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Handbook:
Small scale Anaerobic Digestion (AD) Business Collaboration Models (BCMs)

BIOGAS^3
Sustainable small-scale biogas production from agro-food waste for energy self-sufficiency

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With the collaboration of all the BIOGAS^3 Consortium

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1. Introduction

Anaerobic Digestion (AD) for biogas production is a proven technology that is well known in the municipal waste treatment and wastewater treatment plants (WWTP). This technology has multiple benefits in terms of: energy savings, waste management cost savings, reduction of negative environmental impact and reduction of carbon footprint, etc.

The food and beverage industry produces organic wastes, and their management is usually externalised and represents an economical cost for the companies. Despite the anaerobic digestion process is commercially ready to be used, its application to treat organic wastes from agro-food sector is still not wide and it varies extremely between the EU countries.

In this context, as mentioned before, current AD technology has been developed and widely applied in a large scale concept, which is not completely suitable for agro-food companies due it is not adjusted to quantities of wastes produced by this sector. Moreover, several non technological barriers have been identified in order to increase the sustainability and broader implementation of AD technology for valorisation of agro-food wastes.

This document includes the compilation and analysis of success stories related with existing business models to develop biogas plants in a small-scale concept. Despite most cases are funding by private investment and public subsidies, some examples of business collaboration models applied during operation phase were identified.

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2. Business Collaboration Models (BCMs)

2.1. Definition

A Business Collaboration Model (BCM) is an alliance between two or more organizations, which establishes some type of formula to share technological, commercial or financial resources with the aim to obtain competitive or operational advantages. A business model depicts the content, structure, and governance of transactions designed as to create value through the exploitation of business opportunities[1].

The main interest areas[2] identified in business models are:

- Innovation and technology management.
- Strategic issues: such as value creation in different ways like economic, social or environmental; competitive advantage; and firm performance.
- E-business and the use of information technology in organizations.

According to Chavez and Torres (2014), a business collaborative model must not only provide commercial, financial and operational aspects; also the technological and human considerations are needed. In this sense, some consideration that should take into account:

- How will face competition?
- What opportunities do partners have to reduce costs in the supply chain?
- What information do partners share and how?
- How will partners deal with the introduction of new products, processes, etc?
- How do partners share information to end customers?
- How will partners share the risks, efforts and profits?

2.2. Identification and analysis of BCMs.

Several business collaboration models related with agri-food sector and biogas production are presented below. Some advantages and disadvantages of each BCMs are also included.

2.2.1. Cluster

A business cluster is a geographic concentration of interconnected businesses, suppliers, and associated institutions in a particular field. The *cluster* concept is increasingly used to enhance the economic momentum of territories that compete one with another in a context of globalised economies.

<u>Strong point</u>: The economy of proximity inherent in a cluster provides value-added services close to the end user. Clusters are considered to increase the productivity with which companies can compete, nationally and globally. Clustering strengthens localization economies, facilitates industrial reorganization, encourages networking among firms and permits greater focusing of public resources.

[1] Amit, R., and Zott, C. (2001). Value Creation in E-Business. Strategic Management Journal
[2] Zott *et al.* (2011). The Business Model: Recent Developments and Future Research. Journal of management.

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Weak point: The designing of an industry cluster requires an extensive understanding of the region and its economic processes. Clusters latecomers may not be competitive. The benefits available to members of a cluster provide early clusters with distinct competitive advantages over late imitators.

Examples:

- Cluster *Environment and Renewable Energy of the Murcia Region*[3]. The companies *Estrella Levante* and *Cespa Urban Services* have planned to create this cluster in the Murcia Region (Spain), which will involve the construction of biogas plant in order to investigate in the biogas and compost production from both agri-food by-products and organic waste.
- Cluster *Energy of the Extremadura region*[4]. It is a non-profit business association created in 2008 as an initiative of the Government of Extremadura, which mission is to promote integration, building and strengthening businesses and institutions within the value chain of the energy sector through cooperation and entrepreneurial innovation, in order to ensure high competitiveness in the national and international level.

2.2.2. Coopetition or co-petition

Mix between creating value (cooperation) and its division (competition): *cooperation between competitors*. Coopetition occurs when companies interact with partial congruence of interests. They cooperate with each other to reach a higher value creation if compared to the value created without interaction, and struggle to achieve competitive advantage.

Strong point: This model involves customers, suppliers, competitors as well as providers of complementary products and services. Companies that are in the same market work together in the exploration of knowledge and research of new products. Several advantages can be foreseen, as cost reductions, resources complementarily and technological transfer.

Weak point: Companies that are in the same market compete for market-share of their products and in the exploitation of the knowledge created. Some difficulties exist related to distribution of control, equity in risk, complementary needs and trust.

Examples: no examples have been found of coopetition model applied to biogas production in the agri-food sector. As a theoretical example, a coopetition business collaboration model could involve the participation of several biogas plants using agri-food wastes as co-substrate. In the AD process, the kind of substrate affects the bacterial activity and then the biogas production. In this line, some plants could be more specialized to treat some wastes and the others treat other kind of substrates, depending in all cases of agri-food sector and their wastes.

