The techniques of producing energy from biomass[1]

Wiktoria Sobczyk, Anna Kowalska**

*AGH University of Science and Technology, Cracow, Poland

Summary. The paper describes the sources of biomass and techniques of producing energy from burning biomass: conventional burning, burning in fluidized bed, pyrolysis and gasification. Thermal processing of waste biomass from agricultural production and from the food industry allows to receive energy carriers in the form of liquid or gaseous fuels. Development of alternative energy sources creates a chance of maintaining energy independence. It is also compatible with the idea of sustainable development.

Key words: conventional energy, alternative energy, biomass, wood, straw, fluidized burning, energy plants.

INTRODUCTION

The depletion of energy minerals deposits and recurring oil crises have caused an increasing interest in alternative energy sources. The electric power, the flywheel of the world's economy, is produced mainly in thermal, hydro-electric, nuclear and wind power stations [10]. Thermal power plants produce over 60% of global energy. Unlike thermal power plants, water power stations do not pollute the natural environment. However, they require suitable lay of the land and significant water potential.

Production of bioenergy from alternative sources has been developing for many years in Western Europe, USA and Japan. Basket willow, Pennsylvanian mallow, miscanthus, rose (*Rosa multiphlora*) and grain straws are used for this purpose.

Poland has a significant technical potential of biomass and possibilities of its use for energy production purposes increase every year. Willow cultivation is especially popular [11, 9]. From one hectare of energetic willow plantation one may harvest 20 tonnes of dry mass which has the calorific value of 8 m^3 of heating oil or 10 tonnes of coal. It is estimated that a 30-are plantation (i.e. on fallow lands) can fulfill annual energy needs of a small farm. In the agricultural sector the harvest of willow is conducted in the winter months which is the time of low demand for workforce. Cultivation of multi-hectare plantations on fallow lands could therefore reduce unemployment. The willow as an energy carrier is practically inexhaustible (after 30 years the soil has to be reclaimed and a new plantation can be started) [16].

The produced biomass requires processing. This is associated with construction of new production plants and modernisation of existing boiler rooms used for burning coal or heating oil. The ecological aspect has still greater meaning for the power sector's activity. Objects and installations have to fulfill European Union's standards regarding the permissible concentrations and emissions of pernicious gases. Because of this fact the interest of power plants and CHPs (combined heat and power plants) with biomass increases and new markets open for farmers.

Realisation of projects associated with eco-energy sector is financially supported by EKO-Fund Foundation.

THE ORIGIN OF BIOMASS

Plant resources are a source of different kinds of fuels: solid fuels, bio-alcohol, bio-oil, bio-gas. The process of fuel production begins with acquiring adequate raw material. This can be plant waste from energetic plantations, plants with high sugar content, oil plants.

In agriculture one can mention: straw, hay, beetroot pomaces. Forestry, wood mills and paper industry are also in possession of many different raw materials: chips, sawdust, brushwood, bark (fig. 1), lignin waste water.

1 The paper has been prepared within the AGH University of Science and Technology – statutory research work No 11.11.100.482

Fig. 1. Tree bark

Broad spectrum of materials is offered by agricultural and food industry: waste from sugar factories, distilleries, breweries, straw, food waste [1].

Recently plantations of fast-growing plants and trees have gained large popularity. These include: willow, plane tree, poplar, eucalyptus, sugar cane, rape, sunflower, flax, chosen species of grass (i.e. Sudan grass), grains, potatoes, corn, manioc, sugar beet, soybean, peanuts, sorgo.

On breeding farms one may find waste from animal-farming: liquid manure, bio-gas. The municipal management provides waste sediments, household waste, waste paper, sewage treatment plant waste [5, 6].

TECHNIQUES OF ENERGY PRODUCTION BURNING WOOD WASTE

The form of the fuel has fundamental meaning during the burning process. Wood waste are optimal for burning after being disintegrated into chips. Large contact area in relation to the wood's mass creates a possibility of rapid heating to the ignition temperature and their complete burning. This is the condition for proper use of heat from the burned wood. The best way to use fine industrial waste (chips, sawdust) is to briquette them [2].

Choosing the right furnace for particular forms of wood is also an important factor:

– long pieces of wood should be burned in furnaces with mechanical loading,
– in automatic furnaces one should burn wood in pieces and in form of compressed granulates, pellets (fig. 2) or briquettes (fig. 3) [7, 14].

Fig. 2. Pellets from Olimp wood produced by the company Stelment

Fig. 3. Briquette from oak pulp

– in furnaces with pneumatic loading and separation of carbon black one should burn sawdust (fig 4) [12].

Fig. 4. Sawdust

Burning of wood proceeds in three stages:

– drying and heating,
– degasification,
– proper burning.

