[1.]Ana-Maria TĂBĂRAȘU, [1.]Cristian SORICĂ, [1.]Dragos ANGHELACHE, [1.]Vasilica ȘTEFAN, [2.]Carmen-Otilia RUSĂNESCU, [2.]Valentin APOSTOL

METHODS OF CONVERSION OF BIOMASS INTO ELECTRIC AND THERMIC ENERGY

[1.]The National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry – INMA Bucharest, ROMANIA;
[2.]University Politehnica of Bucharest, ROMANIA

Abstract: Renewable energy sources such as biomass, solar, hydro and geothermal energy can provide important energy services based on the use of available local resources, studies to date show that the potential of these energy sources is enormous, they can cover in principle several times energy demand. This paper presents some considerations on the methods of converting biomass into convenient energy, respectively the most used method for obtaining biodiesel.
Keywords: biomass, biofuels, bioenergy, solar energy, wind energy

INTRODUCTION

Recent studies on the future development of the energy sector show that in the second half of the 21st century by implementing appropriate strategies, the share of total renewable energy sources can increase from 20% to over 50%, which can help meet current energy needs heating in certain (rural) disadvantaged areas / eg biomass *(I. Sobor et al, 2002)*.

Alternative energy types:

- *Solar energy* - used to produce heat by passive or active conversion methods or to supply electricity through photovoltaic systems. In December 2016, solar photovoltaic energy reached the same price or a lower price than fossil fuel in over 30 countries. Solar energy is the energy emitted by the sun. It is one of the renewable energies. Solar energy is used by humans, animals, plants for various purposes. Plants use solar energy for photosynthesis. The sun's rays are either used directly by man or converted by man into thermal energy (heat) or electricity *(Zhang D.et al, 2015)*.
- *Wind energy* - used to produce electricity with wind turbines; Wind energy, a form of renewable energy, it has been used since the beginning of humanity as a means of propulsion on water for various boats and later as energy for windmills. The countries with the highest installed capacity on wind farms are China, the United States, Germany and Spain. At the beginning of 2011, the share of wind energy in total domestic consumption was 24% in Denmark, 14% in Spain and Portugal, about 10% in Ireland and Germany, 5.3% in the EU. The percentage is 3% in Romania at the beginning of 2012. At the same time in Romania there were over 1000 wind turbines, half of them being in Dobrogea *(A. Cherubini et al, 2015)*.
- *Hydroenergy* - hydroelectric power plants with an installed capacity less than or equal to 10 MW (low hydropower), respectively hydroelectric power plants with an installed capacity greater than 10 MW (high hydropower).
- *Geothermal energy* - energy stored in underground geothermal hydro deposits and deposits, exploitable with special drilling and extraction technologies.
- *Biomass* - comes from residues from forestry and agricultural exploitations, wood processing waste and other products; biogas is the result of anaerobic fermentation of animal manure or from municipal wastewater treatment plants *(M.B. Hagberg et al, 2016)*.

Biomass, for most of history, has been the primary energy source powering human development. This energy supply has taken various forms, including wood and dung for cooking and heating, charcoal for metallurgy, and animal feeds for food and transportation. With increasing concerns regarding human impacts on the environment, humanity is once again looking towards biomass resources to meet a significant portion of our energy needs. The challenges today in using biomass are many, but can best be related to scale and density. The scale of energy needed far exceeds all past demands; both the increasing world population and the energy intensity of modern life compound the need for energy as never before. Similarly, the distances over which energy is moved and the concentration of population into dense urban centers results in the need for fuels with high energy density to insure overall efficiency of use. Over the past century, the developed world has enjoyed cheap and abundant energy supplies through the adoption of a fossil energy economy (Nallathambi Gunaseelan V., 1997). The 1900 shave been declared the “Petroleum Century”, with both positive and negative connotations. The widespread use of petroleum allowed rapid economic expansion throughout the industrialized world, increasing national and personal affluence, and enabled the modern ideal of personal automobile owner-ship. With expanded automobile ownership came an increasing demand for liquid transportation fuels, a demand that led to a shift in primary production.

