness raising on this topic and to present the high potential of FAB industry waste as source for renewable energy in Europe.

The following pages provide information on the status of biogas production in Europe, biogas potentials from FAB industry waste, technical solutions and challenges to realize biogas projects and best practice examples on biogas production from FAB industry waste.

If you need further information you can call at our FABbiogas national contact points who offer free advisory services on the topic of biogas production from Food & Beverage Industry waste: www.fabbiogas.eu/en/advisory-services

Wolfgang Gabauer
Project coordinator

1. CURRENT STATUS AND POTENTIAL OF BIOGAS IN EUROPE

In March 2007, the governments of the 27 EU Member States adopted a binding target of 20 % renewable energy from final energy consumption by 2020[1]. Combined with the commitment to increase energy efficiency by 20 % and to reduce GHG emission by 20 % until 2020, Europe's political leaders paved the way for a more sustainable energy future for the European Union. Factors such as the different starting points, renewable energy potential and economic performance of each country are taken into account in the targets. The share of renewable energy in total energy consumption in 2010 and agreed targets for 2020 are shown in Figure 1 for the six partner countries.

Biogas is seen to be one of the key technologies both to reach EU member states targets for renewable energies in 2020 and to meet their requirements within the European waste regulation.

The European Landfill Directive 99/31/EC[2] set mandatory targets for a three-step reduction of biodegradable waste going to landfill. Set against a 1995 baseline, it requires a reduction of 25 % by 2006, 50 % by 2009 and 65 % by 2016. It is necessary to reduce the amount of all types of waste going to landfill. Therefore, it is desirable for the European Union Members to investigate also in novel technologies to reduce the waste and sub-products from the food industry for renewable energy production.

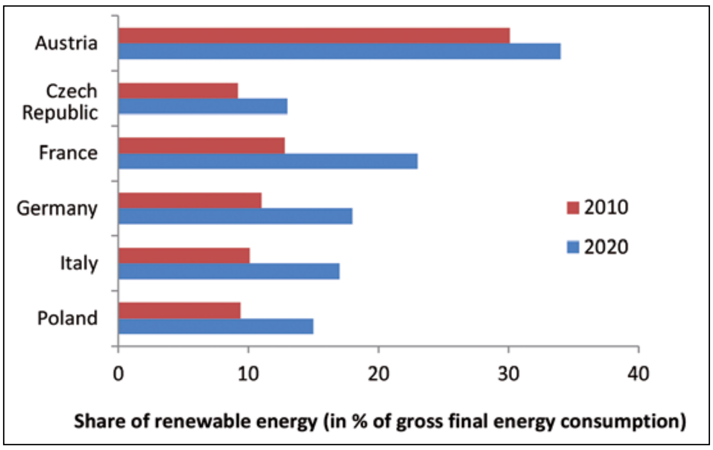

Figure 1: Share of renewable energy in total energy consumption in the partner countries

Biogas plants are regarded as one of the best options to reduce the organic matter in food waste and at the same time produce a renewable energy that – in most cases – can be utilized as process energy. In a former project supported by Intelligent Energy Europe[3] the situation in the agricultural sector was highlighted of most of the partner countries. This brochure focuses on the waste from food and beverage industry.

Austria

In Austria, the installed electrical power rose from 15 MW_{el} to 80 MW_{el} between 2002 and 2007, which was the result of the implementation of the first Eco-power law (feed-in tariffs). There are approximately 350 biogas plants in Austria including ca 64 waste biogas plants processing "animal by-products". Initially, the most commonly used substrate was slurry and small amounts of organic waste, while in 2011 the predominant substrates were agricultural substrates like maize or grass silage (57 %), slurry and manure (19 %) and other substrates like bio waste and food waste (24 %) (e-control, 2011)[4]. Unfortunately, the increase in the prices of energy crops in 2007 caused a significant increase in the operation cost of biogas plants. The following changes of the Eco-power law have led to a reduction of the feed- in tariffs and the subsequent reduction of new biogas plants.

In order to compensate rising costs of raw materials in Austria, substrates subsidies were granted in 2008, and the amendment to the green electricity act in 2012 was expected to ensure the improvement of framework conditions. However, the incentives were all too low to initiate new constructions.

Czech Republic

In the Czech Republic, the main trend in the production of renewable energy is withdrawing biogas from municipal landfills, and the use of anaerobic purification step in wastewater treatment plants. When it comes to the development of biogas plants in the Czech Republic, it is dominated by installations based on agricultural residues and dedicated energy crops. It is planned to build 563 biogas plants, while at the moment there are 303, however, not all of them started operation yet. The report of the Czech Republic[5] shows that there are currently more than 20 biogas plants, in which biodegradable municipal waste and organic industrial waste are used as substrates. Twelve plants are operated on industry waste only including breweries, food and vegetable production as well as pet food. The dynamic development of the biogas market is probably a result of the favorable purchasing price of electric power from agricultural biogas stations and the investment support from EU structural funds, specifically from the Environment, Entrepreneurship and Innovations operational programs and the Countryside Development Program and is also the chief priority of the ECO-energy program established by the Ministry of Industry and Trade. Unfortunately, due to financial limitations, the incentives have been

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[1] Dir 2009/28/EC; http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN
[2] http://ec.europa.eu/environment/waste/landfill_index.htm
[3] http://www.biogasin.org/
[4] http://www.e-control.at/portal/page/portal/medienbibliothek
[5] http://www.fabbiogas.eu/en/download

stopped in 2013 and the positive development came to a complete halt.

France

France counted in 2012 90 agricultural and 106 in industrial[6] plants, 58 thereof in the food and beverage industry. The exact locations are available, along with the installed electrical power for some of these plants [kW] on an interactive website[7] In 2011 the French government has published a number of new initiatives that ensure solid backing for biogas in France. This backing includes increased support for production of biogas on the basis of waste from cities, industry and agriculture and the use of biogas for electricity production, heating and distribution via the natural gas grid. According to a press release from the industry and energy minister, up to 2020, support for biogas in France will increase to a total of EUR 500 million a year. The French targets are ambitious. By 2020, 270 million cubic meters of biomethane are to be distributed via the natural gas grid. Electricity production based on biogas is to be quadrupled and heating based on biogas is to be increased sevenfold by 2020.

