BIOENERGY AND OTHER RENEWABLE ENERGY TECHNOLOGIES AND SYSTEMS

No. 1/2014

Polish Society of Agricultural Engineering
Kraków 2014

UNIVERSITY OF AGRICULTURE IN KRAKÓW
FACULTY OF PRODUCTION AND POWER ENGINEERING

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Auspices: Agricultural Technology Committee of the Polish Academy of Sciences

Publisher: Polish Society of Agricultural Engineering

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ISSN 2391-9140

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A NEW TOOL FOR SUSTAINABLE AGRICULTURE AND AGRICULTURAL PROBLEMS FACED TODAY

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Abstract: This paper introduces a revolutionary tool for sustainable agriculture which will not only combat agricultural challenges of today but will also increase the supply and quality of the produce within a sustainable framework. The world agricultural system is suffering from many problems today including climate change, soil degradation, the increase in diseases and pests, decreases in yield and quality etc. and these problems call for urgent sustainable solutions. One solution we believe that is vital for the agriculture sector is our fully organic fertilizer Bionur™ Microbial, a mixture of a complex bio-product which is composed of regenerative bacteria, algae, fungi, yeast, actinomisets and various beneficial minerals, vitamins, essential amino-acids and Fulvic acid. The principle of Bionur™ Microbial is to use micro-organisms to achieve macro solutions. The main agents of Bionur™ Microbial are the miraculous *Thiobacillus* bacteria which are the very ancestors of life have several remarkable functions such as degrading the nutrients in the soil and making them available for the plant to fully take in, fixing the nitrogen in the air to the plant, destroying heavy metals, harmful bacteria and fungi. They are the main reason Bionur™ Microbial serves as a soil regulator and rehabilitee, an anti-salinization agent, an anti-stress of heat and cold, a multi-nutrient source, which combats diseases and pests, and increase the supply and quality of the produce. In this paper we shall demonstrate how Bionur™ Microbial is an all in one solution by explaining how it works, providing a microbiological analysis of its contents and finally presenting its qualities and effects by referring to several studies and applications of it. The aim of this paper is to bring this product to the attention of the scientific community.

Key words: Regenerative microorganisms, Bionur™ Microbial, sustainable agriculture, fully organic fertilizer, anti-salinization agent, soil regulator, plant anti freeze, Fulvic acid, chelating effect, protection against diseases and pests, microbial fertilizer, bio-control agent

Introduction

According to a UN press release in March 2009 the worlds' population is to exceed 9 billion in 2050 (UN Population Division/DESA). A 2011 special report published in the Economist called Feeding the World states that the FAO estimates that the demand for food will increase by 70% with the growing population in the next 45 years and that production needs to increase accordingly. The FAO believe that it should be easier to produce enough food to satisfy the demand and many scholars, researchers and scientists assert that sustainable agriculture holds the key to feeding the world, as agriculture provides 90% of the world's caloric intake (UNEP). The article in the economist states that "it won't be that easy today" to increase food production through agriculture, as growth in agricultural yield has been slowing down due to poor farming methods, the over exploitation of the environment, the use of chemicals and pesticides, the degradation of arable soil etc.[1]. The reasons of many of these anthropogenic problems are rooted in the previous century.

It's common knowledge that at the turn of the 20th century people began to use agrochemicals and chemical fertilizers to increase yield and a significantly increased yield was indeed achieved especially during the production boom in the second half of the 20th century. Conventional agriculture which dominates developed countries and focuses on the provision of commercial commodities aimed at producing as much as possible as fast as possible and as cheaply as possible. As a result natural processes were replaced by practices which involve external inputs such as agrochemicals and fertilizers. However these chemicals and fertilizers used have severely degraded the quality of arable land, as the continuous use of them has disrupted the natural balance of the soil, destroyed the beneficial microorganisms in the soil and rendered the soil non arable. Furthermore salinization and calcification began in the soil and the fertility of the soil has severely diminished. One could say that a vicious cycle began in which the soil was pumped with chemical fertilizers to increase yield, however as the chemicals began to decrease the fertility of the soil and then even more chemical fertilizers were used to increase yield yet again resulting in the soil becoming increasingly polluted. The cause of this pollution was that the chemical fertilizers could not entirely be taken in by plants and the residue along with irrigation would lead to bedding in the soil. Another disadvantage of the usage of chemical fertilizers is that it leads to the increase of diseases and the increase in variety of diseases, as chemical fertilizers disrupt the natural balance of the soil and destroy the beneficial living organisms in it. The chemical pesticides which were used to get rid of these bacterial and fungal diseases and poisonous detrimental tocsins polluted the soil even more. The result of all this has been polluting the environment, disrupting the agricultural production system, low yield and low quality unhealthy products and the residue problem which is detrimental for human health and may even lead to life threatening diseases such as cancer.

