Biogas^3: Sustainable and Economical Production of Biogas from Food Waste of European Agrifood Industry

Remigio BERRUTO, Valter BOERO, Patrizia BUSATO, Angela CALVO, Alessandro SOPEGNO, Lorenzo VENUDO [(1)], Daniele ROSSI [(2)], Paz GOMEZ, Begoña RUIZ [(3)], Małgorzata KACHNIARZ [(4)]

[(1)] Università degli Studi di Torino, Dipartimento di Scienze Agrarie, Forestali e Alimentari (DISAFA), Grugliasco.

[(2)] Assobirra, Associazione degli Industriali della Birra e del Malto, Roma.

[(3)] AINIA Centro Tecnológico, Departamento de Medio Ambiente, Bioenergía e Higiene Industrial, Paterna

[(4)] FUNDEKO Korbel, Krok-Baściuk Sp.J., Warsaw

For correspondence please refer to

Professor Remigio Berruto, email: remigio.berruto@unito.it

Abstract:

The purpose of this work is to promote the sustainable production of renewable energy from the biogas obtained from agrifood waste in small-scale concepts for pursuing energy self-sufficiency.

Stakeholders were interviewed and two different questionnaires were offered: the first for agrifood industries, the second for biogas plants and component providers. Information obtained was elaborated to have a view of wastage amounts in agrifood sector and get information of available small-scale biogas plants.

Obtained data were used in different project phases: for Smallbiogas calibration (a web application to facilitate small-scale biogas plant business plan setup), plant models calibration and to write Biogas^3 Handbook.

The activities of this work were based on Biogas3 project, co-funded by the Intelligent Energy Europe Programme of the European Union Contract N° IEE-13-477.

Keywords

Food Waste, Small-scale, Biogas, Renewable Energies, Web Applications, Tool for Farmers

Introduction

Roughly one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year (Gustavsson et al., 2011)

In Europe every year almost 180kg of food per capita are wasted (DG Environment, 2010) and a great amount of waste is determined in food production.

Food Waste (FW) determines different impacts: in fact it effects on environmental parameter as CO_2 emissions, natural resources utilisation as well as on economic parameters as production costs, disposal costs and family expenditure. Furthermore social impact cannot be underestimated.

Anaerobic digestion (AD), especially in small-scale solutions (< 100 kW_{el}), is a viable solution for agrifood industry both to decrease waste costs and to produce biogas.

Biogas can be used to produce electrical and thermal energy for agrifood companies' self-sufficiency: this model could be particularly useful for industries with high thermal energy demand (water heating, heat exchanger etc.).

In particular CHP engines seems to be very promising for agrifood companies, since many food industries use both electrical and thermal energies in their processes.

This integrated system between food and energy production determines an abatement of logistics and transport costs, since the organic material for AD is produced directly near the digester. The combination of CO_2 abatement and renewable energy production is particularly interesting regarding the European climate and energy framework for 2030 (EU Council, 2014).

In order to widespread the biogas small-scale technology in the agrifood sector, stakeholders were interviewed and dissemination material was designed.

Questionnaires

Stakeholders were interviewed with two different questionnaires: the first addressed to agrifood companies, the second to plant and components producers.

In this way, the amount and typology of waste from agrifood companies and available technology of small-scale biogas plants on the market were assessed.

The partners of Biogas[3] interviewed more than 150 agrifood companies in the seven countries where the project takes place, so questionnaires were filled in France, Germany, Ireland, Italy, Poland, Spain and Sweden.

Forms were distributed mainly by e-mails and phone contacts, but the most effective approach was represented by phone calls followed by company visit.

Agrifood companies were asked to give information on waste and by-products produced (type and quantity), energy consumption (electrical and thermal energy and vapour consumed annually), barriers identified in the implementation of biogas plants in agrifood sector, waste management and cost.

It can be noticed that waste quantity production vary a lot depending on company's size and type of production.