Germany

Germany is the market leader in biogas technology and is also Europe's biggest biogas producer (Figure 10). More than half of Europe's biogas is of German origin. Thanks to generous subsidies, renewable energies have become economically attractive for farmers, German power companies and local authorities. Especially the amendment of the EEG in 2004 and the renewal in 2009 supported the expansion of biogas plants. In 2011, 7,515 biogas plants were operated in Germany with an installed electrical power of 3,352 MW. They supplied around 23,000 GWh of electricity to approximately 6.5 million households. However, the German market has slumped dramatically since early 2012 forcing the German biogas industry to orient its business strategies towards foreign countries mainly in Europe but also in Canada and China. The break-down was mainly due to the upcoming amendment of the Renewable Energy Act (entered into force in April 2014) in which compensation rates for biogas were reduced with an added tightening of legal conditions. Apart from the reduced feed-in tariffs, German plants are not allowed to use more than 60 % maize anymore. On top, operators are required to use at least 60 percent of the heat produced in CHPs to increase total efficiency. As a consequence, the number of new plants decreased from around 1 300 in 2011 to 350 in 2012. Major substrates for biogas plants so far were energy crops with 49 % and animal manure with 43 %. Industrial and agricultural residues accounted for 1 % (w/w) only of the total input (DBFZ 2012). However, the number of waste utilizing biogas plants is continually rising due to the fact that FiT for waste plants were not reduced in the new legislation. Actually around 300 biogas plants use partially waste from FAB industry. Approximatively 120 large scale plants are operated on waste only.

Italy

In 2012, there were 855 plants linked to agro activities for a total of 720 MW_{el} installed. The average power installed for the biogas plants is less than 1 MW, most are operated at 999 kW_{el}, the limit for the formerly high feed-in tariff. In 2012 4,620 GWh_{el} have been generated, about 35 % more than in 2011. The difference is to be attributed to the biogas plants fed with inter-species catch crops, increasing the electricity production from 1.453 GWh to 2.534 GWh.

The number of biogas plant using by-products from the FAB industries is far more limited. In total 79 biogas plants are digesting FAB waste (5 m tons from industry, 1m ton from slaughterhouses) with 60 MW_{el} installed. Regional distribution shows that the plants are mainly located in the northern regions where the industry is located. Only 10 plants are located in the south of Italy including Sicily (1) and Sardinia (1). About 60 % of the FAB waste plants use co-digestion with animal and agricultural wastes.

Poland

Currently there are 39 installations in operation. Until 2020, according to the Council of Ministers in Poland, 2500 biogas plants with a total capacity of 980 MW_{el} is expected to be built.

The 39 biogas plants digested 469,000 tons of feedstock in 2011. More than half of it, i.e. 277,800 tons, was animal waste; 123,200 tons were energy crops, and only 68,000 tons were waste from the food processing industry. In 2013 however, these proportions began to change rapidly. A very fast growing consumption of waste from agro-food companies was noticed, and a parallel decrease of animal manure and energy crops. The result is that in the first half of 2013, the 39 agricultural biogas plants processed 750,000 tons of substrates. In 19 installations thereof 369,000 tons of waste from the food industry was processed. Five out of the 19 biogas plants use exclusively waste from the food and beverage industry among them the three largest biogas plants in Poland.

[6] EBA Biogas Report 2014
[7] www.atee.fr/biogaz/carte-des-installations-biogaz-en-france

2. SOLUTIONS

Anaerobic microbial conversion of organic matter into a renewable energy source, so called biogas, is a well-established process and state of the art. New techniques and technologies offer possibilities to treat pasty and solid organic wastes by means of anaerobic digestion (AD) as well as liquids.

Solid industrial waste

Often, solid food and beverage (FAB) waste is digested as co-substrate together with other industrial or agro industrial wastes. Commonly, this is done in an agricultural type of plant, i.e. continuously stirred tank reactor (CSTR). These types of digesters have been described in a number of publications. It is the most abundant method for the treatment of FAB industry waste. Sometimes specific high-rate systems are applied. It is a reliable, low cost treatment for FAB wastes. At the same time remaining fractions of organic material after digestion can directly be used as fertiliser on the fields.

Industrial waste water

Diluted FAB waste is sometimes co-digested together with sewage sludge on a waste water treatment plant (WWTP; see Chapter 7). Disadvantages are that the transport distance for liquid industrial wastes are limited for economic reasons and the energy is not available for the industrial process energy. The direct use of AD as an on-site treatment step for FAB wastewater is increasing rapidly to the point where there are now more than 3,000 vendor-supplied systems in operation throughout the world. Over 30 types of industry have been identified as having wastewaters amenable to AD treatment, including processors of beverages, chemicals, food, meat, milk, pulp and paper, and pharmaceutics.

Figure 2: Vertical steel tanks for the digestion of mixed wastes from agriculture and industry in Denmark

Most of the organic compounds in the wastewater are dissolved and therefore easy degradable. Depending on the nature of the compounds, degradation rates are between 80 and 95%. Average concentrations of the waste waters are usually low ranging from > 20,000 mg/l COD to values as low as 1,000 mg/l. Traditionally, industrial wastewater was treated by aeration requiring high energy inputs whereas the process energy of AD is low and in addition biogas as energy source is produced. While aerobic systems are suitable for the treatment of low strength wastewaters, anaerobic systems are suitable for the treatment of high strength. The rule of thumb says that above 2’000 mg/l AD is strongly recommended. Where the digested effluent cannot be used as fertilizer, often an aerobic polishing step is added to meet the effluent discharge standards.

Growth of anaerobic bacteria is slow with doubling times of at least two days. With the fast degradation rates of FAB wastewaters and the large volumes to be treated, liquid retention times in the digester tend to become low bearing the risk that bacteria could be washed out. To counteract washout, dedicated processes have been developed to make the hydraulic retention time independent from the microbial growth.