During the degasification the flammable gases (hydrogen and carbon monoxide) burn up quickly and rise the temperature. After the gasification phase charcoal is created (fig. 5). It burns in ca. 800°C.

Fig. 5. Charcoal

The proper burning proceeds almost without visible smoke. When the humidity of the fuel is high, special vaults are used to make the flame return and increase the drying process speed in the burning chamber [12]. Through the application of blowing the flame can be extended which improves the quality of burning [13].

After modernisation of Power Plant Jaworzno II a modern thermal-electrical power plant was created. Old Soviet Pk-10p no. 1, 2 and 3 boilers were replaced with two fluidized boilers of "Compact" type manufactured by Foster Wheeler. Two turbine sets of WK-50 type were replaced by thermal-condensative sets of 13CK70 type produced by ABB Zamech Ltd. Co-incineration of coal and biomass proceeds in CFB 260 boilers:

– meat and bone dust
– forest biomass: wood chips of calorific value up to 15 MJ/kg,
– “Agro” biomass - sunflower shells and rape oilseed cakes (fig. 6, 7), hop (fig. 8), post-distillation grain dried material, grain bran, beetroot and fruit pomace (fig. 9), grinding grain (fig. 10),
– liquid “Agro” biomass – glycerin.

Fig. 6. Briquette from sunflower shells

Fig. 7. Rape oilseed cake

Fig. 8. Hop pellet

Sunflower shells have calorific value of 17-19 MJ/kg while rape oilseed cake even up to 20 MJ/kg.

Fig. 9. Pellet from beetroot pomace

Fig. 10. Pellet from grinding grain

Fluidized combustion of biomass occurs when fine particles of suspended matter are blown by the air coming from underneath them. Very good mixture of air and fuel particles is created and the large area of their contact increases the intensity of burning (the temperature may reach even 800°C). Thanks to this fact, during burning of biomass the emissions of nitrogen oxides are significantly reduced in comparison to grid furnaces.

PYROLYSIS AND GASIFICATION

Processing of the given raw material occurs during the following processes: gasification, pyrolysis, granulating, indirect burning, leaching, fermentation, pressing or esterification. In the final process we receive a fuel that can be processed into thermal or electric energy as well as into mechanical work.

The biomass is relatively low carbonificated, has high concentration of organic compounds and low ash content. These characteristic of biomass are the main reasons of its attractiveness as a fuel for gasification. The fact that it is not unequivocally defined when it comes to quality can be viewed as its flaw. The efficiency of gasification process (the relation between the chemical energy of the produced gas and the chemical energy in fuel) for the most simplistic installations oscillates around 20%, but for the more advanced ones reaches even 90% [8].

Utilization of waste biomass from agricultural production and from the food processing industry is an important issue. One of the possibilities is to use it for energy production, even if it is direct burning. Thermal processing of biomass allows to produce energy carriers in the form of liquid or gaseous fuels. This is possible during the pyrolysis and gasification processes. Gasification can be carried out in a few different ways: it can be methane fermentation or gasification for production of generator gas with the use of different gasifying media.

Gasification is a well-known and commonly used technology of processing biomass into gaseous fuels. Gasification consists of a number of thermodynamic processes (exchange of heat and mass and omnidirectional exothermic and endothermic chemical reactions which occur in high temperature) and leads to conversion of solid fuel into gaseous form. Water vapour, air, oxygen or carbon dioxide can act as the gasifying media [13].

Gasification of solid biomass is conducted in a similar way as the gasification of coal. The differences result from higher reactivity of the biomass, higher oxygen content in the structure and lower ash melting temperature [15]. The gasification process can be divided into areas of varying temperature: drying, degasification, pyrolysis and proper gasification that occurs in the combustion and reduction zone. Because the biomass is essentially build of carbon, hydrogen and oxygen, in reality the biomass gasification process produces synthesis gas which contains the following flammable components: hydrogen, carbon monoxide, small quantities of methane and incombustible compounds: mainly carbon dioxide, water vapour and nitrogen [8].

The amount and quality of the synthesis gas from biomass gasification depend mainly on the type of biomass, but also on the gasifying medium, temperature, pressure and method of gasification. In the case when oxygen is the gasifying medium, the hydrogen content in the produced gas exceeds 40% and carbon monoxide content is up to 40%. On the other hand, when water vapour is the gasifying medium, hydrogen content exceeds 50% and carbon monoxide content exceeds 15%.

The high level of biomass humidity is not a problem in the gasification process because of a method called hydrothermal gasification in which the humidity of biomass may reach even 95%. In this technology the biomass is transformed into hydrogen and carbon dioxide with the presence of water of critical parameters. The organic substance of the biomass switches into carbon dioxide and hydrogen comes from both the biomass and from water [8]. The generalised schema of the energy system with biomass gasification has been shown in Figure 11.