[3] More information (in spanish): http://www.estrelladelevante.es/estrella-levante-y-cebas-csic-colaboran-en-un-proyecto-medio-ambiental/

[4] More information (in spanish): http://www.energiaextremadura.org/sala-de-prensa/una-de-las-mayores-empresas-de-biogas-en-espana-destaca-el-gran-potencial-de-extremadura-en-esta-energia/

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2.2.3. Synergy

Synergy is the interaction of multiple elements in a system to produce an effect different from or greater than the sum of their individual effects: *Meaning "working together"*, where 1+1=3.

Strong points: Shareholders will benefit if a company's post-merger share price increases due to the synergistic effect of the deal. The expected synergy achieved through the merger can be attributed to various factors, such as increased revenues, combined talent and technology, or cost reduction.

Weak point: Possible ambiguity in roles and responsibility. If the responsibilities of the different stakeholders are not clearly defined their contribution may fall into ambiguity.

Examples:

- *Biogas plant for agri-food wastes in Iscar (Valladolid, Spain)*. The biogas plant was built using private funding. However, its operation is performed using a synergic model between agri-food companies close to biogas plant: **Vegetable processing industries** provide vegetable wastes (potatoes skins, leek leaves, other agricultural wastes) and sludge from their wastewater treatment plant. These agri-food wastes are treated in the biogas plant. A portion of the heat produced is self-consumed by AD process and the other part is used in a **poultry processing company** located close to biogas plant. More information (in Spanish):http://www.santiener.com/ or http://biovec.net/wp-content/uploads/2014/10/avebiom_biogas_santiba%C3%B1ez.pdf
- *Bioenergie Schmienchen (Germany).* The biogas plant was planned and built by organic farmer Hubert Miller. About 40 farmers are the providers of the substrate (cover grass mainly), and in turn they get the digestate produced to be used as a fertiliser in their fields. More information: http://www.sustaingas.eu/bestpractice.html

2.2.4. Collective Actions

Parties, two or more individuals, coming together as a group to realize a common goal.

Strong points: Several parties bring in their own specializations to gather expertise and are more likely to achieve the objectives together than on their own.

Weak point: If different parties cooperate for a common objective through common resources, some might be likely to exploit their rights. It defines that collective action can lead to free-rider problems, when different parties come together.

Examples:

- Collective action between universities and technological centres with companies from agri-food and other sectors. Scientific centres share knowledge with companies to develop products or solve troubles related with waste management. As example, collective actions between an entrepreneur, a private party and a research unit participate in the micro-biogas plant in Studzionka (Poland). More examples of this BCM are included in the section 2.3.5.

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2.2.5. Cooperatives

Cooperatives are autonomous associations of companies that voluntarily cooperate for their mutual economic and social benefits. Cooperatives include non-profit community organizations and businesses that are owned and managed by the people who use its services (a consumer cooperative) or by the people who work there (a worker cooperative) or by the people who live there (a housing cooperative), hybrids such as worker cooperatives that are also consumer cooperatives or credit unions, multi-stakeholder cooperatives such as those that bring together civil society and local actors to deliver community needs, and second and third tier cooperatives whose members are other cooperatives.

Strong points: It is usually inexpensive to register a cooperative. All members and shareholders must be active in the cooperative. Shareholders have an equal vote at general meetings regardless of their shareholding or involvement in the cooperative. A cooperative is owned and controlled by its members, rather than its investors.

Weak point: As cooperatives are formed to provide a service to their members rather than a return on investment, it may be difficult to attract potential members or shareholders whose primary interest is a financial return. There must be a minimum of members. There is a usually a limited distribution of surplus (profits) to members or shareholders and some cooperatives may prohibit the distribution of any surplus to members/shareholders. Active and direct involvement of members/shareholders in the cooperative requires continuous cooperative education programs for members.

Examples:

- Cooperative *Graskraft Steindorf (Austria)*. The cooperative, which is integrated by 54 farmers, has been doing a sustainable biogas project since 2010. 70% of the biogas produced is fed into the gas grid. The basis for this cooperation is open communication between partners and quality management. More information: http://www.sustaingas.eu/bestpractice.html.

- Business collaboration model between the agri-food cooperative the Valle de Odieta and the HTN consortium formed by AN (poultry processing company) and BioRenewables company, in Navarra, Spain[5]. The biogas plant has a treatment capacity of 600 t/day and the main wastes are manure from AN and organic wastes from agri-food industries of the cooperative.

- There are cooperatives that promote the renewable energy consumption. In this sense, cooperatives from agri-food sector promote both production and self-consumption of energy using their own organic wastes. More information (in spanish): http://www.agro-alimentarias.coop/noticias/ver/MjQyNQ==

2.2.6. Other business models

There are some business models where private funding (bank loan or financing by biogas providers) are more common. Also, there are cases where the public economic resources are used to funding part of the total investment costs.