The UN, the FAO and the agricultural ministers of various developed countries have decided to reduce the use of chemical fertilizers for sustainable agriculture and have put into force certain regulations to ensure it. Furthermore it has been decided that close to 200 chemical pesticides which are detrimental for human health, will be banned and it has been decided that they will be pulled out of the market within 2 years. This may sound like good news however due to these decisions the fight against diseases and pests will become even more of a challenge and production levels of farmers will drop. This is a major issue, as an increase in food production is needed to feed the growing population. It is for this reason that innovative biological products, sustainable resources and methods are needed. It is worth mentioning that this process has begun long ago as the Green Revolution, which combined biological (chiefly genetic) improvements with the application of non-biological inputs (chemical fertilizers, agrochemicals, and irrigation water), made impressive contributions to food production over the past three decades [2].

As a solution to the problems we have listed, bio solutions which will not harm human health or the environment are at the top of the list. The worlds' preponderant corporations and research centers have begun to work on solutions. One solution however already exists, Bionur™ Microbial is a bio-controlling agent developed using biological methods, which combats diseases and pests, increases the supply and quality of the produce, rehabilitates the soil, provides anti-stress against heat and cold, enhances the plants fertilizer intake and does not have any side effects against diseases.

What is Bionur™ Microbial?

BIONUR™ Microbial is an organic microbial degradable liquid all-in-one fertilizer produced by Ihsan Organic inc. based in Isparta Turkey. Naturally sourced from a mineral-rich environment it is a totally unique soil conditioner and an unparalleled fertilizer. Numerous naturally-occurring effective micro-organisms in Bionur™ Microbial help restore a rich mineral supply and nourishing energy to topsoil, rebalancing the soil's nutritive content and ensuring a sustainable agricultural and living environment in both the short term and the long term. Bionur™ Microbial contains over 80 naturally occurring minerals, including all the essential elements for healthy plant growth. It increases soil fertility and crop yield by rectifying abnormal or insufficient plant growth and development caused by mineral deficiencies in the soil.

Bionur™ Microbial also contains vital amino acids which determine healthier plant growth throughout all stages of development, boosting photosynthesis and metabolism, and protecting plants from damage caused by extreme weather and stress conditions. The humic acid and fulvic acid in Bionur™ Microbial raise microbial levels in the root area for a more efficient uptake of nutritive elements. Bionur™ Microbial is also enriched by the bacteria *Thiobacillus thiooxidans* and *Thiobacillus ferrooxidans* which strengthen the plant's immune system against parasites, mildew, soil pathogens and cold temperatures. They enable plants to recover from damage more quickly.The first life on earth began in the water with photosynthesis bacteria which were responsible for synthesizing enzymes, protein, amino-acids, hormones, and vitamins. They are also capable of converting solar energy into bio-energy. They were very active in forming coal, petroleum and other bio-energy sources and after the time petroleum had formed they went into a deep sleep within carbon molecules. Now we have awoken them and after various field experiments and studies we observed that these bacteria are a solution to multiple problems and possess many valuable qualities such as enabling the plant to take in the Nitrogen (N) in the air, enabling the plant to fully take in the necessary elements (including the elements which plants can't take in due to the elements bonding such as nitrogen Nitrogen (N), Phosphorus (P), Potassium (K) in the soil by dissolving them using a leaching process, eradicating heavy metals, detrimental fungi and bacteria by entering the harmful cells membrane and changing its chromosomes rendering it harmless.