An early solution was the use of sludge recycling. The so-called contact process consists of a completely mixed, continuously stirred tank reactor (CSTR) and a clarifier (Figure 3A). Biomass washed out of the CSTR is settled or actively precipitated in a clarifier and recirculated to the reactor.

Anaerobic contact systems are particularly efficient when wastewater contains a higher solid content. The design is often found in beverage industry wastewater (e.g. fruit juices, etc.; Fig. 4)

Later, different attached growth systems were developed to retain active cell mass. Today, two basic reactor types are in use: firstly, anaerobic filters (packed bed reactors; Figs. 3B and 5) and, secondly, fluidized bed reactors (Fig. 3C). Both take advantage of the microbial tendency to stick to surfaces. In the first case, microbes are partially attached to a fixed, porous and inert support matrix of e.g. stones, foam glass, plastic bodies or unglazed porcelain. Most often different shapes of plastic material are used. In these cases, bacteria not only attach to the surface but are also withhold within the filter bodies which create cavities. The resistance of anaerobic filters to shock loads and inhibitions make them suitable for the treatment of both high strength and dilute wastewaters.

In fluidised beds bacteria grow on the suspended bed material out of very fine sand or other inert material (< 500 μ). Usually quartz sand is used.

A reactor type emerged from both anaerobic filters and fluidized bed reactors is the Upflow Anaerobic Sludge-Blanket (UASB) reactor (Fig. 3D) (Hofenk et al., 1984[8], Sayed et al. 1993[9]). The influent is fed at the bottom and passes a sludge blanket of biologically formed granules.

It is the most wide spread system for the treatment of industrial wastewater because the developer, Gaza Lettinga, did not patent it, allowing its application also in developing countries. Most of the plant providers and engineering companies offer the design. While the gas leaves the reactor, the particles settle back to the sludge blanket. Because of the induced passive circulation, the reactor does not need to be actively mixed.

UASB technology is still under development. Some years ago, Zoutberg & de Been (1997)[10] presented a new type of UASB reactor; the so-called EGSB (Expanded Granular Sludge Bed) reactor. It is a two-stage system

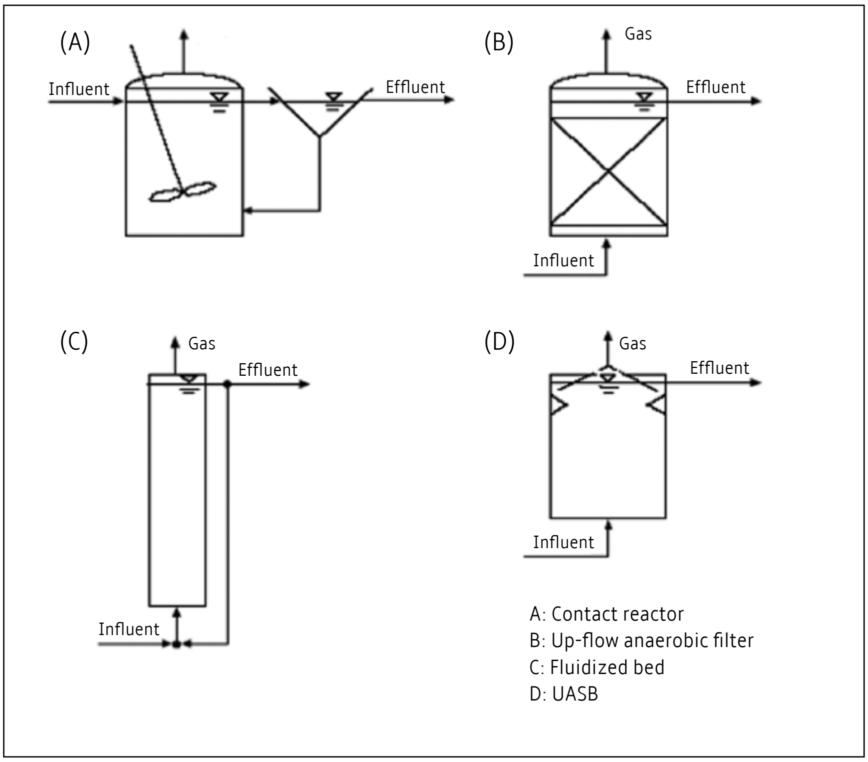

Figure 3: The basic systems of anaerobic industrial wastewater treatment

Figure 4: Digestion of vegetable waste in a contact reactor: Gastro Star, Switzerland (Forster AG)

[8] Hofenk, G.; Lips, S.J.J.; Rijkens, B.A. and Voetberg, J.W. 1984. Final report EC contract No. ESE-E-R-040-NL.
[9] Sayed, S.K.I.,H. Van der Spoel and G.J.P. Truijen (1993): A complete treatment of slaughterhouse wastewater combined with sludge stabilization using two-stage high rate UASB process, Water Science and Technology
[10] www.iwaonline.com/wst/03510/0183/035100183.pdf

Figure 5: Anaerobic Filter digesting brewery waste water: Lupo, Switzerland

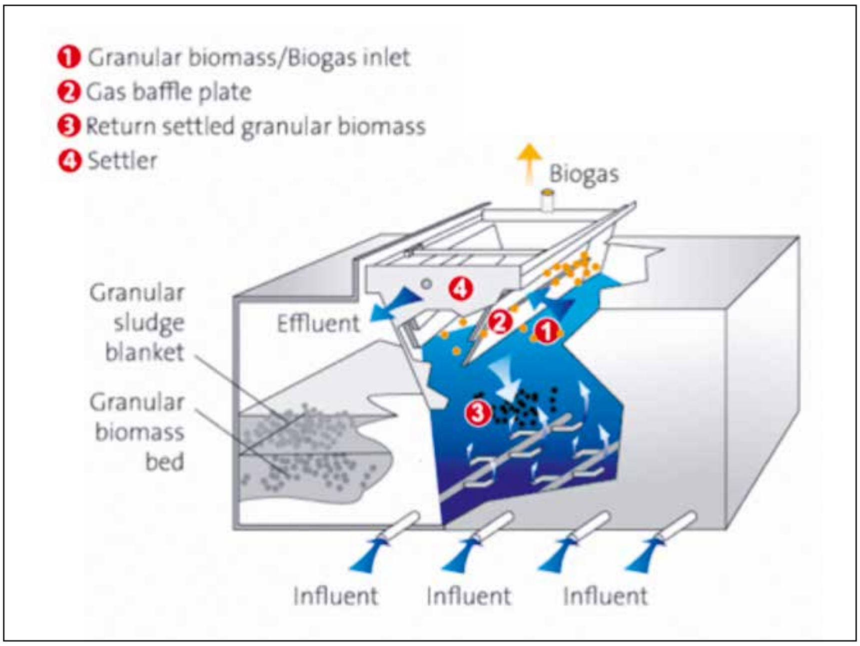

Figure 6: UASB basic design (Veolia)

