

Biomass - alternative renewable energy source to the fossil fuels

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Abstract. The article presents the fossil fuels combustion effects in terms of the dangers of increasing CO₂ concentration in the atmosphere. Based on the bibliography review the negative impact of increased carbon dioxide concentration on the human population is shown in the area of the external environment, particularly in terms of the air pollution and especially the impact on human health. The paper presents biomass as the renewable energy alternative source to fossil fuels which combustion gives a neutral CO₂ emissions and therefore should be the main carrier of primary energy in Poland. The paper presents the combustion heat results and humidity of selected dry wood pellets (pellets straw, energy-crop willow pellets, sawdust pellets), dried sewage sludge from two sewage treatment plants of the Holly Cross province pointing their energy potential. In connection with the results analysis of these studies the standard requirements were discussed (EN 14918:2010 "Solid bio-fuels-determination of calorific value") regarding the basic parameters determining the biomass energy value (combustion heat, humidity).

1 Introduction

As a result of human activity we can observe rapid climate changes which are particularly evident in the increase of the greenhouse gases concentration (carbon dioxide, methane and nitrous oxide) in the atmospheric air. The anthropogenic greenhouse gas emissions are caused by economic activities especially the fossil fuels burning such as coal, oil and natural gas.[4] The carbon dioxide concentration increased for the last 200 years since the beginning of the industrial revolution when the CO₂ concentration reached 280ppm and in 1958 it reached a value of 316ppm. In May of 2013 CO₂ concentration for the first time exceeded 400 ppm, in March 2016 exceeded 405ppm (Fig.1) in the graphs rapid and continual increase in the this gas concentration is shown.

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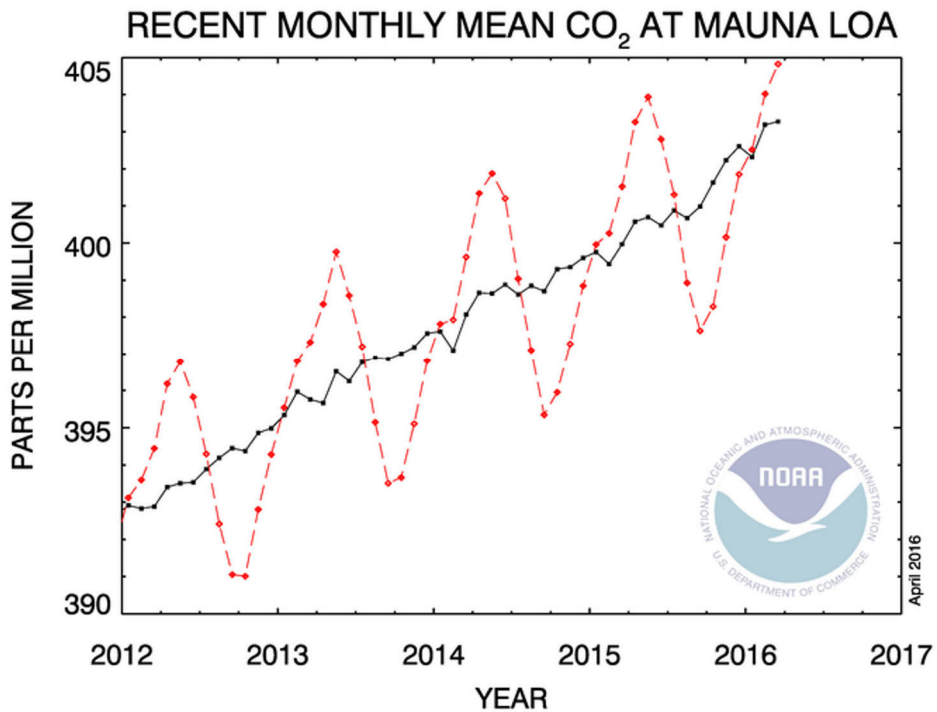
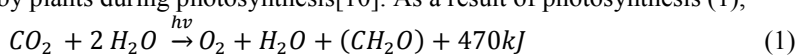


Fig. 1. The carbon dioxide concentration measured at Mauna Loa observatory in Hawaii. Source: Earth System Research Laboratory, Global Monitoring Division (<http://esrl.noaa.gov/gmd/ccgg/trends>).

