BIOGAS PRODUCTION FROM AGRICULTURAL RESIDUES. TEST RIG AND RESULTS

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ABSTRACT

The use of renewable resources has evolved considerably in the last period of time, mainly because of the fact that those resources are inexhaustible and they can be found at lower prices on the market than the fossil fuels. From this category of resources, the biomass is one of the most important source of energy, being the first renewable resource that has been used to produce heat on the stair of human evolution. Currently, biomass is used only for heating purposes, direct burning for cooking and hot water preparing sharing the largest part. About 95% of the biomass currently used is firewood and agricultural waste, the rest is wood waste from industrial processes. Romania has a large biomass potential available for heat and electricity production especially from the stock of wood and from agriculture.

The main purpose of this study is to present the types of biomass used in our days, their use in industry and also to present a model of installation used for transforming the biomass found in agricultural residues in biogas. This model of installation is under construction at the Politehnica University of Timisoara and it's main purpose is to create biogas using residues (sawdust, manure, chopped leafes, etc) that will be mixed with water and acetic acid to realize the needed chemical reactions and will be introduced in two reactors by the means of a submersible pump. The use of this kind of experimental installation will try to give a solution for solving the problem of obtaining the biogas from agricultural residues.

KEYWORDS

Biomass potential, types of biomass, sources of residues, biogas.

1.INTRODUCTION

From all the renewable resources that are known in present, biomass can be considered the only type of renewable energy that can be converted in all the types of fuels : gaseous, liquid and solid.

One of the main advantages of biomass is the fact that, apart from the solar energy or wind power, this type of energy is always available and can be used to convert it through different methods necessary to provide transmittable power.

Even if the use of biomass is one of the oldest methods used for supplying energy to mankind, the modern types of bioenergy carriers like wood pellets, logs, wood gas or biogas can be used in stationary applications offering a range of new solutions that can meet the today's energy demand. As a general information, it's estimated that on the land areas of the Earth grow about 200 billion tonnes of biomass with an energy content of approximately 30,000EJ (1 EJ=1exajoule=$1x10^{18}$J).

Even if this value is an equivalent for the energy content of all the stock of fossil energy carriers on Earth, it's main disadvantage is that this potential cannot be used directly for energy purposes because it is spread to the entire landmass of the planet.

In Europe, according to some scientific materials and studies, biomass is considered to be the largest renewable energy source with the biggest potential of all the renewable energy sources that exist today. (Dr Semida Silveira, Bioenergy, Realizing the Potential, 2005).

In the next graphics it will be presented the technical potential of biomass in Europe (figure 1) and the bioenergy share compared with total energy consumption (figure 2)

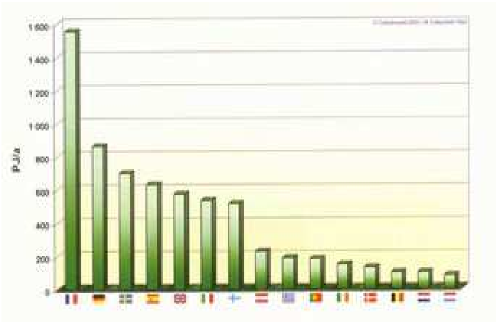

Figure 1 – Technical potential of biomass in Europe

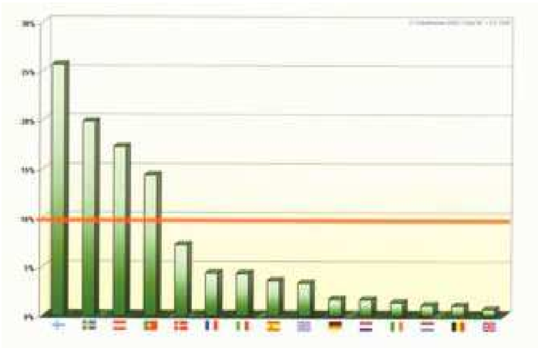

Figure 2 – Bioenergy share compared with total energy consumption

Related with the European Union's project to achieve an average share of electricity from renewable energy sources of 12% by the year 2010, biomass is expected to provide about 10% of the entire European energy supply, which is equivalent to about 5800 PJ (1 PJ = 1 petajoule = 10^{15} J).

The biomass sector in Romania is characterized by a twofold regional distribution; about 90 % of fuel wood and 55 % of wood waste is found in the Carpathians and Sub Carpathians. About 54 % of agricultural wastes are found in the South Plain and Moldavia. About 52 % of biogas is found in the South Plain and the Western Plains.

In Romania there are more than 550 small industrial hot water and steam boilers running on fossil fuel with wood co-combustion and 10 hot water boilers between 0.7 MW and 7MW for heating (totaling 45MW).