Pyrolysis is an independent thermal process or it can constitute as a stage in the gasification process. Pyrolysis can be described as thermal decomposition of the biomass without presence of external oxidizing and reducing media.

Depending on the type of pyrolysis one may receive different solid, liquid or gaseous products. Gaseous energy carriers are used for production of thermal energy and for powering internal combustion engines which in turn power the generators that produce electrical energy (hot fumes are the source of thermal energy). Other technologies of gas purification are in use as well. They lead to an increase in the flammable contents share in the gas of up to 99,9% [8, 4].

THE ADAVANTAGES OF BIOMASS AND BIOGAS

Using waste from the overproduction of food is doubtlessly one of the advantages of producing energy from biomass. This energy is clean and does not lead to creation of any significant environmental pollutants. Let us remind that biomass contains 0,01% of sulphur and after its burning the remained ash has a mass of 1% of the original raw material mass (in comparison - hard coal has between 0,5 and 5% of sulphur and leaves between 10 and 15% of ash). Emission of nitrogen compounds is also seriously reduced because of significant lowering of combustion temperature. The greatest reduction of emission occurs during balancing the carbon dioxide emissions which are responsible for the greenhouse effect. CO_2 emission during burning is equal to the concentration of CO_2 produced during the natural decay of biomass [4].

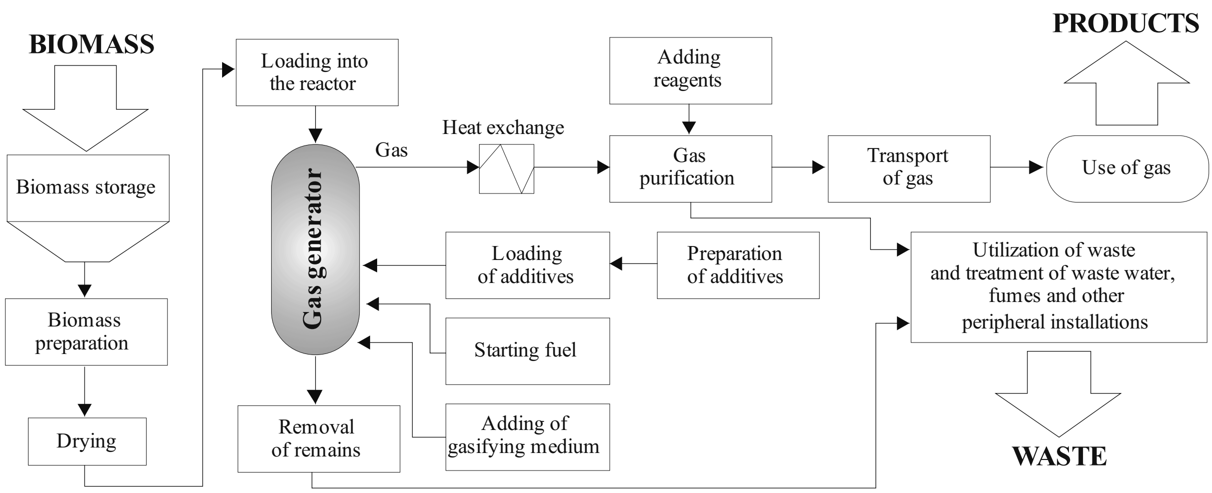

Fig. 11. Energy system of integrated biomass gasification [Piechocki 2010, changed]

The development of alternative energy technologies provides energy safety to the country because of diversification of energy producers' offer. The energy production is decentralized and does not require construction of power lines (there are no transmission-related losses). In comparison to the energy produced using conventional methods it supports economical water management. Production costs of energy from biomass are comparable to the costs of producing electricity from the power grid. Moving further, it should be pointed out that in the poor and developing countries it allows to improve the hygiene and health conditions through cessation of spilling fecal matter directly onto the fields (Chinese and Indian provinces) what has once been a cause of dangerous diseases epidemics.

There are not many flaws of this kind of energy production but they are significant. The calorific value of biomass is two times lower than that of hard coal. Biomass processing installations are capital-intensive investments (large investment costs during the construction phase). Furthermore, it is necessary to strictly follow the fermentation regimes (temperature, acidity, hermetic conditions during the processes). The biomass is usually highly moist which causes problems during its transport and storage. Bio-fuels production requires higher capital expenditures in comparison to the fuels produced during oil processing. Additionally, there are no tax exemptions for the producers of energy from biomass.