The climate change effects observed in all natural systems, among other hydrological systems (melting snow, glaciers), which cause changes in water resources in terms of quality and quantity as well as land-based systems, eg. change in the species geographical ranges [1]. The negative climate change effects also have an impact on the human population by the presence of extreme weather conditions (high temperatures - drought, heavy rain - floods, hurricanes and fires) which also affect crops, residential and public buildings.[8] Increasing the carbon dioxide concentration results in an increased number of fungi spores (*Alternaria* spp., *Cladosporium* spp., *Penicillium* spp., *Aspergillus* spp., etc.), soil bacteria and pollen (*Birch*, *Clone*, *Tilia*, etc.) in the atmospheric air which cause allergies, respiratory diseases in the human population[3,4,5,9]. With the increase of carbon dioxide concentration in the atmospheric air the gas concentration in indoor air also increases[16].

The carbon dioxide high concentrations cause fatigue, headaches, dizziness, disorientation, breathlessness to the humans and in combination with carbon monoxide coming for example from fireplaces or cigarette smoke, through accumulation of the harmful effects of the last gas may in a longer term result in health deterioration. Above symptoms are the same as the symptoms of Sick Building Syndrome (SBS)[1,2,5].

In order to stop advancing climate change, in particular increase the concentration of carbon dioxide in the air in the working biomass is proposed as an alternative fossil fuels[6,13,14]. Biomass can be an essential alternative to fossil fuels due to the zero carbon dioxide emission because during the combustion - CO₂ emissions to the atmosphere is the same as the amount of CO₂ absorbed by plants during photosynthesis[10]. As a result of photosynthesis (1),



and specifically carbohydrate synthesis of 1 carbon dioxide mole accumulates chemical energy of 470kJ. During the year on the earth the biomass amount produced by photosynthesis can be 220bln tones of dry weight. Therefore the energy contained in the biomass can be a significant contribution as a renewable energy source[12].

2 The definition of biomass

Directive 2001/77/EC, of the European Parliament and the Council from 27th September 2001 on the promotion of the internal market for electricity produced from renewable energy sources has introduced a biomass definition[23].

In its meaning biomass is "the biodegradable fraction of products, waste and residues from agriculture (including plant and animal substances), forestry and related industries as well as the biodegradable fraction of industrial and municipal waste"[22-27].

On the basis of the above mentioned Directive in 2005, its interpretation of the biomass definition was also introduced by the Ministry of Economic Regulation on 19th December 2005 on detailed duties scope to obtain and submit to the origin certificates redemption, the substitute fee and purchase of electricity and heat from renewable sources energy[27]. The Regulation defines biomass as "solid or liquid plant or animal origin, which are biodegradable, derived from products, waste and residues from agriculture and forestry, and related industries, as well as parts of other wastes that are biodegradable".

Solid bio-fuels, which include biomass, have been subjected to classification by the European Committee for Standardization CN/TC335[24], and are divided into:

- products from agriculture and forestry,
- plant waste from agriculture and forestry,
- plant waste from food processing industry,
- wooden waste with the exception of wood waste which may contain halogenated compounds or heavy metals, which are a result of wood treatment and waste from construction and demolition sites.

3 Methodology of experimental studies of selected biomass pellets and dried sewage sludge

3.1. Materials and research methods

The research material: willow pellets, sawdust pellets, straw pellets, sewage sludge (Sewage sludge "S" from the sewage treatment plants in Sitkówka-Nowiny (S), subjected to the anaerobic stabilization, dewatered and dried in disk. The nominal capacity of the plant is 72 000 m³/d at load of 275 000 RLM. Sewage sludge "Ł" from the sewage treatment plants in Olsztyn, subjected to the anaerobic stabilization, dewatered and dried in disk. The nominal capacity of the plant is 34 767 m³/d at load of 350 000 RLM).

Research material in the form of pellets was grinded and then separated into fractions with dimensions of 0.5mm, 0.25mm, 0.125mm <0.125mm. The dried sludge was fractioned with a diameter of 0.2 mm[17-21].

Determination of moisture content, ash, and the heat of combustion were carried out on three representative samples of all pellet fraction with a molecular diameter 1g.

When testing the moisture content of the sample in a closed crucible was dried at 105°C for 30 minutes. Drying was repeated until the difference in weight between weighing does not exceed 0.5% of absolute. Samples were weighed with the accuracy 0.0001g.