Numerous beneficial organisms help develop and restore abundant soil micro-flora for a well-balanced eco-system, while also suppressing harmful microbes that cause soil diseases. An outstanding quality of Bionur™ Microbial is its rich microbial content. When applied to soil, the beneficial bacteria in Bionur™ Microbial break down mineral elements into sufficiently small particles to be easily taken up by roots. Plants can then make efficient use of these nutrients for healthy growth and development; the rich supply of amino acids stimulates vigorous plant growth and metabolism.

Humic acid, Fulvic acid and *Thiobacillus* bacteria together ensure better plant development and optimum disease resistance through all stages from germination to harvest. They promote cell membrane permeability for efficient nutrient intake, stimulate cell division, enable strong root systems and increase stress resistance and water retention capacity in dry and wet conditions.

List of Contents

- 16 basic elements which are necessary for soil renewal and nutrition e.g. nitrogen, Phosphorus, Potassium, Iron, Copper, Zinc, Manganese, Calcium, Magnesium etc.
- Nearly all of the minerals in the soil (over 80)
- Regenerative micro-organisms
- Amino-acids
  Algae
  Yeast
  Fungi
  Fulvic acid
- Vitamins (B12, D3, folic acid)
- Actinomycetes
  Enzymes (SOD: Superoxide dismutase)
- pH: 2.2 and EC: 6-8 mS/cm

Table 1
Organic Complex BIONUR™ Microbial Microbiological Analyses

Group	***Microorganism***	***Type***	***Species***	***Strain***
PHOTOSYNTHETIC BACTERIA				
Oxidizes Fe,	Bacteria	*Thiobacillus ferreoxidan*		
Oxidizes S ,	Bacteria	*Thiobacillus thiooxidan*		
N fixation, Denitrification	Bacteria	*Thiobacillus thioparus*		
N fixation, Poly-saccharide	Bacteria	*Arthrobacter*	*Viscosus*	
P solubiliser, N	Bacteria	*Bacillus*	*Megaterium*	*subgroup A*