CONCLUSIONS

Production of energy from conventional sources causes significant damage to the environment. The reserves of fossil fuels are reduced every year and the energy becomes more expensive. The development of alternative energy sources opens a chance for an increase in the country's energy independence, for regional development and creating new jobs. It allows for pro-ecological modernization of the energy systems. For example, the cultivation of energetic willow can be a profitable and interesting area of agricultural development.

The biomass can come from diversified sources: there are special energy plants cultivations and wastes from plant products production and processing.

A lot of attention is paid to the environmental factors when considering energy production. During burning of biomass one may derive from additional benefits, like significant reductions of detrimental substances emissions. Biomass is a cheap, ecological and clean energy source. Looking for alternative sources of energy is also compatible with the sustainable development principles.

REFERENCES

1. **Bowszys T., Sądej W., Wierzbowska J., 2007:** Use of agricultural and communal waste products in fertilization of oilseed rape grown for biofuel. TEKA Komisji Motoryzacji i Energetyki Rolnictwa PAN, vol. VIIA, p. 43-50.
2. **Jakubiak M., Kordylewski W., 2008:** Pelety podstawowym biopaliwem dla energetyki. Archiwum Spalania, vol. 8, nr 3-4.
3. **Kalina J., 2004:** Zgazowanie paliw stałych. Gospodarka Paliwami i Energią, nr 15.
4. **Kaszak M., 2006:** Efektywność energetyczna produkcji nośników energii z biomasy. Praca inż. ATR WM, MiBM.
5. **Kowalik P., 1997:** Światowe tendencje w wykorzystaniu biomasy do produkcji ciepła, elektryczności i paliw samochodowych. Gospodarka paliwami i energią 1/1997.
6. **Kowalska A., 2008:** Overviev of technological methods of energy production from biomass. TEKA Komisji Motoryzacji i Energetyki Rolnictwa PAN, vol. X, p. 209-215.
7. **Kulig R., 2007:** Effects of conditioning methods on energy consumption during pelleting. TEKA Komisji Motoryzacji i Energetyki Rolnictwa PAN, vol. VIIA, p. 59-67.
8. **Piechocki J., Sołowiej P., Neugebauer M., 2010:** Gazyfikacja biomasy odpadowej z produkcji rolniczej. Inżynieria Rolnicza 5 (123).
9. **Sobczyk W., 2007:** Plonowanie wierzby wiciowej - w świetle badań. Polityka Energetyczna, tom 10, zeszyt specjalny 2, Kraków, p. 547-556.
10. **Sobczyk W., 2008:** Wykorzystanie alternatywnych źródeł energii w Zawoi Przysłopie (Małopolska). Folia Scientiarum Universitatis Technicae Resoviensis nr 229, Budownictwo i inżynieria środowiska, z. 47, p. 457-463.
11. **Sobczyk W., 2011:** Evaluation of harvest of energetic basket willow. TEKA Komisji Motoryzacji i Energetyki Rolnictwa PAN, vol. XI, p. 343-352.
12. **Soliński I., 2001:** Biomasa energia odnawialna. Biblioteka Szkoły Eksploatacji Podziemnej. Seria z lampką górniczą nr 9, Kraków.
13. **Tymiński J., 1997:** Wykorzystanie odnawialnych źródeł energii w Polsce do 2030 roku - aspekt energetyczny i ekologiczny. IBMER, Warszawa.
14. **Wach E., 2009:** Poradnik użytkownika pelet drzewnych. Projekt Komisji Europejskiej - Pellets@las. FORCE Technology.
15. **Warowny W., Kwiecień K., 2006:** Paliwa z biomasy i ich wykorzystanie. Przemysł Chemiczny nr 12.
16. **Zaród J. 2006:** Racjonalne zagospodarowanie odłogów i nieużytków w województwie zachodniopomorskim, w: Adamowicz (red.): Zrównoważony i trwały rozwój wsi i rolnictwa. Wyd. SGGW, Warszawa.

TECHNIKI POZYSKIWANIA ENERGII Z BIOMASY

S t r e s z c z e n i e. W pracy opisano źródła biomasy oraz techniki pozyskiwania energii ze spalania biomasy: spalanie konwencjonalne, fluidalne spalanie, pirolizę i gazyfikację. Obróbka termiczna biomasy odpadowej z produkcji rolniczej i przetwórstwa spożywczego pozwala otrzymać nośniki energetyczne w postaci paliw płynnych lub gazowych. Rozwój alternatywnych źródeł energii stwarza szansę na utrzymanie niezależności energetycznej. Jest także zgodny z ideą ekorozwoju.

S ł o w a k l u c z o w e: energia alternatywna, rośliny energetyczne, biomasa, drewno, słoma, spalanie fluidalne.