Prior to the ash content determination the samples were dried to constant weight at 105°C for 30 minutes in closed crucibles. Examination of ash content was carried out at a temperature of 815°C. Samples were weighed with the accuracy 0.0001g.

3.1.1 Measuring the combustion heat of selected biofuels

Applied Technologies: calorimeter KL-12Mn, decomposition vessel (bomb), bottle with pure oxygen, PC, analytical scale, knife grinder for Biomass LMN 100, bio-fuels hydrometer BIO-1, vibrating shaker.

The methodology of research in the field of combustion heat is based on the PN-EN 14918:2010 "Solid bio-fuels - Determination of calorific value"[17], which specifies a method for solid fuel calorific calculations at a constant volume and at 25°C in a calorimeter bomb.

The heat of combustion is the amount of heat, which separates the complete combustion of the fuel mass units, when the combustion process is carried out at constant volume in an atmosphere of gaseous oxygen under the assumption that the temperature of the fuel prior to combustion temperature of the combustion products is 20°C, the products combustion CO₂ and SO₂ are in the gaseous state has not oxidized nitrogen and water content of the fuel by burning and formed during combustion due to oxidation of hydrogen is in the liquid.

The solid bio-fuels combustion heat studies were calculated on the basis of calorimetric research, according to the formula:

$$Q = K (T_3 - T_2 - k) \left[\frac{J}{g} \right] \quad (2)$$

where:

Q - The heat of combustion of fuel samples [J/g]

K - Calorimeter constant

T_2, T_3 – temperature characteristic of the balance sheet

k - correction for heat exchange with the environment calorimeter

where:

$$k = 0,5 [0,2 (T_2 - T_1) + 0,2 (T_4 - T_3)] + 0,2 (n - 1) (T_4 - T_3) \quad (3)$$

where:

n - number of minutes in cycle 2

T_1, T_4 – temperature characteristic of the balance sheet

The work of the calorimeter is divided into 5 cycles:

0 - the inclusion of the calorimeter and stabilize the temperature inside the calorimeter (cycle time is approx. 2 minutes).

1- recording the temperature T_1 and measure a time interval equal to 5 minutes.

2 - recording the temperature T_2 and the ignition of the fuel sample in a bomb calorimeter, this cycle continues until reaching its maximum temperature.

3 - registration T_3 (maximum) and the measurement of the next section of time equal to 5 minutes.

4 - registration of temperature T_4 and finish the job

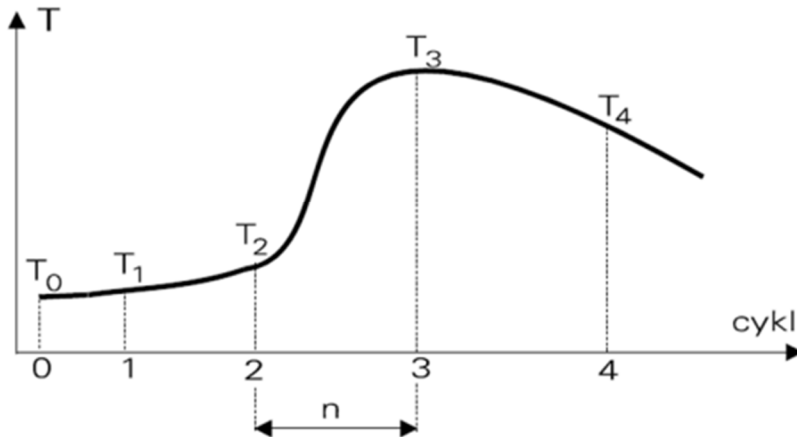


Fig. 2. Changes in temperature measurement cycle in the calorimeter.

The heat of combustion is called the upper calorific value, since it corresponds to the total heat produced from the fuel. The calorific value is a measure of the amount of heat obtained by combustion of unit of mass (or volume) of fuel.

The calorific value of organic substances containing carbon, hydrogen, sulfur and oxygen is described by the following empirical equation:

$$W_u = 33900C + 121000 \left(H_2 + \frac{O_2}{8} \right) + 10500S - 2500 \left(W + \frac{9}{8} O_2 \right) \left[\frac{kJ}{kg} \right]$$

where: C , H_2 , O_2 , S are mass participation of these elements, respectively W is contents of water (humidity of material).