[5] http://www.ain.es/tech/experiencias/proyecto-htn/

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2.3. Success stories

Figure 1 shows a map where success stories related with the construction of small-scale biogas plants are identified in the countries that comprise the BIOGAS3 project: France (4 cases), Germany (1 case), Ireland (1 case), Italy (2 cases), Poland (4 cases) Spain (4 cases) and Sweden (2 cases). More details about each success story are described below:

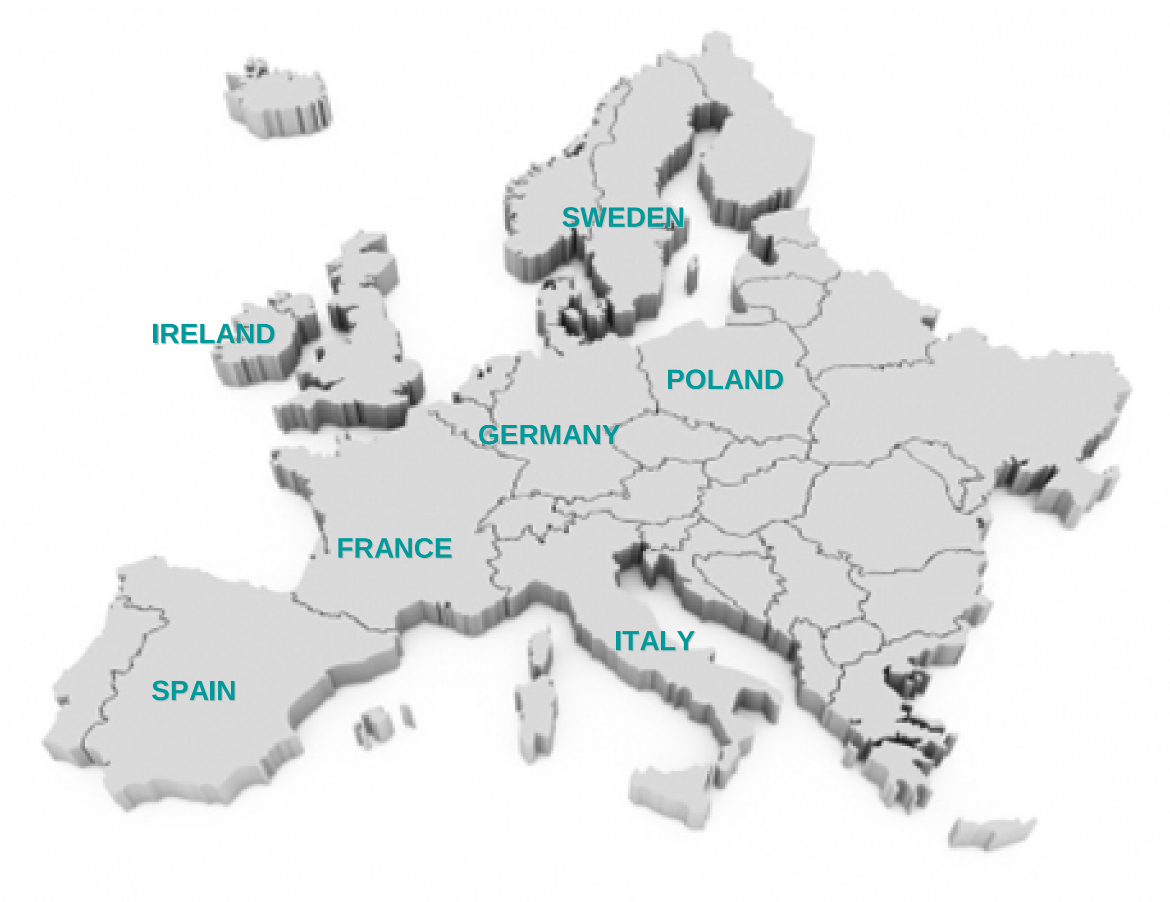


Figure 1. Map with countries involved in the BIOGAS^3 project.

2.3.1. France

Case 1: GAEC du Bois Joly

<u>**BCM: Private funding and support by public subsidies.**</u>

<table>
<tr><th rowspan="3">GAEC du Bois Joly</th><th>Description</th><th>Characteristics</th></tr>
<tr><td>GAEC du Bois Joly is a farm which is a producer of beef meet and rabbits with a 150 cattle breeding and a farrowing and fattening rabbits breeding.

100% of electricity produced (190 000 kWh/year) is injected on the grid and sold to the French national company of electricity.

The heat is valorized as a 77°C hot water which is used to: heat digesters (83%); produce heat and domestic hot water to on-site houses (14%); produce heat for rabbits buildings (3%).

Supplier: Aria Energies</td><td>Substrate treated:
Approx. 1.045 tonnes/year of cattle, rabbit and poultry manure, and fruits, vegetables, cereals wastes and other co-substrates.

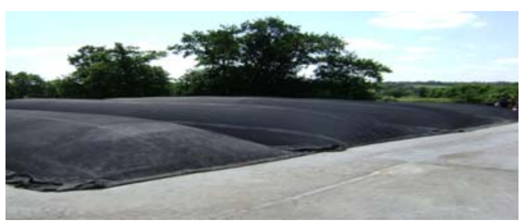
Biogas valorisation unit:
30 kW.

