RENEWABLE ENERGY FOR AGRICULTURAL COMPANIES: A BIOGAS MICRO-CHP PROJECT

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ABSTRACT: In the international energetic scenario, more importance will be given to the renewable energies. To reach the main goals on energetic problems, it's important to study, to analyze and to promote examples of distributed microgeneration CHP plant for agricultural companies and farms. This paper is about one of the possibly solutions for the medium-small farm which have both zootechnical slurry and vegetable biomass like maize. After a small description of the anaerobic digestion process and after a small description of the technical solution for the biogas plants, the authors will present you the productive structure of the company and the description of the pilot plant that will be installed. Targets of the project is to made a research on the right mix finding the biggest production of biogas and to simplify this technologies to promote it for the small agricultural companies.

Keywords: anaerobic digestion, biogas, pilot plant

1 INTRODUCTION

The REACS (Renewable Energy for Agricoltural companies) project was financed by the Italian Ministry for Agricultural and Forestry Politics.

Project REACS is based on the valorization of residues of agricultural and breeding manufacturing in a small Umbrian farm; the technologies is based on the anaerobic process using principally zootechincal slurry.

This project born by an analysis, realized by the Biomass Research Centre (forwarding CRB), about the state of art of the biogas power plant combined whit an analysis about the removal of the slurry in the medium-small Italian farms; CRB has note that there aren't on the Italian territory technologies calibrate for the small size and for needs of small farms.

2 ANAEROBIC DIGESTION PROCESS

The anaerobic digestion process is a thermo-chemical process, that can be realized in lack of ossigen, able to transform organic matters in biogas composed by methane and carbon dioxide principally; this reaction starts naturally also in big heaps of organic matters, like agricultural biomasses. Methane rate goes from 50% to 80% according to the biomass used in the process and according to the typology of the process (see chapter 1.1); this percentage of methane comport a low heating value variable from 4.500 Kcal/m^3 to 6.500 Kcal/m^3.

The biomasse in input must have this characteristics:

- Moisture up to 50%;
- C/N value between 20 and 30;
- pH value between 6,4 and 7,2;
- Low value of ratio between lignin and cellulose;
- For zootechincal slurry, lack of antibiotic elements deriving by medical care of the breeding;
- Lack of phenols [1].

These characteristics are fundamental for the development of the microorganism families necessary to start the process; water in input permit the microorganism to move inside the substratum and to develop itself, like an "house"; non optimal ratio between Carbon and Nitrogen may comport some problems of inhibition of the process according to the elevate percentage of Nitrogen ammoniac (urea of the slurry); pH is an index of the stability of the process; lignin isn't a biodegradable substance, then its an elevate value comports a low efficiency of the plant [2].

Microorganisms families realize the anaerobic digestion by two steps: the first one is a transformation of complex substances in intermediate composts, like acetic acid and hydrogen, that will be the feeding for methanigen microorganisms families during the second step [3]. In figure 1 there is a scheme of all the stages of anaerobic digestion whit their products, feedings and bacterium.

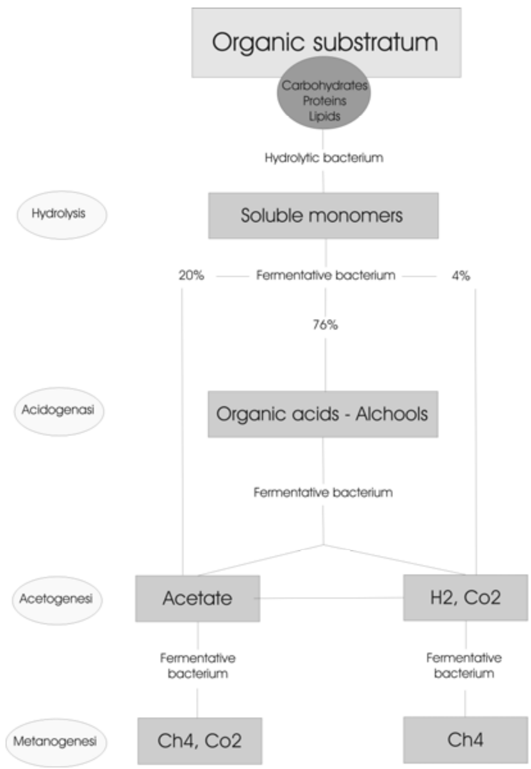

Figure 1: Stages of anaerobic digestion process

All the stages can be also realized in only one step using a digestor: in this case, the digester reactor will have a configuration too many complicated because you have to guarantee optimal condition of development for different microorganisms families [4].