with internal recycling, developed for high fluid and gas velocities.

The internal circulation (IC) reactor is a vertical tank, with height to width ratio of 2:1 to 10:1 (Fig. 7). The wastewater is pumped into the bottom of the reactor using an efficient distribution system, and is mixed with the granular anaerobic biomass. In the lower reactor compartment most of the organic components are converted into methane and carbon dioxide. The biogas is collected in the lower level phase separator. This generates a "gas lift", which forces the water upwards through the riser into the liquid/gas separator on the top of the reactor. The biogas leaves the reactor through this separator, and the water returns back to the bottom of the system, hence the name: Internal Circulation. The biogas formed in the second, upper compartment is collected in the upper phase separator while the effluent leaves the reactor from the top.

An old technology re-recovered is the membrane reactor that holds back the solid particles and recycles them into the digester whereas the dissolved and mostly degraded liquid flows through the pores of the membrane. The system has gained renewed interest because with the development of improved ceramic membranes the system became more robust. The membrane is often integrated in the fermenter.

Whatever the design of the high-rate digester is, it is far more efficient than conventional CSTRs.

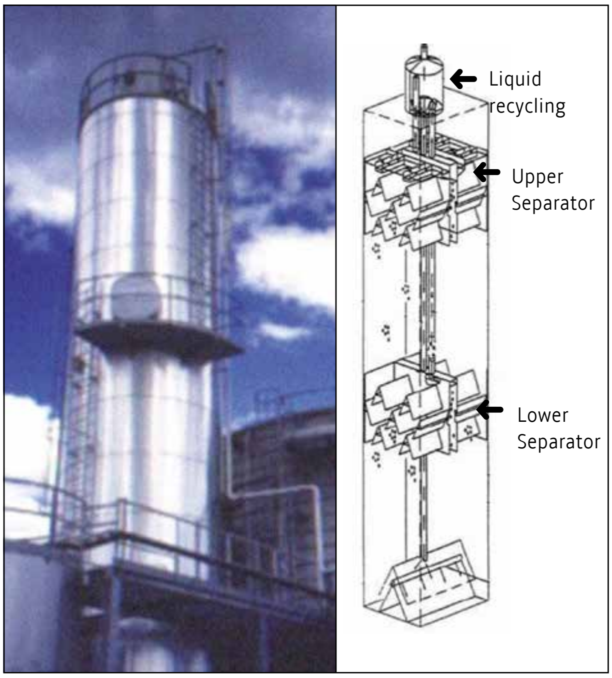

Figure 7: EGSB Dairy waste water treatment with internal circulation, Emmi, Switzerland

3. MOST PROMISING F&B INDUSTRY BRANCHES FOR BIOGAS PRODUCTION

The primary interest of the industry for (pre-) treatment of wastewater and by-products is to reduce the treatment and disposal cost. The production of renewable energy is of secondary importance but adds to good product marketing.

Therefore the most promising branches for implementing AD facilities are those matching several of the following points:

- large volumes of waste streams to be treated
- easy degradable substrates
- high content of organic matter (e.g. COD > 2,000 mg/liter)
- constant substrate availability throughout the year,
- regular demand of process energy,
- high energy need of the food or feed production process

Table 1 cites a number of industries that are successfully operating AD systems.

There is no unique solution to treat all types of industrial waste and wastewater. There are a number of technical solutions for wastewater. The technical solutions for so called solid material, i.e. with dry matter contents of 10-15 % or more are comparable to the widespread designs of agricultural plants. However, there are a few optimized designs specifically designed for industrial applications.

Besides economic benefits a wide range of ecological and social benefits are closely linked to an AD system implemented at industrial production facilities. Figure 9 depicts the interaction of agricultural feed-stock production, industrial production, human consumption and energy supplement-ation.

Figure 8: Industrial design of a waste digester with (from right to left) gas balloon, pre-acidification tank and digester. (Picture courtesy of BDI).

Table 1. Industries with successful operation of AD systems

Breweries	Potato industries
Canning industry	Pulp and paper
Cereal and oil mills	Rendering plants
Coffee and tea products	Sauerkraut production
Dairy industry	Slaughterhouses
Distilleries	Soft drinks and fruit juices
Fish processing	Starch production
Fiber industry	Sugar refineries
Frozen food	Tanneries
Herbs and spices	Wine production
Pharma industry	

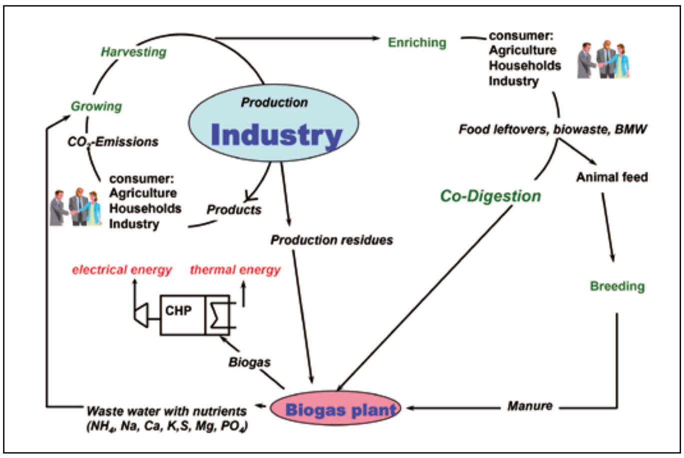

Figure 9: Interaction of the single sectors whilst feedstock processing and food consumption (Source: Atres)