Energy production:
730.000 kWh per year.

Installation:
4 Digester: 740 m³ total volume.

Investment: 314.200 €

Funding by: private investment and French public subsidies (44%).

Estimated payback period: 7 years with subsidies.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="3">Strong points for success:

o Valorisation of electrical energy through the sale of electricity.
o Valorisation of thermal energy for self-consumption.</td></tr>
</table>

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Case 2: SCEA Robin

BCM: Private funding and support by public subsidies.

	Description	Characteristics
SCEA Robin	SCEA Robin is a farrowing and fattening pigs breeding (400 sows). The farmer operates an anaerobic digestion plant with liquid technology. Energy produced is used to heat breeding buildings. Supplier: BiO4GAS	**Substrate treated:** Approx. 10.000 m^3/ year of pig slurry. **Biogas valorisation unit:** 50 kW **Energy production:** 368 MWh_{el} and 588 MWh_{th} per year **Installation:** 1 Digester: 600 m^3 **Investment:** 480.000 € (100 000 € for the CHP engine) **Funding by:** private investment and subsidies from French government and environmental agencies (29%). **Estimated payback period:** 7.5 years with subsidies.

Strong points for success:

- Only one kind of substrate which simplify O&M.
- No dependency of external substrate (self-sufficient).
- Valorisation of thermal energy for self-consumption.

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Case 3: Laiterie de l'abbaye Tamié

<u>BCM: Private funding and support by public subsidies.</u>

	Description	Characteristics
Laiterie de l'abbaye Tamié	Laiterie de l'abbaye Tamié is a dairy and cheese factory which produce 400 kg of Tamié cheese per day. AD plant was built in 2003, and the biogas produced, around 48 000 m^3/year, is used to heat buildings. 	**Substrate treated:** Approx. 8m^3/day white cheese and 4m^3/day whey. **Biogas valorisation unit:** 60 kW_{th} **Energy production:** 270 000 kW_{th} per year **Installation:** 1 Digester: 43 m^3 **Investment:** 255 000 € **Funding by:** private investment and subsidies from French government (31%). **Estimated payback period:** 6 years with subsidies.
		

Strong points for success:

- Investments costs are much lower due adaptation of biogas plant to existing structure.
- Valorisation of thermal energy for self-consumption.
- No dependency of external substrate (self-sufficient).

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Case 4: BOYER SAS

BCM: Private funding and support by public subsidies.

	Description	Characteristics
BOYER SAS	BOYER SAS is a fruit packer which packs around 30000 Tonnes of fruits per year with a strong seasonality. Main fruit of BOYER is melon (20000 Tonnes/year) but they also pack, plums, grapes and exotic fruits. In order to deal with their 2500 Tonnes of by-products every year, the company builds an AD plant in 2011.	**Substrate treated:** Approx. 5 000 Tonnes of fruit by products /year (strong seasonality) **Biogas valorisation unit:** Cogeneration: 104 kW_{el} (installed power) 100 KW_{th} of heat **Energy production:** 75 MWh_{el} per month 99 MWh_{th} per month: Water for cleanings needs and for employees housing **Installation:** 2 phases HYFAD (High Yield Flushing Anaerobic Digester) technology developed by Greenwatt. **Electricity sale :** 65 k€/year **Saving from thermal valorisation:** 12 k€/year **Saving from byproducts treatment:** 150 k€/year **Profit :** 177 K€/an **Funding by:** private investment and subsidies from French government (around 40%). **Estimated payback period:** 3 years with subsidies.

Strong points for success:

- A unit directly connected to the production line for by product treatment
- A technology adapted to subtract whom acidification process is very fast.
- Valorisation of thermal energy for self-consumption.

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2.3.2. Germany

Case: Gießen slurry-only

<u>BCM: Private funding.</u>

Gießen slurry-only

Description	Characteristics
In Gießen (Hessen, Germany) there is a slurry-only anaerobic digestion plant to treat cattle slurry and manure. The livestock units consist of 290 dairy cows, 300 young cattle and 50 breeding bulls, placed in three stalls. Additionally the farm cultivates 400 ha arable land and 200 ha grassland. The thermal energy produced is used for self-consumption. The electrical energy is fed in the local power grid. Supplier: Bio4Gas Express GmbH.	**Substrate treated:** Approx. 10 950 m^3/year of cattle slurry. **Biogas valorisation unit:** 75 kWh_{el}; 89 kW_{th} **Energy production:** 630 MWh_{el} per year. 740 MWh_{th} per year. **Installation:** Digester: 600 m^3 **Investment:** 500 000 € **Funding by:** Own resources. **Estimated payback period:** 6 years

Strong points for success:
- Valorisation of both thermal (self-consumption) and electrical energy.
- Increase of the value of the farm.

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2.3.3. Ireland

Case: Methanogen Biogas, Waterford.