2.1 Typologies of anaerobic process

Temperature is the main characteristic that influences the anaerobic process type because temperature of development is different for the microorganism families.

If the process temperature is between 15°C and 25°C there is the development of psicrophil batters, between 25°C and 45°C mesophil batters, between 45°C and 55°C thermophil batters.

The different types of processes have different retention times: between 30 and 90 days for psicrophilic process, between 15 and 35 days for mesophilic process, about 15 days for thermophilic process [5]. Naturally, different processes have different technologies, costs and efficiency; table I is about the characteristics of mesophilic and thermofilic process.

Table I: Characteristics of mesophilic process and of thermophilic process.

Process type	Management costs	Efficiency (biogas/ substratum)	Organic input
Mesophilic	Medium	Medium	Medium
Thermophilc	High	High	High

An other significant difference between processes types is about the percentage of dry matter contained in the substratum; we speak about “dry digestion process” when this percentage is more than 20%, “wet digestion process” when dry matter is less than 10%, “half-dry digestion” in the other cases [6].

2.2 Digester plants technologies

Based on quantity and on typology of biomasse in input, based on the process type, there are many solutions for build an anaerobic plant.

The simplest technologies solutions are tanks or lagoons, warm or not warm; the main difference between tanks and lagoons is that the second one can be realized directly on terrain, without civil buildings, upon waterproofing, but whit bigger dimensions.

Tanks can be realized on the ground or partially buried. Biogas is catch by floating PVC cloths or using pipes combined whit a compressor to make the pipes on negative pressure and then guarantee the picking up of biogas (see figure 2).

These types of reactor have many problems deriving by the lack of agitation mechanical system, necessary to homogenize slurry and maximize the process efficiency, and by the lack of heating system whit great efficiency, especially for the lagoons technologies, owing to the big size of reactors. Therefore solid contained in slurry can solidify and become a rigid coating whit a consequently block of leak of biogas, in the worst hypothesis.

A second type of digester reactor is the CSTR (Completely Stirred Reactor – see figure 3) make by a cylindrical tank, dimensioned on the quantity and type of biomass used, where a mechanical agitation system guarantees an homogenization of chemical characteristic of the organic matters in the tank. In this case, anaerobic digestion takes place in only one stage; consequently, the plant is cheaper but it has a lower efficiency and more problems in the purification of zootechnical slurry.

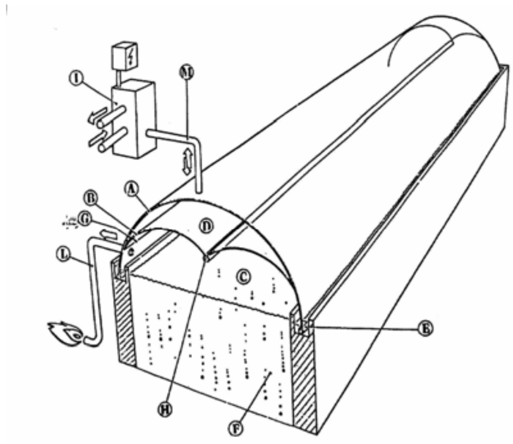

Figure 2: Tank anaerobic digester plant: A) waterproof covering; B) separation membrane; C) biogas chamber; D) air chamber; E) anchorage; F) slurry tank; G) connection between membrane and cover; H) membrane ballast; I) air pump; L) biogas exit; M) air pipe (source Ecomembrane)

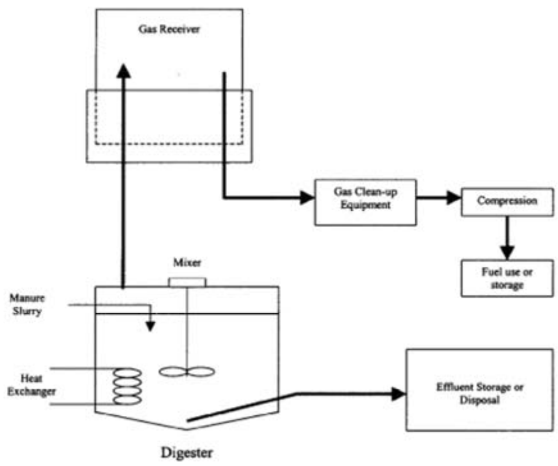

Figure 3: Digester CSTR

The last reactor solution mono-stage is represented by plug-flow reactor (PFR), composed by a prismatic tank whit length bigger then others dimensions (see figure 4).