Huge demand for various oils and their high prices is an apprehension for the mankind. Since there is an increased awareness for eco-friendly issue, there is an urgent need to explore the alternative energy sources. Various alternative energy sources like nuclear power, solar, wind and biofuels are well known, where biofuels (solid, liquid, gas fuels) sounds as one of the best representative candidates in terms of usage and the production process. Biofuel, is the process where energy of organic materials (renewable biomass) is replaced the function of fossil fuels. When gasoline supply and demand are inelastic, they serve as a buffer supply of energy, helping to reduce prices (*Weiland P., 2009; Vlăduț. V. et al., 2016*). The inelasticity of supply and demand is an assumption which is valid in the short run, whereas in long term both supply and demand are elastic . Processes like trans-esterification which converts animal and vegetable oils into usable 2 fuel forms. From different sources, algae, produces a large amount of energy. Algae represent as the significant group of biological systems, where few of them are known to produce vast quantities of lipids relative to their total biomass. However, it is important to note that the technology has so far not been sufficiently developed to allow these biofuels to be produced commercially. Economics is playing a crucial role in ensuring a smooth transition to a biofuel future. Biomass and biofuels are the only renewable energy source that can replace fossil fuels directly for our present and future energy constraints (*Weiland P.,2009; Nallathambi Gunaseelan V.,1997*).

MATERIALS AND METHODS

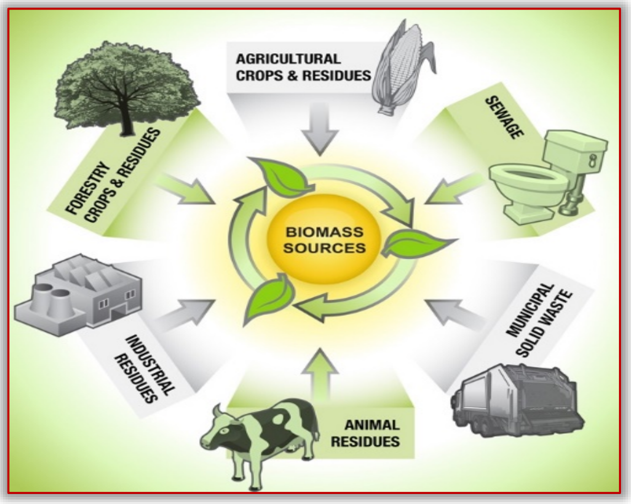
Biomass represents an abundant carbon-neutral renewable resource for the production of bioenergy and biomaterials, and its enhanced use would address several societal needs.

Advances in genetics, biotechnology, process chemistry, and engineering are leading to a new manufacturing concept for converting renewable biomass to valuable fuels and products, generally referred to as the biorefinery. The integration of agroenergy crops and biorefinery manufacturing technologies offers the potential for the development of sustainable biopower and biomaterials that will lead to a new manufacturing paradigm (*Chiru A. et al, 2010*).

The term biomass applies to the mass of substance generated by the development of living organisms, be they microorganisms, plants or animals. The term also includes agricultural products, waste from agriculture or from the processing of agricultural crops, including cereal straw, residues from the production of sugar, starch, beer, etc. (*Lunguleasa A. et al., 2007*).

Biomass is a form of storage of solar energy in the chemical energy of molecules of organic substances, being one of the most popular and widespread resources on Earth. It provides not only food, but also energy, building materials, paper, fabrics, medicines and chemicals. Biomass has been used for energy purposes since the discovery of fire by man, so that today it is used from heating rooms to producing electricity and fuel for cars (*Ed. J. Coombs and D. O. Hall. London, 1981*).

The ability to produce electricity from biomass is based on its physical and chemical properties. A very important parameter is the humidity, respectively the dry matter content of the biomass.