<u>BCM: Private funding.</u>

Methanogen Biogas, Waterford, Ireland

Description	Characteristics
Early design digester built in 1992; this anaerobic digester is the longest running digester in Ireland. Initially designed to run on farm wastes such as slurry and chicken litter in recent years the plant has been upgraded with pasteurization equipment to process ABP (Animal By Products).	**Substrate treated:** Approx (daily): $4 m^3/day$ **Biogas valorisation unit:** $2 \times 20\ kW_{th}$ **Installation:** 2 stage Digester: $70+70\ m^3$ **Investment:** 35 000 € **Funding by:** private investment **Estimated payback period:** 7 years

Strong points for success:

- Plant design allows solid litter to be mechanically loaded.
- Onsite use of thermal energy for self-consumption.
- Simple design, process and usage.

2.3.4. Italy

Biogas plants in food industries:

- MENZ & GASSER

European market leader for high quality single serving jams and semi-finished fruit products. Located in Novaledo, Trento – Trentino Alto Adige Region.

Substrates are fruits residues and production waste. Production of both electrical and thermal energy by biogas valorisation unit of 125 kW. The electricity is sold to the public grid and the steam generated by this cogeneration system is used in their production process as well as for hot water, which it is used for washing activities.

- Solana Spa: Tomato Processing and Allevamento Biancardi Limousine.

Solana Spa is located in Maccastorna, Lodi– Lombardy Region, Italy. It is a modern tomato factory with a processing capacity of about 200.000 tons per year.

Allevamento Biancardi Limousine (Maccastorna, Lodi – Lombardy Region, Italy): is cattle farm.

The biogas plant has been created for both companies since 5 years ago. 500 tonnes/day of slurry and manure from beef cattle supplemented with hulls of tomato and tomato wastes, which are added chopped corn or shredded wheat.

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2.3.5. Poland

Case: Biogas plant KUJANKI

BCM: Private funding.

Biogas plant KUJANKI	Description	Characteristics
	The agricultural biogas plant in Kujanki[6] is the smallest of eight AD installations owned by Poldanor S.A. It was built in 2006 in order to produce heat for the neighboring pig farm (ca. 13 000 pigs). In 2009 the plant was equipped with a CHP unit. The produced electric energy is consumed by the pig farm (25%) and by the biogas plant (5-10%). The remaining 65% is sold to the national power grid.	**Substrate treated:** Approx. 35-40 t/day pig slurry and 4-5t/day glycerin (85% of the substrates originate from Poldanor S.A.) **Biogas valorisation unit:** 330 kW_{el} + 390kW_{th} **Energy production:** Ca. 2600 MW_{th} per year **Installation:** 1 Digester: 1 000 m^3 1 Post-digester: 1 000 m^3 **Investment:** 700 000 – 950 000 € **Funding by:** 100% private funds of Poldanor S.A. **Estimated payback period:** 10-15 years
		

Strong points for success:

- Self-consumption of the produced thermal energy (pig farm and biogas plant).
- Adaptation of the existing infrastructure (storage tank for the digestate liquid fraction)

[6] The plant has been operating in the current location until 2014. Currently it is being moved – information on the new location will be updated in 2015.

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Poland has plants which are not subject to registration with the Agricultural Market Agency and have lower capacities. These waste biogas plants include:

- Biogas plant in Wapielsk (Kujawsko-Pomorskie Province, investor: Agricultural Farm Wojciech Radoszewski) with installed power of **80 kW**.
- Biogas plant in Adamow (Lublin Province, investor: Agricultural Farm Czeslaw Momot, Eko Pol Sp. z o.o) with installed capacity of **30 kW**.
- Biogas plant in Studzionka (Silesian Province, investor: Agricultural Farm Bibiana and Grzegorz Pojda) with installed capacity of **35 kW**.
- Biogas plant in Wisla Mala (Silesian Province, investor: Agricultural Farms Janusz Mikolajec) with installed capacity of **30 kW**.

In addition to the aforementioned micro-installations, there are biogas plants with smaller capacities that have been set up in the form of co-operation between scientific institutions and entrepreneurs: installation in Poznan with a capacity of 20 kW and also in the form of a consortium of two research units (installation with a capacity of a 10 kW).

Moreover, several examples of BCMs are listed below:

Collective actions

- **Cooperation of a scientific unit with an entrepreneur – the use of company resources for the implementation of a new project**

An example of such cooperation is the case of a micro-biogas plant in Poznan, where a process-based design prepared by the Institute of Technology and Life Sciences in Poznan (www.itp.edu.pl) was used to build a container micro-biogas plant with a capacity of 20 kW by the company Mega Sp.J. (www.megabelzyce.pl) engaged in the construction of machines for the food industry. A big advantage of the constructed system is its mobility and performance. Weaknesses are the processes of mixing and preparation of the substrate.

- **Cooperation of entrepreneurs with a scientific unit and an agricultural holding: a joint project on the farm**

Another case of successful cooperation between an entrepreneur, a private party and a research unit is the installation of a micro-biogas plant in Studzionka (installed capacity 35 kW). A concept of a private individual was supported by a professional company engaged in the construction of reservoirs for on-farm use and biogas plants – Wolf System (http://www.wolfsystem.pl/). The process-based design was developed by Jan Cebula (Silesian University of Technology in Gliwice) and Ludwik Latocha.