Figure 4: Digester PFR

PFR is the reactor whit the biggest efficiency and can use slurry whit high percentage of solid elements; this reactor doesn’t need a mechanical agitator system because the organic matter must to go away slowly to guarantee a constancy in all the sections of the reactor of nutritive matters and bacterium concentrations, gradually variable until the optimal conditions on the last section.

If the solid elements percentage is minor than 13%, we can find PFR technologies combined whit mechanical agitator systems.

The pilot plant object of the project REACS is an evolution of PFR digesters whit shortest dimensions and better efficiency (double stage co-digestion reactor).

2.3 Some examples of biomasses in input

Using different material we will have different efficiency both in quantity both in quality of biogas produced by anaerobic digester.

In this paragraph we will present you the evaluation of biogas produced by different types of biomasses in the anaerobic digestion process (see tables II and III).

Table II: Characteristics of biomasses in input (% of dry substance)

Material	Dry Substance (%)	Organic Substance (% d.s.)	Biogas (m^3/tons o.s.)
Breeding			
Bovine sewage	6 - 11	68 - 85	200 – 260
Bovine manure	11 – 25	65 – 85	200 – 300
Swine sewage	2,5 – 9,7	60 – 85	260 – 450
Swine manure	20 – 25	75 – 90	450
Bird sewage	10 – 29	75 – 77	200 – 400
Bird manure	32,0 – 32,5	70 – 80	400
Agriculture			
Maize	34	86	350 – 390
Grass	26 - 82	67 - 98	300 - 500
Straw	85 – 90	85 – 89	180 – 600
Pole of maize	86	72	300 - 700
Agro-industry			
Vegetal rejects	5 – 20	76 – 90	350
Molasses	80	95	300
Whey	4,3 – 6,5	80 - 92	330

Table III: Biogas yield for volume unit

Material	Volume (m^3)	Weight (tons)	Biogas (m^3)
Bovine sewage	1	1	15
Bovine manure	1	0,3	10,1
Swine sewage	1	1	15,6
Swine manure	1	0,3	23,5
Bird sewage	1	1	44,5
Bird manure	1	0,3	29,3
Maize	1	0,625	67,6
Grass	1	0,5	89
Straw	1	0,04	12
Pole of maize	1	0,4	123,8
Apple rejects	1	0,3	2,6
Molasses	1	0,3	68,4
Whey	1	1	15,3
Vegetal rejects	1	0,4	14,5
Olive Mill Water	1	0,5	357

As you can see, the biogas yield of zootechincal slurry is not the biggest one: compared whit biogas from maize, the yield of slurry is about half quantity. However, it’s not possible to make an anaerobic process using only maize because substratum doesn’t have the right characteristics for the development of microorganisms families, whit a consequently increase of activation time of digestion process.

From literature data, we can underline the elevate yield of Olive Mill waste Water (OMW), rounded 360 m^3 of biogas for 1 m^3 of OMW; using this substance in anaerobic process, there will be some problems deriving from the presence of phenols and from the seasonal supply, estimated around 90 days for years. Moreover, at the end of anaerobic digestion process, the substratum has an elevate percentage of Nitrogen that you must pulling down using traditional metodologies; this problem bind to build a plant so much complex than other plants dedicated to different input biomasses [6].

3 BIOGAS PLANTS IN EUROPE AND IN ITALY

In Europe there are countries where biogas plants are widespread in all regions, especially in nord-Europe contries like Germany; in Sweden, 10% of biogas produced is purified and used for auto traction of rounded 6.000 vehicles (data from 2004), whit a traditional fuels saving of rounded 360.000 liters for year.

To have a complete idea on the European situation of biogas plants, we report the data referred to 2006 year:

- about 1.600 plant working whit depuration sludges;
- about 400 plants build for treatment of industrial waters wastes whit elevate percentage of organics substances;
- about 450 plants for recovering of dumping biogas;
- about 130 plants for production of biogas deriving by Urban Solids Wastes or Industrial Organic Wastes;
- more than 2.500 plants of biogas from zootechincal slurry; the 80% of these plants are situated in Germany (out of these, the 90% work in co-digestion whit other biomasses); in Sweden there are 7 plants working whit animal by-products; in some regions of Austria, biogas is used in the civil methane net;
- in Italy, at the 2004 year, there was 100 plants for biogas production deriving by zootechincal slurry.

4 DESCRIPTION OF INNOVATIVE PILOT PLANT DESIGNED FOR PROJECT REACS

We are building an innovative pilot plant in a umbrian farm near the city of Perugia.

4.1 Productive structure of the selected farm

The actual productive structure of the company provide the breeding of approximately 140 wet nurses “chianina” cows that graze for six months for year, 130 “frisona” milk-cows and 90 between calf and heifers: consequently, using literature statistics, the daily production of zootechnical slurry is round 12 m^3/day.