<table>
<tr><td>fixation, Denitrification</td><td>Bacteria</td><td>Bacillus</td><td>Megaterium</td><td>subgroup B</td></tr>
<tr><td>P, K solubiliser</td><td>Bacteria</td><td>Brevibacillus</td><td>Choshinensis</td><td></td></tr>
<tr><td rowspan="3">Smell, Aroma, Shelf life</td><td>Bacteria</td><td>Deinococcus</td><td>Erythromyxa</td><td></td></tr>
<tr><td>Bacteria</td><td>Micrococcus</td><td>Luteus</td><td>subgroup C</td></tr>
<tr><td>Bacteria</td><td>Micrococcus</td><td>Lylae</td><td>subgroup A</td></tr>
<tr><td>N fixation</td><td>Bacteria</td><td>Psychrobacter</td><td>Phenylpyruvicus</td><td></td></tr>
<tr><td colspan="5">The photosynthetic or phototrophic bacteria are a group of independent, self-supporting organisms. These bacteria synthesize beneficial substances from secretions of roots, organic matter and / or harmful gases (hydrogen sulphide), by using sunlight and the heat of the soil as an energy source. The beneficial substances developed by these organisms include amino acids, nucleic acid, bioactive substances and sugar, all of which promote plant growth and development. The metabolites developed by these microorganisms are absorbed directly by the plants and act as substrates for increasing beneficial microbial populations. For example, Vesicular Arbuscular (VA) mycorrhizae in the rhizosphere are increased due to the availability of nitrogenous compounds (amino acid) which are secreted by the phototrophic bacteria. The VA mycorrhizae in turn enhance the solubility of phosphates in soils, thereby supplying unavailable phosphorus to plants. VA mycorrhizae can also coexist with Azotobacter and Rhizobium, thereby increasing the capacity of plants to fix atmospheric N.</td></tr>
<tr><td colspan="5">ALGAE</td></tr>
<tr><td colspan="5">Algae are early colonizers of newly exposed material in damp conditions such as paddy fields and the very widespread shallow pools in the Arctic. When in sufficient numbers they help to form a crust at the soil surface thereby preventing soil erosion. They are considered as early initiators of the carbon and nitrogen cycle.</td></tr>
<tr><td colspan="5">LACTIC ACID BACTERIA</td></tr>
<tr><td></td><td>Bacteria</td><td>Lactobacillus acidophilus</td><td></td><td></td></tr>
<tr><td colspan="5">Lactic acid bacteria produce lactic acid from sugars and other carbohydrates, developed by photosynthetic bacteria and yeast. Lactic acid is a strong sterilizing compound and suppresses harmful microorganisms and enhances the decomposition of organic matter. Moreover, Lactic acid bacteria promote the fermentation and decomposition of materials such as lignin and cellulose, thereby removing the undesirable effects of organic matter which hasn’t been decomposed. Lactic acid bacteria have the ability to suppress disease-inducing microorganisms such as Fusarium, which occur in continuous cropping programmes. Under normal circumstances, species such as Fusarium weaken crops, thereby exposing them to diseases and increased pest population such as nematodes. The use of lactic acid bacteria reduces nematode populations and controls the propagation and spread of Fusarium, thereby inducing a better environment for crop growth.</td></tr>
<tr><td colspan="5">FUNGUS</td></tr>
<tr><td rowspan="2"></td><td>Fungus</td><td>Aspergillus</td><td>Flavus</td><td></td></tr>
<tr><td>Fungus</td><td>Penicillum</td><td>sp</td><td></td></tr>
<tr><td colspan="5">They are natural antibiotics which protect plants against diseases and kill dangerous bacteria and microorganisms.</td></tr>
<tr><td colspan="5">YEAST (SACCHAROMYCES)</td></tr>
<tr><td rowspan="5"></td><td>Yeast</td><td>Candida</td><td>Fructus</td><td></td></tr>
<tr><td>Yeast</td><td>Candida</td><td>lambica</td><td></td></tr>
<tr><td>Yeast</td><td>Candida</td><td>lusitaniae</td><td></td></tr>
<tr><td>Yeast</td><td>Candida</td><td>maritima</td><td></td></tr>
<tr><td>Yeast</td><td>Candida</td><td>philyla</td><td></td></tr>
</table>

	Yeast	*Candida*	*sake*	
	Yeast	*Candida*	*tropicalis*	
	Yeast	*Candida*	*valida*	
	Yeast	*Candida*	*zeylanoides*	
	Yeast	*Cryptococcus*	*albidus*	*var. Albidus*
	Yeast	*Cryptococcus*	*neoformans*	*subgroup B*
	Yeast	*Dekkera*	*custersiana*	
	Yeast	*Kluyveromyces*	*marxianus*	*var. Lactis*
	Yeast	*Rhodotorula*	*rubra*	
	Yeast	*Trichosporon*	*beigelii*	*subgroup A*
Yeast synthesizes ant microbial and other useful substances required for plant growth from amino acids and sugars secreted by photosynthetic bacteria, organic matter and plant roots. The bioactive substances such as hormones and enzymes produced by yeast promote active cell and root division. These secretions are also useful substrates for Effective Microorganisms such as Lactic acid bacteria and Actinomycetes.				
ACTINOMYCETES: *(Actinomyces Bovis st I, Actinomyces D0I,* and following)				
	Actinomycetes	*Zygosaccharomyces*	*Bailii*	
	Actinomycetes	*Zygosaccharomyces*	*Bisporus*	
	Actinomycetes	*Zygosaccharomyces*	*Rouxii*	
Actinomycetes are second in abundance to bacteria preferring dry warm grassland and neutral conditions. There are a large number of genera of which the Streptomycetes are dominant. They have a characteristic musty odor and produce antibiotics and enzymes that kill bacteria and other microorganisms. They are very important as decomposers of organic matter particularly polysaccharides and chitin.				