4. CURRENT AND POTENTIAL BIOGAS PLANT CAPACITY FOR F&B WASTE

In all partner countries the biogas market especially in FAB industries is slowly but yet still growing (Fig. 10), despite the often unfavourable conditions. A recent survey performed within the EU project BiogasIn[11] showed that the permitting procedures represent a barrier for biogas market development. Thereby, the main reason for inefficient permitting procedures seems to be lack of knowledge and competence of people responsible for administrative procedures. Along with this, changes in the legislation and unstable governmental policies towards the biogas energy signals instable market and consequently higher risk for investments. Even in the countries, which had favourable policy frameworks like Germany or Austria, the governmental support has decreased during the past 18 months. This had an impact on the market development.

However, in all six partner countries major waste streams from household and industry are generated that are ideal substrates for biogas plants. Increasingly, industrial organic waste is used as co-substrate in agricultural biogas plants replacing the expensive maize silage. Only the increase of new plants on industrial sites has slowed down due to concentration of industry and closing of smaller factories eventually with biogas plants.

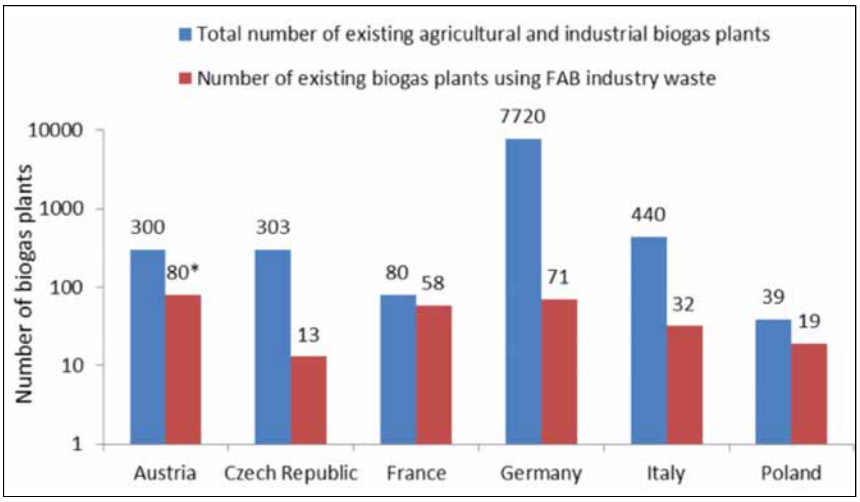

Figure 10: Number of biogas plants in partner countries (2010/11)

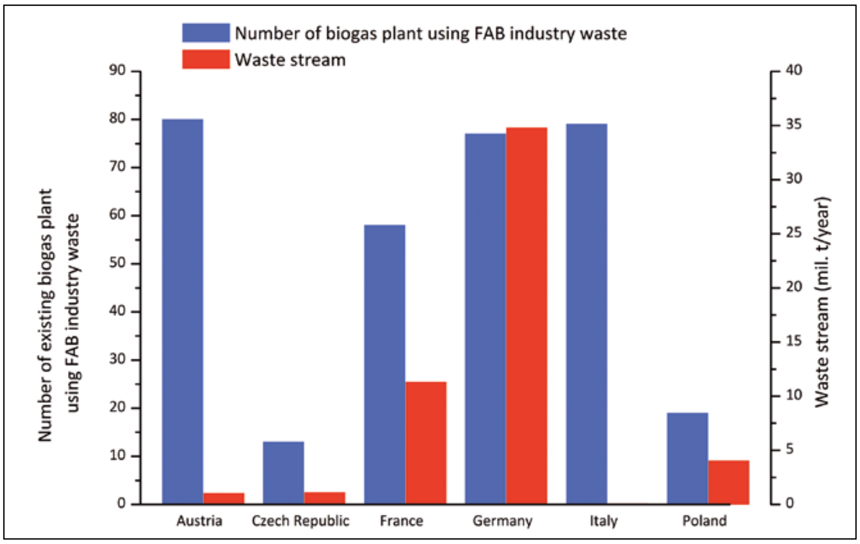

Figure 11: Comparison of waste streams and number of biogas plants using FAB industry waste

[11] http://www.biogasin.org/files/pdf/WP3/D31_IWES_WIP_EBA_EN_2010-12-20.pdf

The positive trend

With the revised RED under discussion in the European parliament (decision will be taken in May 2015) the utilisation of energy crops (1st generation) should be reduced in favour of the waste streams. This will open the doors wide for FAB wastes leading to lower recovery cost or even to net compensation for the waste. The new German law on compensation of electricity from biogas has already implemented this new trend.

The potential for new plants is still considerable in most of the partner countries as is shown in Fig. 11 where waste streams are compared to the number of existing biogas plants. In the six partner countries there are in total 9154 agricultural and industrial biogas plants, but less than 3 % (257) use waste from food and beverage industry as substrate[12]. In France most (58 out of 80) plants use FAB waste for biogas production.

Poland counts the smallest number of biogas plants using F&B waste (19 out of 39 plants). However, the potential production of methane from organic waste in Poland is impressive with 183M m^3/year. The trend for more FAB waste utilisation is reflected in the most recent figures. While in 2011 the 19 plants treated 277,800 tons of slurry, 123,200 tons of energy crop and only 68,000 tons of waste from food processing industry, last year these proportions began to change rapidly. In the first half of 2013, agricultural biogas plants processed already 369,000 tons of waste from the food industry.

Figure 12: Overview of FAB waste digesting plants in the partner countries (nearby plants are covered by one dot)

The largest waste streams are generated in Germany and France mainly from food and beverage industry.

However, it should be highlighted that F&B industry has already made substantial progress in establishing AD as a low-cost, energy efficient and sustainable method of waste water treatment. The overview on FABbiogas' partner countries shows the significant amount of biogas plants built working on FAB waste or waste water.