The daily production of biogas produced by a cow of 500 kg weight is round 0,750 m^3/day: for the company selected, considering 120 cattle of 400 kg weight, 90 cattle of 350 kg weight and 110 cattle of 600 kg weight, the daily production of biogas is approximately 215 m^3/day.

The farm has also about 60 ha, then the owners can use part of these terrains (about 10 ha) to cultivate maize and realize a co-digestion process whit two stage higher efficiency reactor.

4.2 Innovative pilot plant

During our works, we decide to concentrate our attention on a specific type of digester: horizontal digester. This technology is modular and so flexibly on the farm needs and can be installed in a very simple way; the reactor developed itself in an horizontal axe, type PFR reactor, working on thermophilic conditions. The reactor is realized in stainless steel whit double face (see figure 5); this configuration allows to have small maintenance costs because solids contained in input will drag in the lowest section of the reactor and ejected whit substratum at the end of the process, avoiding the formation of rigid coatings. The double face is necessary to take the right thermal conditions inside the reactor; to realize this, the plant will use hot water deriving from the biogas energetic conversion section.

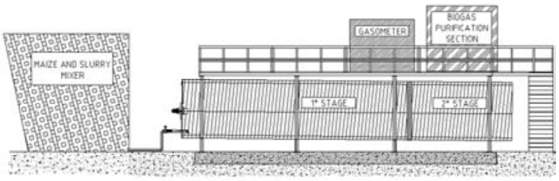

Figure 5: Pilot plant scheme

The reactor pipe has maximum dimension of 2,50 m diameter and a length under 15 m to guarantee the respect of Italian law limits about road haulage.

The useful section of reactor is rounded ¾ of total volume because it must reserve a part of the pipe for the expansion of biogas. To increase the capacity of the plant, intended to drain a bigger quantity of slurry, it will build two reactors pipes.

This plant will use all the daily production of zootechincal slurry of the farm mixed whit maize. The final outputs power obtained by the plant is about 50 kW electric and 70 kW thermal power, running for 6.000 hours for year.

The reactor is provide whit a mechanical agitator system set by a little electric engine, which provide a very slow rotation of the system (about 1 round every 5 minutes).

Auxiliary components will be positioned on side of reactor pipes; in particular these sections will be: biogas depuration section (dehumidification, desulphurizer), gasometer for biogas accumulation, energetic valorization biogas section (biogas engine), hot water accumulation system (necessary to guarantee thermal conditions inside reactor), security torch for thermo destruction of biogas in case of emergency.

The estimated total plant cost is about 250.000,00 €.

4.3 Experimental plan

Principle experimentation on biogas pilot plant is about the set up of the technology by a correct analysis on energy and mass fluxes both in the reactor and in the energetic valorization system.

To optimize development period of microorganisms families during start up time or after maintenance periods, we will inoculate the different bacterium families inside the reactor; in this way, it's possible to receive the better conditions for start of anaerobic process in a few time.

The innovative anaerobic pilot plant can play in co-digestion of slurry and herbaceous biomasses; we will feed the digester whit maize, in different quantity during our experiments, starting by 800 Kg for day. After the experimentation period whit maize, we will research and study other different type of herbaceous biomasses, like fiber sorghum not dried; the experiments will make also whit mixes of different herbaceous biomasses to find the mix that maximize efficiency in terms of production of biogas.

To make possible these experiments, we will use our small experimental batch reactor able to realize preliminary analysis about efficiency of different substratum (see figure 6).

Figure 6: Batch reactor of CRB

We have already realized some efficiency analysis whit bovine slurry, bird manure, organic fraction of urban solid wastes and some species of algae coming from Trasimeno Lake [8]. This little batch reactor could be used both for researches about the better mix and for estimate the correct volume of expansion of the biogas inside the reactor to prevent all the possible causes of alarm and system malfunctions.

5 CONCLUSIONS

The descripted plant is dimensioned on the Italian farm situation and can be a modular and so simply replicable solution for zootechnical slurry swallow problems.

Modularity of the plant permit to calibrate the size on the real needs of the farm and of the breeding. Moreover, modularity also allow to develop anaerobic plant side by side whit the increase of breeding: in fact, if the number of cows duplicate, it will simply be necessary to place another digester section composed by other two pipes reactor, while the other sections we can decide to duplicate or not.

The possibility of co-digestion process whit slurry and herbaceous biomasses increase the production of biogas and, consequently, allows owner's farm to have a shortest payback period (about 6 years).

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