A big advantage of this system is its low operating costs – about 800 PLN per month (ca. 190 EUR) and little time spent on maintenance. The biogas plant uses most of the waste from the farm (37 hectares of land, breeding hens and pigs). In addition, the use of the existing infrastructure and the adaptation of unused tanks (an old rail tank) allowed for the reduction of investment costs. Annually, the biogas plant processes approximately 700 tons of chicken manure and 300 tons of pig slurry, as well as additional substrates – about 350 tons of maize and grass silage and organic waste from the farm. Electricity is used for the farm's own needs and thermal energy – to heat both livestock and residential buildings. Digestate from the biogas plant is used as fertilizer. It is a prototype plant (the first micro-biogas plant in the country), partially built with traditional methods – hence its small cost. Capital expenditures for the construction of the biogas plant amounted to about PLN 400,000 (ca. 95,000 EUR).

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- **Cooperation based on substrate / education**

An interesting example of cooperation aimed at the construction of a biogas plant with a capacity of up to 250 kW is a project in Przybroda (Wielkopolskie Province) run by Fubis Sp. z o.o. and the University of Life Sciences in Poznan (an ongoing project). A farm owned by the University of Life Sciences in Poznan is the main supplier of substrate, the recipient of digestate and the lessee of the plant site, and the entrepreneur is responsible for the construction of the plant, acquisition of additional investment capital and operational management of the facility. After a period of 10 years the plant is to be taken over by the University. In addition, the plant itself has to have an educational component for the students of the University of Life Sciences. The presented model offers the possibility of managing waste produced at the University owned farm, the use of the digestate in the fields of the University and, what's more, the possibility of student training at the modern industrial plant.

- **Biogas plants in the vicinity of farms**

Large livestock farms often have a problem with managing waste in the form of slurry and manure. Therefore, more and more often they decide to build biogas plants which operate solely on substrates from the farm. In addition to solving the problem of waste, the biogas plant provides extra revenue from the sale of electricity and heat. The farming company, POLDANOR S.A., is a pioneer in this type of activity. This is the first biogas plant in Poland, founded in 2005 near a Poldanor pig farm in Pawlowko. Three years later, plants were build in Kujanki and Plaszczyca. Satisfactory results, as well as promising regulatory environment, resulted in the decision of Poldanor to further develop the electricity production sector. Currently, the company is the undisputed market leader in agricultural biogas plants in Poland – it operates eight biogas plants with a total installed capacity of 7.4 MWel. In the coming years, the company plans to build another 6 biogas plants.

In addition to using pig manure in biogas plants, Poladanor has decided to utilise large amounts of maize silage, which requires the cultivation of corn on hundreds of acres. A different strategy was chosen by the owner of a biogas plant in Niedoradz with a capacity of 250 kW – the Bio Agri Sp. z o.o. company. The facility was established in the vicinity of a large pig farm. The farm owned a pipeline infrastructure pumping slurry into open lagoons. Local residents complained about odors emitted from the stored slurry. This is one of the reasons why the biogas plant has been established there with the partial use of the existing infrastructure. One insulated tank with a reinforced concrete membrane roof and two containers (one for the CHP system, the other – for the transformer station) have been constructed. Slurry is pumped directly from the farm buildings and the operator of the biogas plant has the possibility of adding other substrates as well. In Niedoradz small amounts of chicken manure and maize silage are added to the slurry. The Biogas Agri biogas plant was a relatively cheap facility because of its location and the already existing infrastructure. The cost of its installation was around PLN 2.5 million (EUR 0.6 million).

- **Biogas plants in the vicinity of industrial plants**

In 2011, a biogas plant with an installed capacity of 0.526 MWe was installed in Skrzatusz. The biogas plant was built by a Polish company Biogas Zeneris. It is located on a plot adjacent to a currently operating agricultural distillery and the distillers' grains constitute a major substrate for the plant. The biogas plant consumes about 43 tons of distillers' grains, 7 tons of carrot pomace, 15 tons of potato pulp and about 15 tons of corn silage per day. The plant is also adapted to the treatment of meat waste (it has an unloading hall and a unit for the

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pasteurisation of wastes prior to feeding them to the fermentors), but currently they are not used because other waste substrates are more readily available. The biogas plant has a steam boiler with a capacity of 205 kWt, which produces process steam for the needs of the agricultural distillery. It is a substrate-energy model of cooperation between enterprises which is relatively popular in Poland.

In connection with the launch in 2014 of Prosumer – a new programme of the National Fund for Environmental Protection and Water Management – the implementation of RES micro-installation projects in cooperation with local government units is expected in the nearest future. A new model will be created, with local governments as facilitators of solutions related to micro-sources, including micro-biogas plants.

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2.3.6. Spain

Case 1: MOURISCADE BIOGAS PLANT

BCM: Public investment.