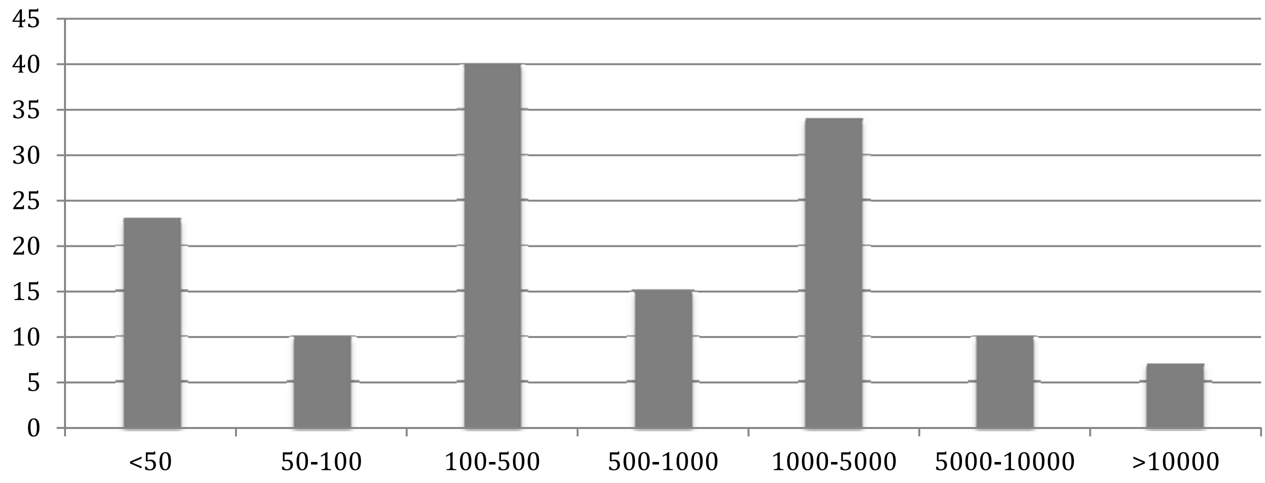


Figure 1. Amount of waste produced by interviewed agrifood companies.
Number of companies (axis y) and range quantity in t year^{-1} (axis x)

Results of the waste produces is shown in Figure 1, the weighted average produced by those companies is about 2000 tons a year. In Table 1 a comparison between different substrates quality is offered, equal weight. It can be noticed that waste and by-products from different food industries could feed different plant size, depending on the substrate. Anyhow, on average waste quantities, small-scale solutions appear to be suitable for this sector.

Table 1. Comparison between different substrate

Substrate (2000 t)	MWh_{el}	MWh_{th}	CHP Power (kW)
Silo dust waste	635	962	83
Milk whey	137	208	18
Bovine ruminal content	214	325	28
Potato peels	248	376	33

Questionnaires addressed to plants and components providers granted relevant data of available technology of small-scale digesters available on the market.

Questionnaires were filled in mostly by phone contacts and e-mail. Providers seemed more interested in the initiative than agrifood industries, maybe because they saw an opportunity for company's marketing and visibility.

About 70 companies filled in the questionnaire. It was decided to interview mostly all-in-one providers, since this is the easiest solution for agrifood companies interested in building a plant. All-in-one providers have been included in the fifth section of Biogas[3] Handbook. Small-scale plant and CHP engine costs were processed and used for the calibration of the economical section of Smallbiogas® report. Furthermore, information obtained from all the plant and component questionnaires contributed to the technology section of the handbook.

Handbook

In order to disseminate information about biogas among agrifood company, an handbook was designed: *Biogas^3 Handbook - a tool to promote sustainable production of renewable energy from small-scale biogas plants for* pursuing *self-sufficiency.*

The handbook will be distributed in agrifood industries in the following stages of the project, to widespread information about anaerobic digestion, implementations currently working all over Europe, technological-technical and environmental benefits by using AD in agrifood sector.

Figure 2. Biogas^3 Handbook cover

The handbook is divided into 8 sections: Introduction, biogas, substrates, technology, companies, models, implementations and legislation, as shown in Figure 3.