The area of agricultural soil in Romania is about 148.000 km^2, of which 94.200 m^2 is arable land. The residues from agricultural crops could be entirely utilized as fuel. Considering the possibilities of collecting and baling it in order to be transported the following types of agricultural waste could be utilized: straw, stems, corncobs, grapevine cords. In figure 3 is presented the energetic potential allocation of biomass in Romania.

Figure 3 - Energetic potential allocation of biomass in Romania.

2.TYPES OF BIOMASS AND FORMS OF BIOENERGY SOURCE

Regarding the forms of bioenergy source, biomass can be divided according to its origin :

Solid bioenergy sources - in this category the largest group consists in products made from wood, due to the industrial processing of wood products. As an example for this products, it can be considered wood logs, wood chips, wood briquettes or wood pellets. Those materials can be used in wood fire places, stoves, cheminees, wood log furnaces, or tiled stoves. It's estimated that for each hectare of forest, between 0,4 and 0,8 tonnes of air dry firewood can be obtained from these forest wood residues. When the round trunks are machined into planks and beams, the main result is the production of large quantities of residues, but a big part of them is used for other materials in the wood industry.

Also, another part of those residues cannot be used for utilization as a wood product because it has fragments of dark bark. The dark bark is ideal for energy recycling. In figure 4 is presented an image for this kind of material.

Figure 4 : Bark as a by – product of wood processing

Liquid bioenergy sources – in this category of sources are included ethanol from alcoholic fermentation and methanol from lignocelulose biomass such as wood. The most widespread energy crops are rape and sunflower.

The fuels from liquid bioenergy sources are CO_2 neutral and also have better emission properties and a low potential for pollution.

Gaseous bioenergy sources – those category of sources are the result of converting natural biomass. They can be produced by microbiological processes such anaerobic methane fermentation and also can arie trough the thermochemical conversion of solid biomass in gasification processes.

Biogas is created in the fermentation of vegetable and animal biomass without the action of oxygen. In practice, this phenomenon happens in agricultural biogas installations or in landfill bodies.

Related with all the general information given for the existing types of energy sources and the potential that those sources have for the industrial application, the estimated contribution of unconventional energies in the year 2025 is presented in Table 1. Table 2 presents the contribution of biomass in covering the necessary of primary resources

Table 1 : The preponderance of the main energy sources in the year 2025

Energy source	**Energy cuantity [TW]**
Energy from the sun	1,5
Biomass	3,5
Hydro and geothermal	2,5
Wind energy	1,0
Fision energy	0,5
Fossil fuels (oil, coal)	9,0
Total	**18,0**

Table 2 - The contribution of biomass in covering the necessary of primary resources

Country	Contribution of biomass	
	TJ/year	%
Romania	49.290	2,3
Belgium	14.278	0,7
Danemark	33.371	4,5
Germany	144.417	1,3
Greece	24.446	2,7
Spain	90.133	2,5
France	404.619	4,4
Italy	124.395	1,9
Irland	3.554	0,9
Luxemburg	641	0,5
Netherlands	18.280	0,6
Portugal	47.746	7,3
United Kingdom	19.335	0,2
Austria	128.843	11,8

Related with the contribution of biomass in covering the necessary of primary resources, it can be said that in Romania only 2,3% from the resources is covered from the biomass, the rest is being covered from the fossil fuels.

Biomass applications for biomass can be grouped into the following main segments:

• substitution of part of the fossil fuels in existing district heating schemes (wood chips)

• enhanced uses of biomass as industrial fuels (wood chips and logs as industrial fuel for steam or hot water boilers) instead of oil

• improved uses of biomass for new district heating schemes for small towns and villages near the resources, in the countryside, where the population has no access to central co-generation or gas supply

• uses of straw and other agricultural by-products in appropriate biomass boilers for heat supply of farms and small villages (in the medium term)

• the top priority is the use of biomass for thermal applications, substituting oil.

• the most promising regions for the agricultural waste utilization are the South Plain and the West Plain where agricultural production is high.

• the expected development of the wood industries will encourage the rehabilitation of the existing boilers from the existing auto producer's thermal plants which account about 550 steam boilers, or the construction of the new ones.

In figures 5 and 6 it is presented the biomass potential from wood and agricultural waste.