[12] EBA 2014; Member country

5. BASIC EVALUATION CRITERIA

Today, AD offers treatment for a wide range of substrates. Basically any liquid or solid organic waste from e. g. food and agricultural industry like whey, slaughterhouse wastes, flotation fat or waste water – just to name a few - can be utilised for AD. Type and characteristics of the substrate define the technology of the AD plant and the processing – not every AD plant is suitable for each substrate.

Due to this fact the challenge of implementing and operating an AD plant starts with defining and understanding the substrate. Substrates differ widely in chemical and physical characteristics.

The physical composition of a substrate defines to a large extend the type of system and the pre-treatment (handling, unpacking, removal of unwanted components like plastics, metals, grinding, etc.). The chemical composition of a substrate determines the quantity and quality of biogas as well as the residence time. Both, chemical and physical characteristics influence the economy of an AD plant.

Biogas as a renewable energy source helps to reduce the consumption of fossil energy carriers and also to reduce CO_2-emissions. Mostly biogas is used in combined heat and power plants (CHP) to generate electricity and heat. Biogas can also substitute natural gas in steam vessels. In industrial applications adsorption coolers using surplus heat offer new oportunities.

Choosing the right way and technology for utilizing biogas is part of the feasibility study and decisive for the rentability of an AD facility.

The FABbiogas-Calculator

In order to avoid major drawbacks it is recommended to plan the design of a plant very carefully. For a first approach FABbiogas developed an on-line calculation tool[13] allowing a rough estimation of gas production and size of the installation. The data for the calculation is available from the providers of biogas plants. The output of the online tool shows the basic energy potential of an AD plant. However, for an in-depth planning a detailed analysis of the waste substrate should be carried out. Based on such an analysis a system type can be chosen as well as the corresponding pre- and post-treatment processes. In other

Phase and Step		***Purpose and Issues to Consider***
Feasibility Phase	Prefeasibility	Biomass quantities, calorific values, capacity, siting, energy use based on literatures values
	Decision	Decide whether to investigate further or to abort the project
	Pre-engineering	Biomass quantities, caloric values, capacity, siting, energy use in detail, based on laboratory and/or real values
Project Preparation Phase	Site-engineering	Layout of components, piping diagrammes, control system design, wiring diagramm etc.
	Preparation of Tender Documents	Detailed financial engineering, specifications, prequalification of components and tendering of documents
Project Implementation Phase	Political Decision	Decision on financial package and procedures in detail and final go-ahead
	Construction and Supervision	Construction and supervision of plant
	Commissioning and Startup	Testing of all performance specification, settlements, commissioning, training of staff and startup
	Operation and Maintance	Continuous operation and maintance of plant. Continuous procurement of spare parts and supplies

Figure 13: Process scheme with the different planning steps

[13] www.fabbiogas-calculator.eu

words, the planning of an AD plant has to focus on a specific site. Great effort needs to be taken into thorough feasibility studies, based on validated facts and figures. The more effort is taken in the beginning, the more successful a plant will run afterwards resulting in a profitable operation.

National contact points for basic support

For information beyond the calculation tool, FABbiogas has established national contact points where a free advisory service is available[14].

They provide information and eventually addresses and contacts to specialists for further information (see Table 2).

Once, a first rough clarification of a project on a given site has proven a positive result, a multi-step approach is recommended as highlighted in the process scheme (Fig. 13).

Table 2: List of national points contacts

Country	*Name of organisation*	*Biogas expert / contact*
Austria	ECOPLUS Niederösterreichs Wirtschaftsagentur GmbH	ZEDERBAUER Martina Niederösterreichring 2, Haus A, 3100 St. Pölten Tel.: +4327429000-19676 E-mail: m.zederbauer@ecoplus.at
Czech Republic	PK ČR Potravinářská komora České republiky	VACEK Tomáš Počernická 96 108 03 – Praha Tel.: +420296411181 E-mail: vacek@foodnet.cz
France	ANIA Association Nationale des Industries Alimentaires	GORGA Françoise 21, rue Leblanc, 75015 Paris Tel.: +33153838617 E-mail: fgorga@ania.net
Germany	Cluster Ernährung Kompetenzzentrum für Ernährung	REITMEIER Simon Hofer Str. 20, 95326 Kulmbach Tel.: +49 9221 407 82 52 E-mail: simon.reitmeier@kern.bayern.de
Italy	FEDERALIMENTARE Federazione Italiana dell' Industria alimentare Associazione	NOTARFONSO Maurizio Viale Pasteur 10 00144 – Rome Tel.: +39065903347 E-mail: SPESadm@federalimentare.it
Poland	Technical University of LodzDepartment of Bioprocess Engineering	KRZYSTEK Liliana Ulica Zeromskiego 116 90 924 Lodz Tel.: +48426313737 E-mail: krzystek@p.lodz.pl

[14] http://www.fabbiogas.eu/en/advisory-services/

6. OPPORTUNITIES AND CHALLENGES

Opportunities

Solid wastes

There are not too many FAB industries producing significant amounts of solid waste. The most common are slaughterhouses and rendering plants, vegetable production (market fresh, canned or frozen) and production of herbs and spices.

There are some special designs on the market allowing high loading rates (i.e. the amount of organics added per day and m3 of fermenter volume) but often the industry delivers the (semi-) solid waste to agricultural plants for co-digestion (Figs. 8 and 14).

Wastewater

Commonly FAB industries produce high strength waste water with COD values between 2,000 and 100,000 g COD/m^3 (COD stands for Chemical Oxygen Demand) or the corresponding values in BOD (Biological Oxygen Demand). As a very rough rule of thumb BOD in FAB waste waters is usually about half of COD. Since anaerobic bacteria prefer high concentrations of organic substances, 2,000 g COD/m^3 is considered to be the lowest value (Chapter 3).