3.1.2. Measuring the moisture content of selected biofuels

Applied Technologies: analytical scale, laboratory oven.

The research method in determining the moisture content in the tested specimens prepared on the basis of PN-EN ISO 18134-1:2015-11, "Solid Bio-fuels - Determination of Moisture Content - Drier method - part 1: Total Moisture - Reference Method"[20]. Test methods described in this International Standards applies to all solid bio-fuels. The moisture content of solid bio-fuels (in the operating state) is always given in relation to the total weight of the test specimen (wet state).

Moisture content (W^a) of biomass in the test sample is calculated by the formula:

$$W^a = \frac{m_2 - m_3}{m_2 - m_1} 100\% \quad (4)$$

where:

m_1 - is the mass of the empty drying container, in g;

m_2 - is the mass of the drying container and test portion before drying, in g;

m_3 - is the mass of the drying container and test portion after drying (weigh when still hot), in g;

3.1.3. The measurement of the ash content in selected biofuels

Applied Technologies: muffle furnace, analytical scale

Research methodology for the ash content determination in the tested specimens was calculated on standards: PN-ISO 1171:2002, PN-EN ISO 18122:2016-01 Solid bio-fuels - Determination of Ash Content[18,19].

The ash content was calculated from the formula:

$$A = \frac{m_3 - m_1}{m_2 - m_1} \times 100 \quad (5)$$

where:

m_1 - is the mass of the empty drying container, in g;

m_2 - is the mass of the dish plus the test sample, in g;

m_3 - is the mass of the dish plus ash, in g;

4 Test results and discussion

The combustion heat, ash and moisture content form the basis for the solid fuels technical evaluation in terms of their suitability for energy purposes. For each tested pellets fraction moisture was examined, combustion heat and ash. The combustion heat, moisture and ash content test results in the tested specimens are shown in Table 1 and figure 3,4.

The ash content results is expressed as the average weight of two measurements with an accuracy of 0.1%. The results from two tested specimens calorific determinations did not differ among themselves more than 120 J/g, the result is given as the average arithmetic number of the determinations.

Table 1. Results of combustion heat, calorific value and ash investigated pellets

The research material	Fractions	Moisture [%]	Combustion heat [MJ/kg]	Calorific value [MJ/kg]	Ashes A [%]
Willow pellet	0.5 mm	6.13	21	20	0.7
	0.25mm	6.09	22	21	0.9
	0.125 mm	6.20	23	23	1.1
	< 0.125 mm	6.48	22	21	1.5
Gray straw pellet	0.5mm	7.00	22	21	0.5
	0.25mm	7.23	23	22	0.7
	0.125mm	6.85	22	21	1.0
	< 0.125mm	6.44	23	22	1.4
Sawdust pellet	0.5 mm	6.41	22	21	0.6
	0.25mm	6.32	22	21	0.8
	0.125 mm	6.20	22	21	1.3
	< 0.125 mm	6.70	23	22	1.6

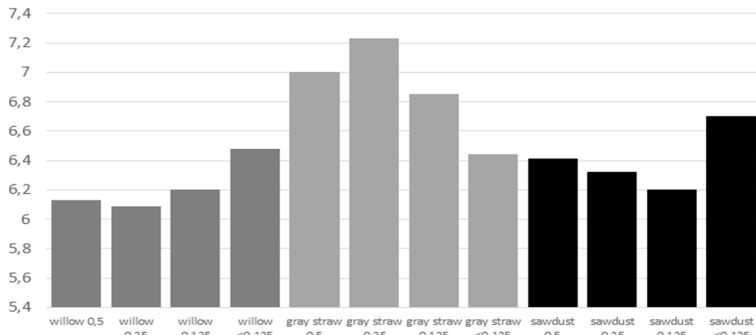


Fig. 3. Moisture particular types of pellets with the division into factions

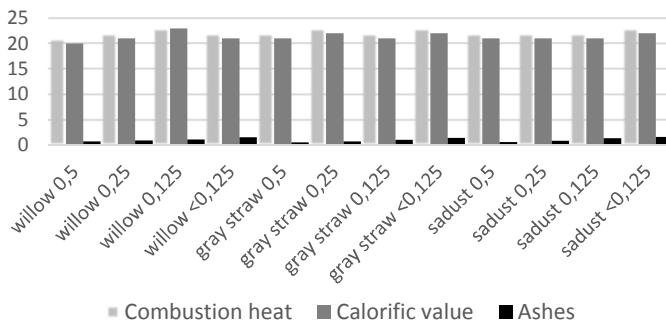


Fig. 4. Comparison of combustion heat, calorific value and ash content of pellets investigated.