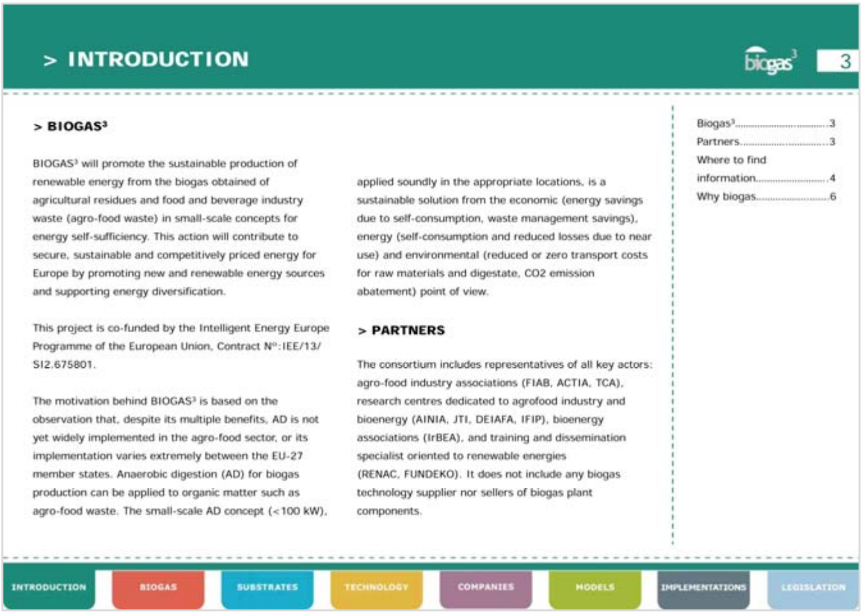
The first four chapters are related to information about AD process, by-products and waste exploitable for biogas production and plant technology.

The 5th section is a meeting place for stakeholders. In fact, agrifood industries can find all-in-one plant providers nearby, with a detailed form of the plants available on the market (plant description, costs, provider information and contacts).

The 6th section is about models studied by DISAFA, where models of small-scale biogas plants for food industry and farms are presented. These models are set with a CHP engine configuration (since it grants the best results for agrifood industries) divided into three sizes (30, 60 and 100 kW_{el}).

The 7th section provides three examples of small-scale working plants in Europe with different sizes (30, 50 and 102 kW). These implementations were chosen mainly for the valuable utilisation of the thermal energy surplus generated by the CHP engine (home heating, straw drying etc.), sparing fossil fuel consumption.

In the last section legislation issues are listed, so that agrifood companies can get links to government measures for the main aspects concerning biogas plants in their country.



> INTRODUCTION

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> BIOGAS³

BIOGAS³ will promote the sustainable production of renewable energy from the biogas obtained of agricultural residues and food and beverage industry waste (agro-food waste) in small-scale concepts for energy self-sufficiency. This action will contribute to secure, sustainable and competitively priced energy for Europe by promoting new and renewable energy sources and supporting energy diversification.

This project is co-funded by the Intelligent Energy Europe Programme of the European Union, Contract N°:IEE/13/ SI2.675801.

The motivation behind BIOGAS³ is based on the observation that, despite its multiple benefits, AD is not yet widely implemented in the agro-food sector, or its implementation varies extremely between the EU-27 member states. Anaerobic digestion (AD) for biogas production can be applied to organic matter such as agro-food waste. The small-scale AD concept (<100 kW), applied soundly in the appropriate locations, is a sustainable solution from the economic (energy savings due to self-consumption, waste management savings), energy (self-consumption and reduced losses due to near use) and environmental (reduced or zero transport costs for raw materials and digestate, CO2 emission abatement) point of view.

> PARTNERS

The consortium includes representatives of all key actors: agro-food industry associations (FIAB, ACTIA, TCA), research centres dedicated to agrofood industry and bioenergy (AINIA, JTI, DEIAFA, IFIP), bioenergy associations (IrBEA), and training and dissemination specialist oriented to renewable energies (RENAC, FUNDEKO). It does not include any biogas technology supplier nor sellers of biogas plant components.

INTRODUCTION | BIOGAS | SUBSTRATES | TECHNOLOGY | COMPANIES | MODELS | IMPLEMENTATIONS | LEGISLATION

Figure 3. Template of the handbook chapters

Smallbiogas®

Smallbiogas® is a web application that helps agrifood industries in small-scale biogas plant business plan setup. According to previous cases, web applications appear to be useful for dissemination, since they provide many outputs and information from a small number of inputs, as demonstrated in other EU projects (Busato & Berruto, 2014).

In particular Smallbiogas® is addressed to agrifood industries interested in building a biogas plant. This tool allows users to analyse the technical, economical and environmental feasibility of small-scale biogas plants. The user has to insert inputs as substrate (type and quantity), plant type (CHP, boiler); examples of data insertion are shown in Figure 4 and Figure 5, in particular regarding substrate and financial data.