MOURISCADE BIOGAS PLANT

Description	Characteristics
Mouriscade is biogas plant located in Lalín (Pontevedra, Spain). Manure from around 100 cows and fodder are the substrates treated in this plant. Both electrical and thermal energy produced are used for self-consumption in the farm. Supplier: Biovec.	**Substrate treated:** Approx. 1 600 tonnes/year of manure and fodder. **Biogas valorisation unit:** 20 kW turbine **Energy production:** 150 MWh_{el} per year. **Installation:** Pretreatment tank: 12m^3 Digester: 257 m^3 **Investment:** 245 000 € **Funding by**: Public investment. **Estimated payback period:** 7 years.

Strong points for success:

- Valorisation of both thermal and electrical energy for self-consumption.
- Digestate is used as fertilizer in agricultural activities.

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Case 2: CASTELLÓ DE FARFANYA

BCM: Private investment.

CASTELLÓ DE FARFANYA BIOGAS PLANT

Description	Characteristics
Castelló de Farfanya (Lleida, Spain) there is a biogas plant to treat pig slurry and poultry manure. Both electrical and thermal energy produced are used for self-consumption. Supplier: Ecobiogas.	**Substrate treated:** Approx. 16 500 m^3/year of pig slurry and 1 800 tonnes/year of poultry manure. **Biogas valorisation unit:** 100 kW_{el}; 121 kW_{th} **Energy production:** 800 MWh_{el} per year. 968 MWh_{th} per year. **Installation:** Digester: 2000 m^3 **Investment:** 500 000 € **Funding by:** Own resources. **Estimated payback period:** 6 years

Strong points for success:

- Valorisation of both thermal and electrical energy for self-consumption.
- Digestate is used as fertilizer in agricultural activities.

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Case 3: AGRONSELLA BIOGAS PLANT

BCM: Private investment.

AGRONSELLA BIOGAS PLANT	Description	Characteristics
	Agronsella S.A is a farm located in Undués de Lerda (Zaragoza, Spain). Manure is the by-product treated in this biogas plant for thermal self-consumption. Supplier: Biovec.	**Substrate treated:** Approx. 2 000 tonnes/year of pig slurry concentrated. **Biogas valorisation unit:** 170 kW boiler. **Energy production:** 900 MWh per year. **Installation:** Pretreatment tank: 55m^3 Digester: 670 m^3 Postreatment tank: 580m^3 **Investment:** 220 000 € **Funding by:** Own resources. **Estimated payback period:** 4 years.
		

Strong points for success:

- Valorisation of thermal energy for self-consumption.
- Digestate is used as fertilizer in agricultural activities.

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Case 4: ISCAR BIOGAS PLANT

BCM: Private investment. A synergic model is applied for operation of the biogas plant between agri-food companies close to the biogas plant.

ISCAR BIOGAS PLANT	Description	Characteristics
	Biogas plant Located in Iscar (Valladolid). This plant treats agri-food by-products from processing industries of vegetables and potatoes. Thermal energy produced is used for self-consumption and the rest is sent to poultry slaughterhouse. Operator: Santibáñez Energy. Customer: Grupo Hidalgo 	**Substrate treated:** 2 800 tonnes/year of by-products from processing industries of vegetables and potatoes. **Biogas valorisation unit:** 100 kW_{th} **Energy production:** 950 MWh per year. **Installation:** Pre-treatment tank: 30 m^3 Digester: 570 m^3 Postdigester: 300 m^3 Gasholder: 533 m^3 Digestate tank: 900 m^3 **Investment:** 0.41M € **Funding by**: Own resources. A Synergic model is applied for operation of the biogas plant. **Estimated payback period:** 6 year.
		

Strong points for success:

- Valorisation of thermal energy.
- Digestate is used as fertilizer in agricultural activities.
- Reducing cost of residue treatment.

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2.3.7. Sweden

Case 1: Långhult Habo

BCM: Private funding and support by public subsidies.

Långhult Habo

Description	Characteristics
Beef cattle producer with a 320 head herd. Part of energy produced (100 MWh_{el}) is utilized on the farm and sells the rest (300 MWh_{el}) to the grid as well as sells 600 MWhheat to neighbouring greenhouse. The synergy business model applied has advantages related with that low commitment level = low risk to partners and therefore easy to form partnership. In contrast, there is a limited control over the most important substrate.	**Volume treated:** Liquid and solid manure as base-substrate to the plant, and receives 200 tonnes/year high energy food processing waste as co-substrate. **Energy production:** 75 kW_{el} installed capacity CHP Unit; 200 kW heat. **Installation:** Preheating tank: 45 m^3 Digester: 510m^3 Post-digestion: 19 m^3 **Investment:** around 550 000€ **Funding by:** private and public subsidies (30%)

Strong points for success:

- Valorisation of thermal energy for self-consumption.
- Digestate is used as fertilizer in agricultural activities.

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Case 2: Kulbäcksliden

BCM: Private funding and support by public subsidies.