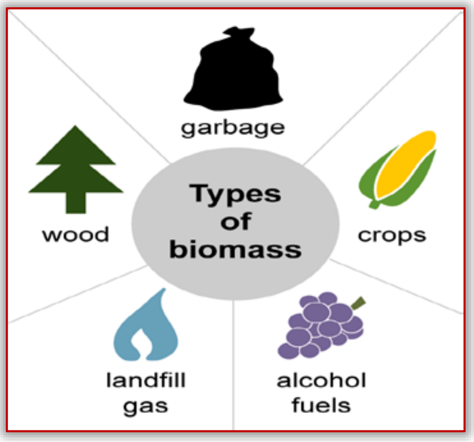


Figure 1. Biomass sources (*Chiru A. et al, 2010*)

Biomass can be converted into convenient energy by several methods. These conversion methods are:

- Thermal conversion of biomass (dry process):
  - Combustion;
  - Pyrolysis;
  - Gasification;
- Biochemical or biological conversion of biomass (wet process):
  - Fermentation;
  - Anaerobic digestion.
- Mechanical conversion of biomass.
- Chemical conversion.

RESULTS

— Thermal conversion of biomass

Combustion: the process of direct combustion of biomass is the most widely used process of energy use. This process is verified in practice and commercially available at very high levels. Combustion devices have different designs and performance, they are able to burn any wood fuel (timber), bales of straw to municipal waste. It is important to burn wood and agricultural waste (straw). The heat generated is used in manufacturing processes (heat processing) and power generation. Wood combustion takes place in the following stages (*Aghamohammadi N. et al, 2011*):

- The water inside the lumber starts to boil (old and relatively dry wood contains 15% water in the cell structure);
- The wood fuel gas is gradually released, for a good combustion it is important that the gas is burned not released through the chimney;
- The resulting gas is mixed with atmospheric air and burned at high temperatures.
- The rest of the wood (mostly carbon) burns well, and produces ash waste.

For efficient combustion it is necessary to ensure:

- Sufficient air;
- Sufficiently high temperature;
- Enough time to ensure complete combustion of biomass.

Although direct combustion is the simplest and most widely used way to use biomass, it is not always an efficient process. The design of a combustion boiler, which is characterized by a much higher efficiency, requires an understanding of the entire combustion process. An important step is to understand the evaporation of water from the lumber, a process that consumes energy. The energy consumed, however, represents only a small part of the available energy. Modern combustion devices are very similar to those used for coal and have a combustion efficiency of 90%.

Pyrolysis consists in the thermochemical decomposition of solid biomass, a process that takes place at temperatures of 300-800°C and in the absence of oxygen. This process results in heat, various gases (hydrogen, methane, carbon monoxide, etc.), bio-oil and coal. Combustible gases can be separated and captured, and the resulting coal, also called biochar, can be used as fertilizer and agricultural amendment, a use that is also an efficient and economical way to sequester carbon.

There are many technological variants of biomass pyrolysis, all of which are characterized by relatively high costs, to which the initial stage of biomass preparation also contributes (storage, drying, crushing and feeding). Heat transfer to solid biomass is also a technological challenge, as a slow transfer favors coking (see Figure 2). Pyrolysis in fluidized bed reactors is the most widespread technological variant for the production of bio-oils, its principle scheme being presented in figure 3. A bed of sand or other thermally stable material at operating temperature is maintained in a "fluid" state, in suspension, by introducing a stream of hot gas at the bottom of the reactor. Subsequently, the reactor is fed with crushed biomass, in a very small proportion, so that the heat transfer takes place almost instantly to the biomass particles.

This principle is the basis of many technologies, the differences between them being to address the problems raised by the formation of coal and coke in the fluidized bed, the accumulation of ash and heat recovery (*Lunguleasa A. et al, 2007*).