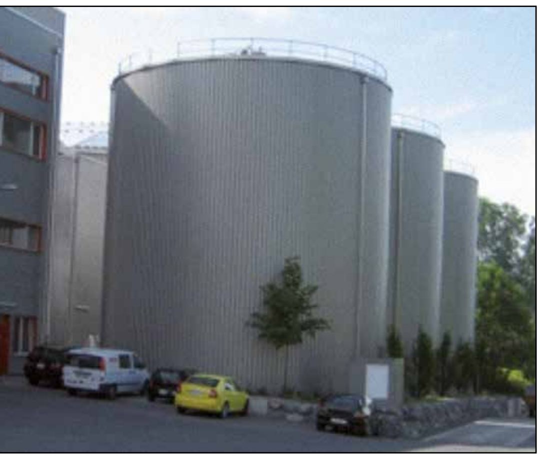

Figure 14: Digestion of expired food from distributors and rendering waste (Bösch Brothers, Switzerland)

Most widespread are AD plants in the following industries:

- ***Dairy industry:*** Most often dairy waste water is highly diluted but rich in fat and proteins with BOD values of 0.05 to 1kg/m^3 that makes it interesting for biogas production. Digestion of whey is an excellent alternative if it cannot be fed to pigs. Even the permeate after removing lactose is interesting for AD.
- ***Sugar factories:*** Sugar factories using sugar beet, produce substantial amount of sugar rich waste water with CODs of 0.5 to 3kg/m^3 water. The choice of the digestion system is influenced by the fact that beet campaigns are timely limited to fall and winter. About half of the year the AD plant has to survive without substrate addition.
- ***Breweries:*** Breweries have waste water that is perfectly suited for AD. The world's largest brewery companies are using AD on their production sites. BOD values are in the range of 0.4 to 3.3 kg/m^3.
- ***Vegetable processing:*** This includes waste water from peeling, and blenching of vegetables. Reported values are in the range of 20 to 50 kg COD/m^3.
- ***Fruit products:*** To this category belongs production of fruit juices, water from fruit washing, waste water from cleaning, vinegar factories, dried fruits or natural aromatic herbs and spices. COD values vary considerably in the range of 20 to 50 kg COD/m^3.
- ***Starch production (potatoes):*** The amount of washing water is large and therefore concentration is limited however, still in the order of 10 kg/m^3 .

Challenges

Substrate preparation

Before solid substrates can be added to an AD plant most often a mechanical or chemical pre-treatment is needed, requiring additional technical equipment such as grinder, mixer, sterilizer, etc. Pre-treatment systems have to be adapted to the substrate. Impurities have to be removed mechanically. Glass, stones, wood, plastics electronic parts (batteries) and bones etc. may be found in bio wastes. A thorough pre-treatment does not only increase the surface of substrate to support microbial degradation but also prevents pipes or pumps from blocking, sedimentation and scum layers.

Sterilisation, homogenization, solid/liquid separation or pH-adjustment may furthermore be required. To prevent odor nuisances from raw substrates the entire handling of substrate should be in house and extracted air cleaned with bioflters.

Bochmann and Montgomery (2014)[15] specify numerous pre-treatment steps of organic materials that should be considered in an evaluation in addition to their anaerobic digestibility. Table 3 lists exemplarily some materials.

In case of doubt or missing data additional analysis have to be carried out and a digestion test is recommended. This ensures that the substrate is appropriate for AD and does not affect the process negatively, e. g. by an exceeding heavy metal content or inhibitory substances like detergents and disinfectants. Addition of inhibiting compounds often leads to a rapid process breakdown, followed by a time consuming restart process – and accompanied by a lack of biogas production. Interrelated to process malfunctions are financial losses, which are rarely calculated in advance by the operators.

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[15] www.iea-biogas.net/files/datenredaktion/download

Table 3: Evaluation of organic by-products for the use in anaerobic digestion

Material	Excellent	Good	Poor	Remarks
Expired food		+		expensive unpacking required
Dough, confectionary waste	+			liquéfaction(dilution) required
Whey	+			No pretreatment required
Residues from cans and frozen food		+		expensive unpacking required
Residues from fruit juice production		+		chopping advisable

Adjusting the nutrient balance

It is necessary to maintain a well-balanced nutrition for the microorganisms by a proper composition of the daily load of substrate. The content of macro elements like carbon, nitrogen and phosphor is responsible for the quantity and quality of biogas being produced as well as for the growth of microorganisms.

Especially high ammonia contents formed during the degradation of proteins are sometimes a challenge. This is true for all slaughterhouse and rendering waste. In these exceptional cases ammonia has to be stripped but can be recovered in form of ammonium sulphate which is a valuable fertilizer.

Furthermore trace elements are essential for microorganisms´ growth and metabolism, resp. biogas production. Methanogens are especially dependent on trace metals like cobalt, nickel, zinc, manganese, molybdenum, selenium, tungsten and boron. The metals are often lacking in industrial waste water and residues and have to be added.

Influence of the pH

The major challenge is to maintain a stable pH within the methane formation reactor. pH values lower than 7 or higher than 8.5 may show a negative impact on the microbial system. Process disruptions and instabilities are the consequences; in the worst case methanogenesis is severely inhibited.

Especially in wastewater treatment facilities the adjustment of the pH with chemicals is responsible for sometimes exceeding operational costs.

To prevent digestion and especially methanogenesis from uncontrolled acidification a certain pre-treatment might be necessary. Therefore a pre-acidification buffer tank or a two-phase digester system should be implemented.

Inhibitors and toxic substances

As mentioned before, inhibitors and toxic substances may affect the digestion process negatively. In general the influences of e. g. ammonia, sulfide, tensides or phenolic derivate are known as being inhibitory. Wherever it is possible, additional precautions should be taken helping to make by-products suitable for AD. Finally, to reduce an exceeding loading a specific selection and a blend of substrates might be options.

For example, it should always be declared what type and composition of detergents and disinfectants are used in the industrial production process. A simple change in cleansing products might change the biodegradability of wastewaters radically. Absolute acids or bases are microbial inoffensive. Exceeding use of phosphoric acid may result in a phosphor-elimination-step before discharging the effluent. Sulphur acid increases the production of sulphuric substances and H_2S under anaerobic conditions. Tenside solutions may have a negative impact on a stable process.