<table>
<tr><th rowspan="2">Kulbäcksliden</th><th>Description</th><th>Characteristics</th></tr>
<tr><td>Kulbäcksliden is a farm in the north of Sweden with milk production from 155 cows. The biogas plant is in operation since 2013. The biogas is used for heat and electricity production.</td><td>Substrate treated:
6 200 m³/year of cattle slurry

Biogas valorisation unit:
CHP unit of 55 kW electric

Energy production:
270.000 kWth per year

Installation:
Digesters: 2x350 m³

Investment: 500 000 €

Funding by: private investment of 322 000 € and investment grant 178 000 €</td></tr>
<tr><td colspan="3">Strong points for success:
o Investments costs are kept low by self-construction and consultants from MMG consult.</td></tr>
</table>

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2.4. General comments

Biogas production in the European Union is mainly addressed to electricity and heat, which are the most important energy recovery techniques. According to Eurobserv'ER (2013) energy recovery from biogas has taken a leap forward in EU. Purpose-designed biogas plants, such as AD units in decentralized farms or other agri-food companies have begun to dominate the spread of biogas production by means of implementing the small-scale concept.

Four examples of small-scale biogas plants were presented in **France**: 2 farms, 1 Associations of Food Industries (AFI) and 1 agri-food Company. These examples are varied in terms of CHP engine or a boiler, dry or liquid processes, farm or AFI agri-food companies, different suppliers and technologies.

Despite high investment costs in France, subsidies (public investment) still allow developing biogas plants. It is important to take into account the following considerations in order to reduce costs. All these considerations can be applied in most cases to all countries.

- Developing of standardized equipments (e.g. SCEA Robin, France).
- Developing biogas units as simple as possible by using infrastructure already existing on the site (e.g. Laiterie de l'abbaye Tamié, France).
- Use as much as possible near and simple substrates to decrease operating and management costs (e.g. SCEA Robin, France).
- Simplify administrative management during the creation of the project and during the operating phase of the biogas unit.
- Thermal energy use for self-consumption (Boyer SAS, France).
- Adaptation to real needs. Sometimes a boiler is a better option than a CHP engine when thermal needs are significant. The advantages of a boiler in comparison with a CHP engine are that the investment costs are much lower as well as decrease of administrative tasks (complicated management when electricity is produced and bought by electrical company). On the other hand, the profitability with a boiler is often lower than with a CHP engine. The choice will depend on thermal needs, the will of the project leader and the project configuration.

In **Italy** the biogas plants for agro-livestock farms have been principally built in the North, where most of these farms are located. The Lombardy Region is the most active one compared to the others. Regarding size, biogas plants have reduced size (250 kW) for internal purposes and energetic self-consumption. However, this aspect is related to the size of the farm in terms of waste production and energy consumption. This aspect is directly related to the objectives of BIOGAS^3 project.

Biogas plants' main feedstocks are the wastes resulting from breeding (manure and slurry), and a minor percentage of biomass (soil maize, triticale and chopped corn, corn silage, etc). The reasons which pushed them to build a biogas plant are different but common:

- Diversify the company activity (other source of income if electricity is partially sold out).

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- Make the most of the intrinsic potential of manure.
- Use the digestate as alternative fertilizer for land, more rich in nitrogen.
- Both electrical and thermal energy for self-consumption (for reducing the dependency from the power supply and consumption of methane or other gases such as LPG).

The existing system of support for renewable energy sources in **Poland** has promoted the development of plants with a capacity above 1 MW_{el}. Only 42% of currently operating 50 plants using agricultural biogas (as of May 2014) does not exceed 1 MW_{el}.

Micro-biogas plants in Poland are developed mainly based on business cooperation between universities, scientific institutions and private entities. Scientific centres as centres of knowledge and technology, in collaboration with entrepreneurs, implement the concept of micro-installations.

Facilities of small capacity (installed capacity of approximately 250 kW) are often built in close cooperation between a party with the necessary raw materials (substrates) or constant demand for energy (electricity or heat) and a technology provider. Technology companies propose trade credits to make the implementation of the projects possible. Moreover, small plants are often created near large agricultural holdings, which alone can supply the plant with substrates from their own production. At the same time, they possess the capital required for investments.

In **Spain**, the business model generally applied for construction and operation of agro-industrial small-scale biogas plants is related to the investment through private funding (own resources and/or loan). In this case, both electrical and thermal energy use for self-consumption in agri-food industries with high energy demands in their processes allow reducing in a high percentage the need for energy and it also reduces economic and environmental impacts.

Biogas plant construction for thermal energy use (self-consumption and/or sell to nearest companies) is an interesting alternative to build simplified biogas facilities with low investments costs.

An interesting business collaboration model (BCM) has been identified in the biogas plant located in Iscar (Valladolid). This synergy model implies: i) agri-food processing industries of vegetables and potatoes as by-product producers, ii) O&M company in charge of the biogas plant, and iii) agri-food industry of poultry slaughterhouse as consumer of the thermal energy produced in the biogas plant. All parts of the model are located in a close area in order to reduce/remove economical costs related with transport and eventually long storage period of by-products.

In **Poland** there are few examples of biogas plants a small-scale. Most of them treat organic wastes from farms, and they are not subject to registration to the Agricultural Market Agency. On the other hand, there are examples of cooperation and collective actions between companies, technological centres and universities in order to promote anaerobic digestion.

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