The literature data and results indicate that the lower the humidity the higher the energy (eg. Gray straw fraction <0.125)[7,11]. The results (table 1, figure 4) indicates that the analyzed pellets willow, straw, sawdust has a very low ash content, compared to the sludge or coal if the ash content may be approx. 22%. Compared to the available technical data of coal and lignite, whose calorific value is in the range 24-31 MJ/kg, the results of the tested pellets of solid biomass essentially do not differ. Indicate that it could have the potential to replace fossil fuels, renewable energy source which is biomass.

The ash content in the analyzed fuels increased with decreasing fraction used to study the material. Smaller fractions of biomass have a higher content of mineral substance in the composition.

The lack of correlation between the diameter of the fraction of the pellets tested and the result of the heat of combustion.

Table 2. Results moisture combustion heat, calorific value and ash investigated sewage sludge

The research material	Fractions	Moisture [%]	Combustion heat [MJ/kg]	Calorific value [MJ/kg]	Ashes A [%]
Sewage sludge „S”	0,2 mm	7,98	18	17	65,7
Sewage sludge „L”	0,2 mm	9,43	17	16	67,1

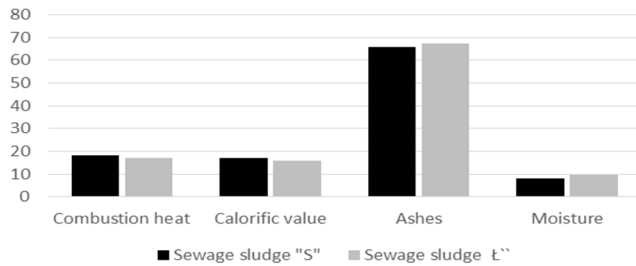


Fig. 5. Comparison moisture combustion heat, calorific value and ash content of the dried sewage sludge from two sewage.

Sewage sludge is also a "clean" biomass in terms of CO₂ emissions during the combustion. However, in the sewage sludge case there is a problem with the ash content and this problem is also reflected in research methodology (PN-EN 14918:2010)[17] of combustion heat, which assumes the performance correctness of the complete specimen combustion in a calorimeter bomb[15]. In the case of sewage sludge as well as some plants species it is not possible to achieve complete combustion in a calorimeter bomb, for the sludge specimen of "L" from 1 specimen gram the residue was 0,7094g, in the case of sewage sludge "S" 0.6995g. Residues weight after combustion is similar to the ash content in the specimen. Therefore, the research methodology work should taken which will include all types of biomass.

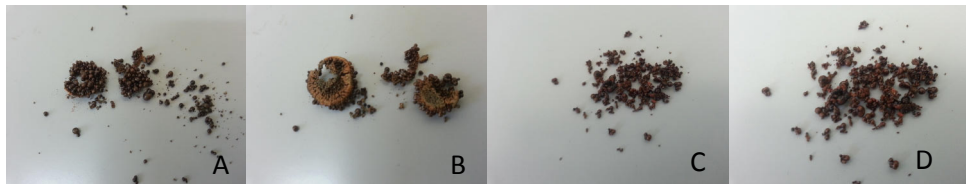


Fig. 6. Picture of the residues after combustion of 1 g tested specimen of the sewage sludge 'L' (pic. A,B) and 'S' (pic. C,D).

5 Conclusion

1. The intensive growth of emissions from the fossil fuels combustion caused air quality deterioration as well as the indoor air deterioration. Fossil fuels replacement with biomass can be of fundamental importance for the protection of public health.
2. Continuous increase in the carbon dioxide concentration increases the temperature of our planet resulting in long-lasting period the heat waves, increased the air pollution in terms of microbial contamination, fires, droughts and floods - all of these climate changes have a major impact on the human population health.
3. The results of the research will be the basis to develop their own research methods in the humidity, the heat of combustion and ashes.
3. The research on the research methodology development should be continued especially on the combustion heat of all biomass types.

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