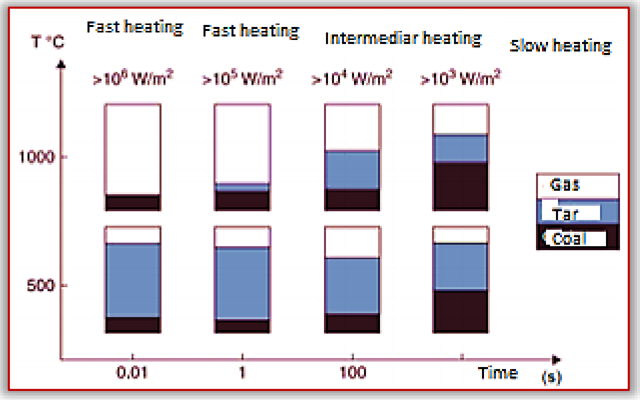


Figure 2. Variation of pyrolysis products with temperature and exposure time

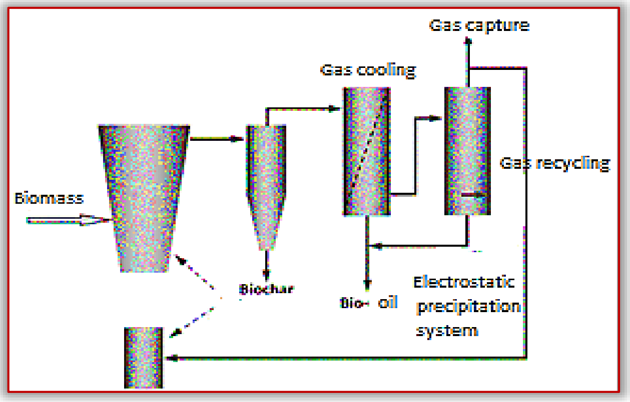


Figure 3. Pyrolysis of biomass in fluidized bed reactor (*Lunguleasa A. et al, 2007*)

Gasification: is a process by which solid fossil fuels, natural gas or biomass are transformed into a combustible gas, called synthesis gas (singaz) or biosingaz, mainly representing a mixture of carbon monoxide and hydrogen, plus carbon dioxide (CO_2) and possibly hydrocarbon molecules, such as methane (CH_4) and is one of the earliest and oldest energy conversion processes. In general, the gasification process is defined by the reaction between the solid fuel with an oxidizing agent (air or oxygen) in the presence of the moderator (steam) at a high temperature between 1200 - 1500ºC and resulting in the synthesis gas used to generate of electricity or as a raw material for the synthesis of substances such as methanol, urea, ammonia, etc. (*Lunguleasa A. et al, 2007*).

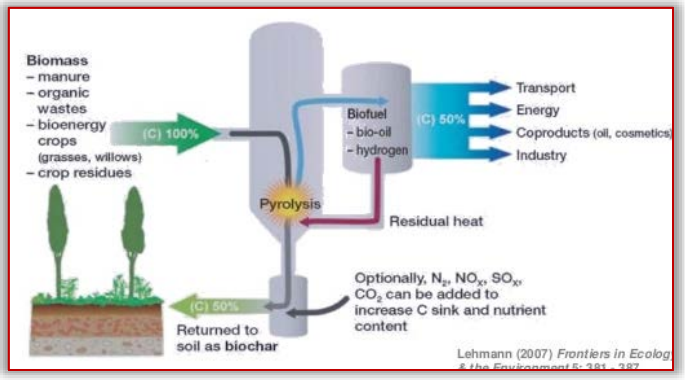


Figure 4. Thermal conversion of biomass (*Nallathambi Gunaseelan V., 1997*)

— **Biochemical or biological conversion of biomass**

Fermentation: is generally used for the production of bioethanol and includes the following steps: the biomass is crushed, then the starch is converted into sugars by enzymes, followed by sugars being converted into bioethanol by yeast (an organism that secretes catalytic enzymes) and finally separation and purification of bioethanol by distillation. The conversion by fermentation of ligno-cellulosic biomass such as wood and herbaceous plants is a more complex process due to the presence of large molecule polysaccharides and requires acidic or enzymatic hydrolysis before the resulting carbohydrates pass into bioethanol by fermentation.