List of Effects and Qualities of Bionur™ Microbial

Speeds up the intake of all fertilizers used
Speeds up plant development
Boosts photosynthesis
Strengthens stem and leaf nodules
Prevents the formation of detrimental fungi, mould and bacteria
Increases resilience against heat, cold and salinization
Enhances resilience of carrying stress
Increases flowering
Is suitable for drip and sprinkler irrigation in root and leaf applications
Strengthens the root system
Enriches the soil with minerals
Enhances the colour, aroma and smell of products
Enables the minerals in the soil to be taken in by the roots easily
Revitalizes the organic matter in the soil
Increases microbial activity in the soil
Regulates the salinity level of the soil
Protects against a variety of diseases and pests
Balances the soils Ph to a level of 6.0-7.0

Soil regulator

Soil is one of the main foundations of agricultural productivity and the pH value is one of the most important qualities of the soil which affects the nutrition value. Whether the soil is acidic or alkaline Bionur™ with a pH of 2.2 balances the pH level of the soil between 6.0 and 7.0. This pH range enables the nutrients in the soil to be taken in by the plant in the most sufficient way. In addition to this the Fulvic acid in Bionur™ Microbial increases the microbial activity in the soil and hence the soil is enriched and the quality increases.

Plant Regulator

Bionur as a plant regulator improves soil quality, provides convenient cultivation and reduces the need to use chemical fertilizers, provides strong root development, promotes budding, shooting and blooming, improves the form of the crop, accelerates maturation and prolongs the shelf life of the product.

Anti-salinization Agent

One widespread problem resulting from over-fertilizing is the salinization of the soil. This issue increases environmental pollution and leads to the development of the plant to slow down. As a result the increase in salt concentration negatively impacts benefitting from the fertilizers being used. This leads to a halt in the plants development, decrease in the yield and quality of production and increase in costs. BIONUR™ Microbial reduces the soils salinity and gets rid of the negative impacts. BIONUR™ Microbial thanks to its perfect electrical conductivity in the plant cell membrane allows the plant to absorb exactly the amount of minerals it needs. The problem of salinization world wide shall be solved with Bionur™ Microbial long term and short term usage.

Organic multi-nutrient and chelating effect

A 2012 UNEP (United Nations Environmental Program) synthesis report on sustainable agriculture and agro ecology farm-scale methods included increasing plant efficiency through integrated nutrient management (INM) which relies on more organic means of fertilization and it aims to make better use of nutrient cycles in the soil. Building up organic soil matter is essential in maintaining productivity especially in areas with relatively infertile soil. INM is done by enhancing soil organic matter, and promoting active soil aeration [3]. Bionur is both an organic multi nutrient which enhances the organic matter in the soil.

Nutrients such as N, P, K, Fe, Ca, Mn and Zn are of vital importance to plant development. Plants can't fully absorb these chemicals due to their large particles. To make the intake easier chemical chelating agents have been produced. The duration of these chelating agents staying in the soil without breaking up is still subject to scientific debate. Hence whether they actually serve their purposes is also open to debate. At this point compared to chemicals nutrients in Bionur™ Microbial such as the natural bacteria, sulphate, calcium, magnesium, sodium, phosphorus, copper, iron, zinc, potassium etc make a big difference in their form at nano level. All fertilizers used in agriculture today are of petrol, mineral or gas origin. The intake and usage of these products by plants is maximized with the optimum conditions being provided. BIONUR™ Microbial reduces these minerals to the nano level via the bacteria it contains. Then the nutrients are carried to the plant with the Fulvic acid and other organic acids and are rapidly transformed into the product and thereby maximum benefit is yielded from the fertilizer being used.