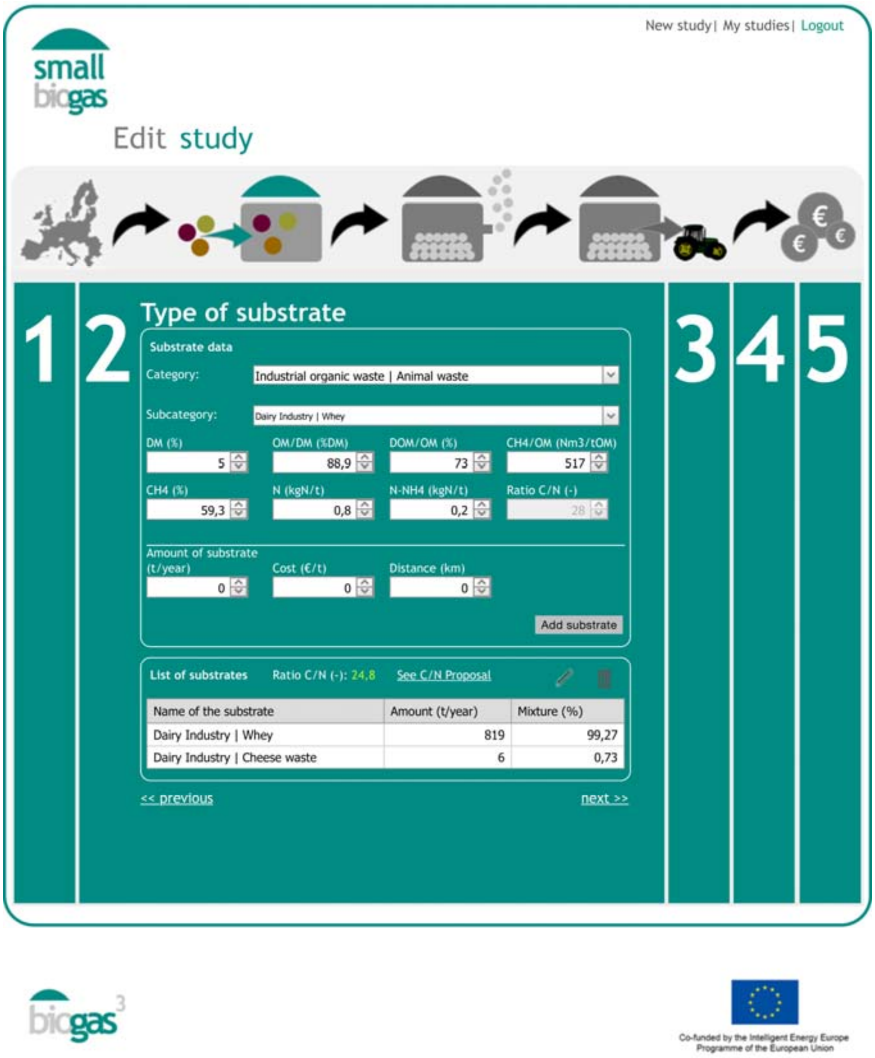

Figure 4. Substrate data insetion in Smallbiogas®

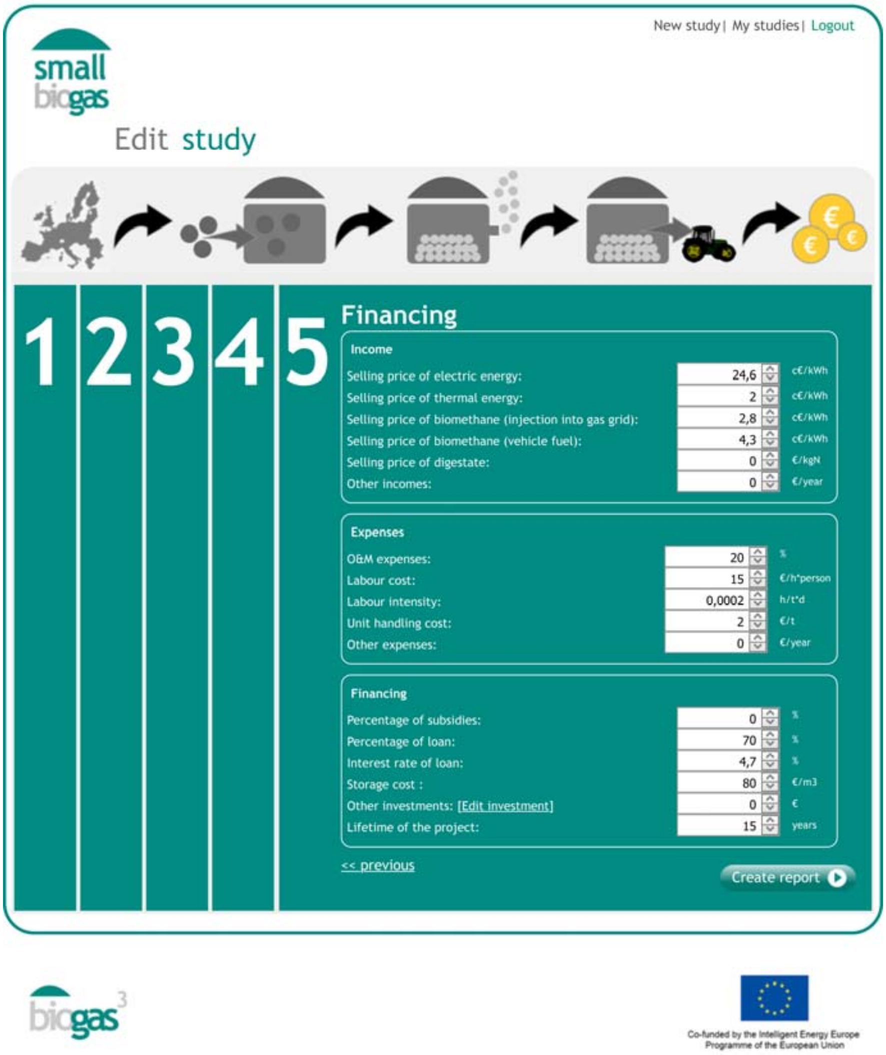

Figure 5. Subsidies and fundings data insertion in Smallbiogas®

The web application is user friendly, since it suggests inputs data: for example financial parameters as selling price of energy or labour cost are set in function of the selected country in the first step of the process, while other parameters as percentage of O&M expenses or loan are set as standard parameters that the user can change.

Once the inputs are set, the tool generates a comprehensive report that will help agrifood companies in making decisions.

The report provides information about the AD process (annual amount introduced in the digester, C/N ratio, gross methane production etc.), plant parameters (m^3 of the digester, CHP or boiler power etc.) and economic viability (plant costs, payback period etc.). A page of the report is shown in Figure 6, in particular the economic viability analysis is presented.

small biogas **Viability report**

Economic viability analysis. Financial study of the investment project.

Financing	1.064.871,24	€
Subsidies	0,00	€
Own funding	319.461,37	€
Loans	745.409,87	€
Percentage of subsidies	0,00	%
Percentage of own funding	30,00	%
Percentage of loan	70,00	%
Interest rate of loan	4,70	%
Financial indicators		
Gross operating profit or earnings before interest, taxes, depreciation and amortization (EBITDA)	127.269,69	€/year
Net present value (NPV)	179.075,68	€
NPV/initial investment	0,168	-
Internal return rate (IRR)	2,33	%
Payback period	8,37	years
Weighted Average Cost of Capital (WACC)	5,90	%
Capital Recovery Factor (CRF)	10,23	%

Environmental viability analysis

Primary energy obtained from the recovery of the biogas	1.119,78	MWh/year
Savings of CO2 emissions	311,30	t/year
Savings in artificial fertilizers	57508,8	kgN/year
Utilization of the digestate in	Vulnerable area	
Cultivation area required for application of digestate	338,29	ha

Co-funded by the Intelligent Energy Europe Programme of the European Union
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Figure 6. Detail of a Smallbiogas® report - economic viability analysis. 102 KWe

Since Smallbiogas® is a web application, the data is always up to date and agrifood companies can use the last version of the tool. For example, if there is any change in one country's financial subsidy, the parameter can be updated and all the report will be up to date.