Fermentation of carbohydrate-rich matter with the help of anaerobic bacteria or green algae can produce hydrogen, especially in the absence of light. The process that uses fermentation in the dark produces H_2 and CO_2 combined with other gases such as CH_4 or H_2S, depending on the biomass used and the process reactions.

Anaerobic digestion: is a microbiological process of decomposition of organic matter, in the absence of oxygen, found in many natural environments and applied today on a large scale for the production of biogas in reactors, sealed against air ingress, generically called digesters. A wide variety of microorganisms are involved in the anaerobic process, resulting in two final products: biogas and digestate.

Digestate is anaerobically decomposed biomass, rich in micro and macro nutrients that can serve as fertilizer for plants (*Mitroi A. and ML-A. Imireanu*).

— **Mechanical conversion of biomass**

Mechanical conversion is not a proper conversion of biomass, because it does not change the nature of biomass. These conversions consist of mechanical processes of compressing biomass (compaction, pelletizing, briquetting, etc.) in order to use it in thermal processes (*V. Arion et al*).

— **Chemical conversion of biomass**

Chemical conversion consists in the transformation of mechanically processed biomass and its transformation into vegetable oil, by treatment with an alcohol and generation of esters (eg methyl esters and glycerol). In the next stage, the purified biodiesel can be burned in diesel engines.

Currently, biodiesel is mainly produced in batch reactors. The use of ultrasound in the transesterification of oils into biodiesel allows continuous line processing at any scale. Ultrasonication leads to an increase in biodiesel yield of up to 99%. Ultrasonic reactors reduce the processing time to less than 30 seconds (conventional processing 1 - 4 hours / batch). More importantly, ultrasonication reduces the separation time from 5-10 hours (using conventional agitation) to less than 60 minutes.

The most widely used method for obtaining biodiesel is enzymatic transesterification with methanol (methanolysis). The reaction takes place by heating a mixture of 80-90% oil and 10% and 20% methanol, respectively, plus a small amount of catalyst. The biodiesel resulting from this reaction is called FAME - Fatty Acid Methyl Ester. The following figure shows the general scheme of the process of transesterification of organic oils into biodiesel by methanol (*V. Arion et al*).

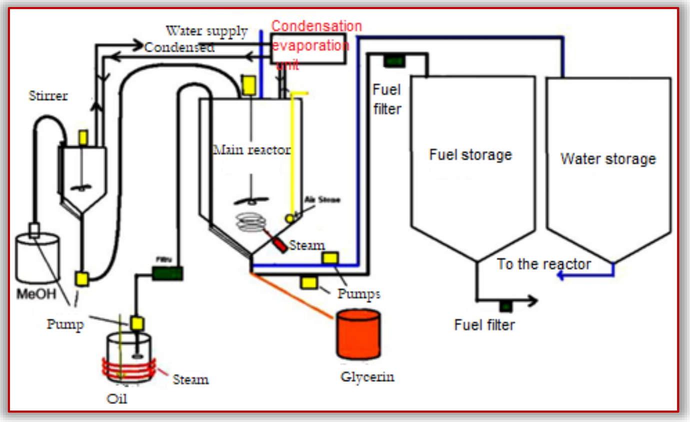


Figure 5. Schematic representation of the technology for the production of methyl esters by transesterification (*https://en.wikipedia.org/wiki/Biomass*)