Therefore a lively dialog between the AD plant´s engineer, the detergent producers and the technical management of the industry is necessary prior to the engineering and operation of the biogas plant.

7. BEST PRACTICES

Slaughterhouse waste St. Martin, Upper Austria

Biogas Plant Grossfurtner

This biogas plant in the village of St. Martin is directly integrated into the largest abattoir of Austria. The company Großfurtner slaughters 550,000 pigs and 50,000 cattle per year. It is the first biogas plant worldwide which exclusively uses slaughterhouse waste as substrate for biogas production. All in all 10,000 tons of blood, rumen content, colon content and grease separation material is used to produce 3.6 Mio. kWh electricity and 3.6 Mio. kWh heat per year.

The aim of the project was the improvement of the economic and ecological performance of this abattoir. Two cost intensive areas in the company are the energy costs (natural gas, electricity) and the disposal costs for the slaughterhouse waste.

By using the slaughterhouse waste as substrate for biogas production Großfurtner can reduce the disposal costs and can cover approximately 33 % of their electricity demand and 75 % of their heat demand with renewable energies.

Technology at a glance

- Biogas production: 5,000 m^3/day;
- Methane content: 67 % – 69 %
- Installed power: 525 kW$_{el}$, 525 kW$_{th}$
- Digesters: 1x600 m^3, 2 x1,000 m^3
- Substrate/year: 2,000 m^3 blood, 1,000 t rumen content, 3,000 t colon content,

  4,000 t grease separation material
- Input waste/substrate: 170 – 230 t/week
- Pre-treatment: continuous pasteurization
- Operating hours: 8,400 h/ year

Distillery waste St. Laurent de Cognac, France

Biogas Plant

The biogas plant in St. Laurent de Cognac was built in 1970 to valorize distillery waste from

Cognac production. Approximately 300,000 t/a of vinasses are treated to produce 20,000 MWh worth of biogas. The vinasses are concentrated by mechanical vapor compression and tartric acid is precipitated with calcium carbonate. The vinasses are then sent to the 4 infinitely stirred – down-flow recirculation – type digesters. Retention time is 3–4 weeks. The digestate (1200-1500 tonnes dry matter /a) is decanted, mixed with ground plant matter waste, and used as agricultural compost. H_2S is eliminated in a soda washing tower and the gas is dehydrated by condensation on an exchanger. A mobile tank containing activated carbon removes most pollutants. The gas is then compressed and valorized via four microturbines with an installed electrical power of 200 kW each. The electricity produced is sold and thermal energy is used for own purposes.

Technology at a glance

- Biogas production: 20,000 MWh (converted to 13,500 MWh/a thermal energy + 3,300 MWh/a electric energy)
- Installed power: up to 20,000 m^3/ day biogas production capacity
- Digester type and volume (m^3): infinitely stirred with down-flow recirculation; 17,500 m^3
- Type of waste used: Cognac distillery residue
- Amount of waste/raw material used as substrate: 300,000 t/a

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Sewage sludge and industrial waste Radeberg in Saxony, Germany

Co-fermentation Plant

The plant in Radeberg demonstrates that the combined co-fermentation of sludge, domestic and industrial organic waste in an anaerobic sewage sludge treatment plant leads to synergistic effects. As part of the extension of the sewage treatment plant, a complete sludge treatment was integrated additional to an aerobic biological purification. In two anaerobic digesters 41,000 tons of sewage sludge and 15,000 tons of organic waste are treated per year.

The plant has separate lines to process the different waste fractions of sewage sludge, liquid biological waste (e.g. industrial fat) and solid biological waste. Therefore the plant is highly flexiblefor the frequently changing availability of biological waste. Two fermenters with a capacity of 2,300 m^3 each, can be operated separately. The pretreatment facilities of the organic waste include wet processing with a mill, a magnetic separator, a pulper and a drum screen. The mechanical cleaned waste is hydrolyzed and hygienized at 70°C for one hour.

The plant produces around 40 m^3 Biogas per ton of input, which supplies two gas engines with an installed electrical power of 380 kW each. The generated electricity covers more than the total demand of the plant, thus surplus electricity is fed into the public grid. The produced heat covers the demand of the waste treatment plant, the service building and a nearby school. The dewatered digestate is used as a secondary fuel in an extern co-incineration plant. If biowaste is processed separately the digestate can be used as fertilizer. With higher fat input, the biogas production is doubled and the methane content of the produced biogas rises to 65 %.

Technology at a glance

- installed. electr. power of CHP: 2 x 380 kW
- Installed therm. power of CHP: 2 x 550 kW
- Installed therm. power of heating boiler: 335 kW
- Biogas production: 40 m^3/t input (mixture)
- Gas storage: 780 m^3, double membrane

▲

Větrný Jeníkov, Czech Republic

Biogas Plant ZEVAR

Biogas plant ZEVAR in Větrný Jeníkov, Czech Republic is a well-handled integration of biogas technology into food & beverage industry producing alcohol. It has started its operation in November 2011.

The plant is operated on distillery waste and improves the efficiency of the alcohol production processes. Main input material consists of distiller's liquid waste supplemented with potato processing waste and other kinds of purposely grown biomass, which the plant has been designed for as well. Both electricity and heat produced is fully used for process electricity respectively process heat.

Technology at a glance

- Biogas production:
  7,920,000 m^3 per year
- Installed power: 1,998 kW_{el}
- Installed heat capacity: 2,128 kW_{th}
- Digester volumes (gross/net):
  6,551 m^3 / 6,176 m^3
- Substrates:
  40,200 t/yr dissolved waste water
  3,700 t/yr potato waste
  1,000 t/yr cereal meal
- Annual electricity production
  gross: 6 – 6.4 GWh
  net: 5.7 – 5.9 GWh
- Annual heat production
  gross: 6 – 6.5 GWh
  net: 6 – 6.5 GWh

Information on financing

Year of realisation: 2011
Investment costs: 70 mio. CZK

FAB biogas

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