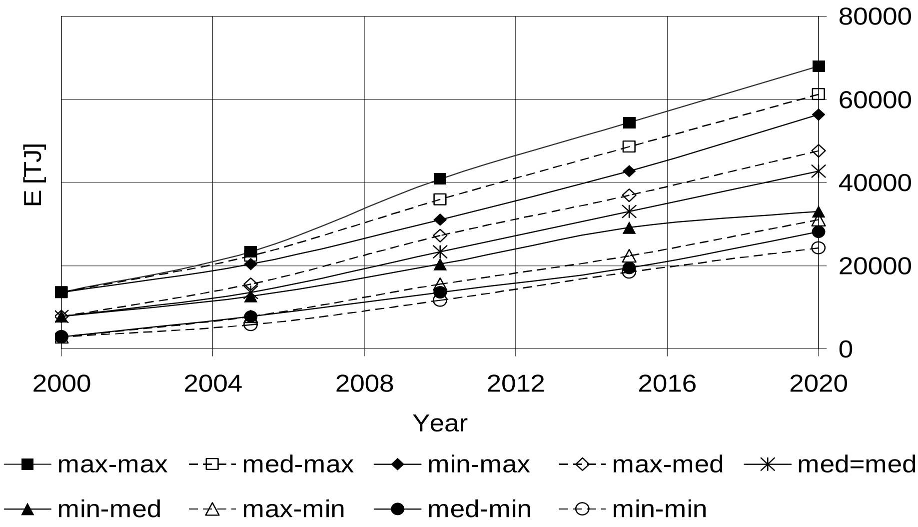

Figure 5 – Biomass potential from wood waste

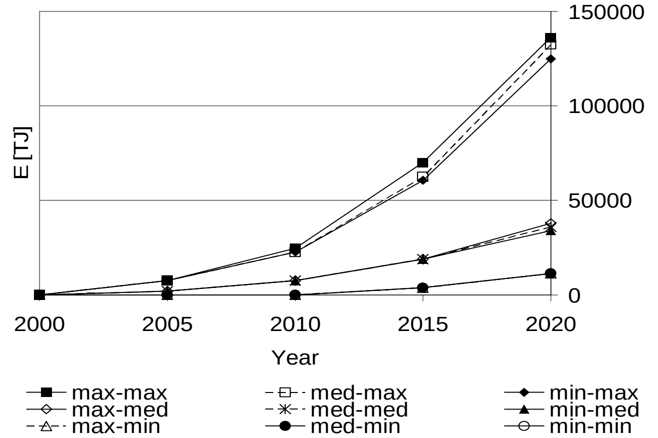

Figure 6 – Biomass potential from agricultural waste

3.THE DESCRIPTION OF THE DEMONSTRATIVE INSTALLATION FOR THE PRODUCTION OF BIOGAS FROM AGRICULTURAL RESIDUES.

This chapter will describe in short some aspects related with the anaerobic fermentation (digestion), the preparation of the residues, and the components of the demonstrative installation that is under construction at the Politehnica University of Timisoara.

For the use of those vegetable residues in the installation, they need to be minced to very small dimensions so the anaerobic bacteria could have a good contact with them and start the process of anaerobic fermentation.

This process consists in several parts, in which the organic matter is transformed by anaerobic bacteria to a gas consisting mainly of CH_4 and CO_2, and a residue called sludge or biosolids. The main result for this process is the storage of a significant fraction of the original biomass energy in methane, as the reactions that occur only give out a small quantity of heat.

In the first stage there are used different acids for the modification of the pH of the residues using acetic acid, or even sulphuric acid.

After the modification of the pH hydrolysis takes place in different kinds of temperature :

- at low temperature (25 - 30°C) – for a duration of a number of days
- at intermediate temperature (80 - 90°C) – for a duration of 1-2 hours
- at high temperatre (120 – 150°C) and pressure of 5-10 bar – for a duration of 10 – 15 minutes.

Figure 7 presents the variation of the pH as a function of the acetic acid concentration.

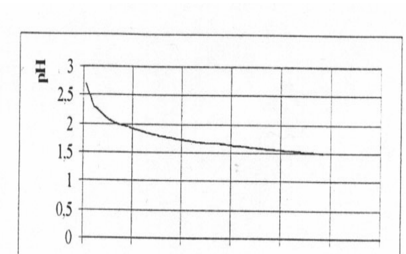

Figure 7 : Variation of the pH as a function of the acetic acid concentration

Table 3 presents the general characteristics for sawdust, one of the biomass residues used in the pilot installation.

Table 3 – General characteristics for sawdust

Characteristics	**Symbol**	**IS units**	**Value**
Density	ρ	kg/m^3	-
Total humidity	W_t^i	%	9.97
Ash	A^i	%	0.25
Volatiles	V^i	%	76.20
Sulphur	S_t^i	%	0.12
Hydrogen	H^i	%	5.80
Carbon	C^i	%	44.60
Inferior heating value	H_i^i	kJ/kg	17660
(Oxygen & Nitrogen) by difference	$(O + N)^i$	%	3845

The methanogenesis process can take place in three different regimes :

- criophilic (10 ÷20^{o}C) during 90-120 days ;
- mezophilic (25÷35^{o}C) during 25-30 days ;
- termophilic (40÷55^{o}C) during aprox. 10 days.