The power of subsidies

Incentives and subsidies on renewable energies are not the same all over Europe: some countries do not foster biogas plants, while in others funds allocated to biogas incentives seems to be over. Fundeko compared the 6 small-scale plant models made by DISAFA putting the models on Smallbiogas® tool with different subsidies, depending on the country where the plant was going to be set. In Table 2 comparison between both dry and wet models are shown. It can be noticed that payback period is more feasible in countries where huge subsidies on biogas plants are disbursed.

Table 2. Payback period comparison of wet & dry models made by FUNDEKO of the models studied by DISAFA using Smallbiogas

	PAYBACK PERIOD (years)						
WET Model (with CHP)	Italy	Spain	Ireland	France	Sweden	Germany	Poland
30 kW no subsidies self consumption	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*
30 kW no subsidies sale of energy	4,56	>15	11,4	>15	>15	>15	>15
30 kW 30% subsidies self consumption	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*
30 kW 30% subsidies sale of energy	3,19	>15	7,98	11,01	>15	10,54	13,36
60 kW no subsidies self consumption	8,8	8,29	>15	>15	>15	14,14	>15
60 kW no subsidies sale of energy	5,33	>15	13,3	>15	>15	14,37	>15
60 kW 30% subsidies self consumption	6,16	5,8	12,26	>15	>15	9,9	>15
60 kW 30% subsidies sale of energy	3,73	>15	9,31	12,9	>15	10,06	>15
100 kW no subsidies self consumption	10,94	6,47	12,79	>15	>15	9,01	>15
100 kW no subsidies sale of energy	7	>15	10,17	>15	>15	9,09	>15
100 kW 30% subsidies self consumpotion	7,66	4,53	8,96	>15	>15	6,31	>15
100 kW 30% subsidies sale of energy	4,9	>15	7,12	11,71	>15	6,37	>15
	PAYBACK PERIOD (years)						
DRY Model (with CHP)	Italy	Spain	Ireland	France	Sweden	Germany	Poland
30 kW no subsidies self consumption	3,56	3,08	4,83	5,94	10,27	7,57	3,82
30 kW no subsidies sale of energy	2,25	6,4	3,82	2,9	9,97	6,68	3,09
30 kW 30% subsidies self consumpotion	2,49	2,15	3,38	4,16	7,19	5,3	2,68
30 kW 30% subsidies sale of energy	1,58	4,48	2,67	2,03	6,98	4,68	2,16
60 kW no subsidies self consumption	>15	>15	>15	>15	>15	>15	>15
60 kW no subsidies sale of energy	3,15	>15	>15	8,34	>15	>15	>15
60 kW 30% subsidies self consumpotion	>15	>15	>15	>15	>15	>15	>15
60 kW 30% subsidies sale of energy	2,21	>15	>15	5,84	>15	>15	>15
100 kW no subsidies self consumption	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*
100 kW no subsidies sale of energy	3,73	>15	10,93	11,21	>15	11,72	>15
100 kW 30% subsidies self consumpotion	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*	n.a.*
100 kW 30% subsidies sale of energy	2,61	>15	7,65	7,85	>15	8,21	>15

* the defined needs of energy are higher than the production of energy from biogas (the software SmallBiogas does not generate results in such cases)

When energy needs are higher than the energy production of the plant, the report generated by Smallbiogas® do not show payback period and other parameters, this issue should be resolved in the following steps of the project.

Conclusions

Currently the future of this integrated model of food and energy production seems to be promising; nevertheless some barriers still have to be overcome.

Food industries often do not have land to spread digestate or they do not produce enough waste amounts: in this case a tight collaboration between farmers and food industries could be considered.

Furthermore for other companies waste is not produced in a continuous way. in this particular case some solutions can be found: for example some agrifood waste and by-products can be stored for a longer time, even using heat surplus from the CHP engine (e.g. drying or silage). Biogas is produced in a continuous way, but some agrifood industries need electrical and thermal energy only for the production processes: in this case the most viable solution is represented by biogas storage.

This work made possible to have a precise overview on waste production in agrifood companies, the further steps of the project will deal with explaining these companies how to exploit waste and by-products in order to create energy, avoiding waste disposal to landfill and reducing CO_2 emissions.

IEE projects will produce a significant impact in terms of the European sector of renewable energies, in particular Biogas[3] will adopt a trainer approach, in order to ensure impacts beyond the project duration. For this purpose webinars and other dissemination initiatives with agrifood companies will be carried out.

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