CONCLUSIONS

Like wind, solar, and other renewable energy sources, biomass can make a positive impact on our atmosphere by lessening our dependence on climate change-inducing fossil fuels. Biomass energy differs from other renewables, however, in the extent to which its use is directly tied to the farms, forests, and other ecosystems from which biomass feedstocks are obtained. Because of this close association, the use of biomass has the potential to result in a wide range of environmental and social impacts, both positive and negative, above and beyond its use as a substitute for fossil fuels. Impacts on soils, water resources, biodiversity, ecosystem function, and local communities will differ depending on what choices are made regarding what types of biomass are used, as well as where and how they are produced. This is why biomass needs to be produced and harvested as sustainably as possible. In this sense, sustainability refers to choosing management practices that minimize adverse impacts and complement local land-management objectives, such as farm preservation, forest stewardship, food production, and wildlife management (*Swithenbank et al, 2011*).

Acknowledgement

This work was supported by UEFISCDI under the „Complex projects carried out in RDI consortia (PCCDI)" Program, Project "Innovative Technologies for Renewable Energy Production from Integrated Natural Sources in Complex Installations" - contract no. 81PCCDI / 27.03.2018.

Note:

This paper is based on the paper presented at ISB–INMA TEH' 2020 International Symposium (Agricultural and Mechanical Engineering), organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in

Environmental Protection (INCDPM), Research-Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, 30 October, 2020.

References

[1] Aghamohammadi, N., Sulaiman, N., Aroua, M.K. (2011), Combustion characteristics of biomass in South East Asia, Biomass and bioenergy, vol.35;
[2] A. Cherubini, A. Papini, R. Vertechy, M. Fontana, Airborne wind energy systems: A review of the technologies Renew Sustain Energy Rev, 51 (2015), pp. 1461-1476;
[3] Chiru, A., Sacareanu, S., Hofbauer, H., Rauch, R., Stanescu, R.C. Brasov, Romania, 2010- In Analysis on World Energy Reserves and Biomass Fuel Solution, 11th International Congress CONAT 2010 Automotive and Transport Engineering;
[4] Ed. J. Coombs and D. O. Hall. London: Applied Science Publishers, 1981- Biomass;
[5] Găgeanu I., Voicu Gh., Vlăduţ. V.and Voicea I. (2016) – Consideration on obtaining biomass pellets, International Symposium ISB INMA TEH Agricultural and Mechanical Engineering, Bucharest, pp. 655-660;
[6] I. Sobor, D. Ungureanu, A. Chiciuc, M. Pleşca, P. Todos, Renewable energy - Feasibility study, Ministry of Ecology, Constructions and Territorial Development, 2002-158p;
[7] Lunguleasa, A., Costiuc, L., Paţachia, S., Ciobanu, V. (2007) Ecological combustion of wood biomass, d. University "Transilvania" from Braşov;
[8] Mitroi A., ML-A. - Imireanu Technical premises for adapting to the new guidelines and regulations of the European Union in the field of production and use of biomass energy. Scientific papers INMATEH, II, Bucuresti;
[9] B. Hagberg, K. Pettersson, E.O. Ahlgren, Bioenergy futures in Sweden – Modeling integration scenarios for biofuel production Energy, 109 (2016), pp. 1026-1039;
[10] Nallathambi Gunaseelan V. (1997) – Anaerobic fermentation of biomass for methane production: review. Bioenergy from Biomass, 13, p.:83-114;
[11] Swithenbank, J., Chen, Q., Zhang, X., Sharifi, V., Pourkashamiani, M. (2011) Wood would burn, Biomass and bioenergy, vol.3.
[12] V. Arion, C. Bordeianu, A. Boşcăneanu, A. Capcelea, S. Drucioc, C. Gherman – Biomass and its use for energy purposes;
[13] Weiland P. (2009) – Biogas production: current state and perspectives, Biotechnology and Applied Microbiology, 85, p.: 849–860;
[14] Zhang D., Huang G., Xu Y., Gong Q, Waste-to-energy in China: Key challenges and opportunities Energies, 8 (12) (2015), pp. 14182-14196;
[15] https://en.wikipedia.org/wiki/Biomass.

ISSN: 2067-3809