After the stages presented above, the methanogenesis process takes place, in this phase the resulting products are inserted in the fermentation reactor, where, under the influence of the anaerobic bacteria the biogas production process takes place according to the next chemical reactions :

CH_3-CH_2-CH_2-$COOH \rightarrow CH_4 + CH_3$-$CH_2COOH$

CH_3-CH_2-$COOH \rightarrow CH_4 + CH_3$-$COOH$

$CH_3COOH \rightarrow CH_4 + CO_2$

$2\ CH_3$-$CH_2OH + CO_2 \rightarrow CH_4 + 2CH_3$-$COOH$

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

The motivation for using the acetic acid in the process is motivated by the fact that this acid is not very strong and it can be processed from the bacteria at CH_4 and CO_2.

Some of the parameters that could affect the process are:

- The C/N ratio – a ratio between 20 – 30 is considered to be an optimum value for the anaerobic fermentation.
- The heating speed – it represents the quantity of material that is fed on the volume unit in the reactor / day. If the reactor is overloaded then the acidification rises and the production of biogas decreases.

The time of residence in which a certain quantity of material stays in the reactor for the bacteria to realize the process in order to obtain a high efficiency.

- This time depends also of the temperature of the process.

Figure 8 presents the installation and the description of it's components.

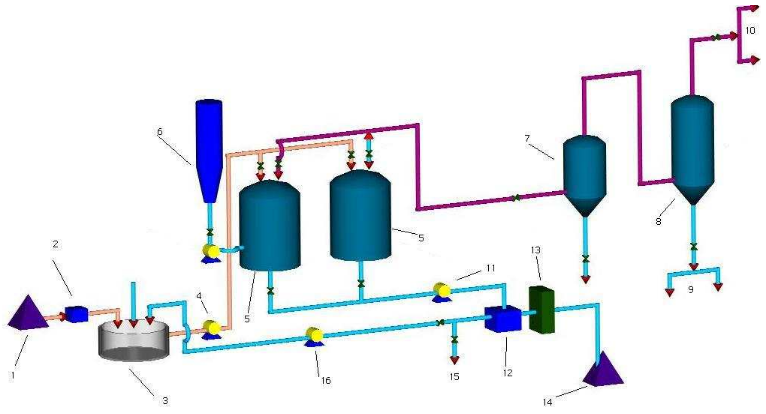

Figure 8 : The schematics of the demonstrative installation

1.biomass deposit; 2. mill; 3. tank for the preparation of the biomass suspension; 5. anaerobic fermentation reactor; 6. tank for the correction agent for the pH; 7. retaining filter; 8. CO2 absorber and pump;9.CO2 desorber and compressor; 10. utilisation of the biogas; 11. pump for the evacuation of the used material; 12. compost filter; 13. compost drier; 14. tank for compost; 15. liquid evacuation; 16. pump for the recirculating material;

Also it has to be mentioned that the two reservoirs are heated through the means of one boiler.

The hydrolysis reactor has a cylindrical shape. It's made of steel and has a cover on it's upper part on which it's installed the agitator.

The fermentation reactors have on their upper parts a connection for feeding the biomass and evacuation of the biogas, for feeding the reactives, for measuring the pressure and the pH.

The heating system is composed mainly from a boiler made for an installation having a calorific value of 18KW/h., enough for heating the biomass at a temperature of 35 - 40°C, and maintaining it there. The purification and the processing of the biogas will be realized trough a filter filled with steel material trough which the H_2S will be eliminated. After the filtering process, a part of the CO_2 is eliminated trough another filter with ceramic components that "washes" the gas of CO_2. The electric installation will be relatively simple, it will be composed from an electric

panel trough which the pumps of feeding / evacuation and recirculation of biomass will be commanded.

The next images will present some of the components of the installation.

Figure 9 – Front view of the biogas production installation

Figure 10 – the H_2S filter (in the back) and the CO_2 filter(in the front plan) of the installation. Also in front of the two filters there are the pumps that will be commanded by the pH sensors of the installation.

Figure 11 – The electric panel of the installation

Figure 12 – The biogas storage tank

4. CONCLUSIONS

From all the renewable resources, biomass is the only one which remains available at all times and also can be converted through different methods necessary to provide transmittable power.

The general form in which biomass is converted is biogas and the installations created for this purpose are in a large range.

Biomass is one of the most important renewable resource in the Romanian territory. Traditionally, it has been used by the rural population and on the towns' outskirts, but with traditional equipments and technologies.

On the long term, significant amounts of biomass for electricity and heat generation are available and should be provided by short rotation energy plants or by annual intensive crops

A model of installation used to produce biogas was presented in this study with it's components and a short description of the process that takes place inside the installation.

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