It is believed that 16 basic elements are necessary for plant growth and development. Plant nutrients are divided into two groups macro nutrients (ones that the plant uses most) and micro nutrients (ones that are needed less) and the soil which contains at least thirteen of these minerals is accepted to be healthy. Unfortunately the endeavour to enrich the soil in natural nutrients has not been successful despite the continuous usage of chemicals. The reason is that these thirteen elements may not be the only crucial elements for plant development. In the end regular plant tissue is composed of 92 natural elements. Studies have shown that other elements other than the 16 elements are also absorbed by the plant. These elements are to be sure not absorbed by mere chance. Even though they have many key functions they still have not been fully understood by scientists. This ground-breaking notion may be the future of agriculture. In support of this notion BIONUR™ contains over 80 elements such as titanium, silicon, silver and gold. It is a product which nourishes the soil like no other fertilizer could.

Protection against the heat and cold

Adapting to changing temperatures is another major issue in agriculture. The article in the Economist which was referred to before quotes Hans-Joachim Braun, the head of CIMMYT's wheat programme and states that An increase of 2°C in global temperatures, says Hans-Joachim Braun, the head of CIMMYT's (International Maize and Wheat Improvement Centre) wheat programme, could cause a 20% fall in wheat yields [4].

With the complex effect of the *Thiobacillus* spp. Bacteria Bionur™ Microbial contains, vitamin B12 and many other minerals Bionur activates the Anti Freeze Protein (AFP) synthesis in the leaf and roots of the plant. As a result three different effects are seen. First of all it renders the plant resilient down to -4°C in a way that reduces the frost effect and up to 50°C heat against heat stress. Secondly it prolongs the harvest season and lastly it provides continuous protection to the cooling effect during shipping.

Bio-control Agent

Another significant sustainable agriculture method presented by the 2012 UNEP report was managing pests and diseases without using chemicals but through biological control and ecosystem management. There are living organisms inside and outside of the cropland which naturally control crops diseases and pests. However the use of chemical pesticides can destroy these organisms [3]. Bionur™ Microbial on the other hand restores these organisms back to the soil and combats various diseases and pests without harming the environment.

When used as a bio-control agent Bionur has proven to be effective against various pesticides and diseases. Numerous studies have been conducted and further research is being carried out. According to several studies Bionur has proven to be effective against: powdery mildew, downy mildew, apple scrap diseases, *botrytis cinerae, alternia* early blight, *fusarium* sp., bacterial wilt, *acari* (European red mite, brown mite, and straw mite), leaf miner, pinus scale insect.

Studies and Research on the Effects of Bionur on Crops

I. Bio-control Agent

"Effect of some biological preparations against root rot diseases in tomato caused by *Fusarium oxysporum f.sp. Radicis-lycopersici and Pythium deliense"* was studied. At the end of this study: compared to the controls, significant decreases in disease severity were obtained with treatments of Bionur Microbial [5].

"The effects of some biopreparations and activators on root rot fungal diseases caused by *Fusarium graminearum and Rhizoctonia cerealis* on Turfgrass" were investigated with another study. At the end of this study, Bionur™ Microbial was the most effective bio-preparation in controlling both *Fusarium and Rhizoctonia* diseases on Turfgrass, Bionur Microbial had the highest fresh weight and dry weight of Turfgrass and it increased the density and intensity of Turfgrass by 70% [6].

According to study in the name of "Suppressive effects of Bionur™ Microbial and Akvasis including *Thiobacillus* bacteria to Root-knot nematode on tomatoes" found also similar results: It was observed that Microbial Bionur™ had a greater effect than the untreated control in suppressing Root-Knot nematodes in tomatoes compared to control plants. Plant height, fresh plant weight and root length in Bionur Microbial was higher than untreated control plants. A second experiment using microbial Bionur and Akvasis using different applications is currently being carried out under controlled conditions [7].

"The Effects of the Application of Bionur on Potato Wart Disease (*Synchytrium Endobioticum*), Other Diseases and Parasites, Yield and Quality of Potatoes (*Solanum Tuberosum*)" were investigated by Bayhan and Aksu (2011). Results: In order to produce 60 ton/ha tuber yield of potato, chemical fertilizer and different doses (1, 2/3 and 1/3) of Bionur™ Microbial compared according to quantitative and qualitative yield parameters. As quantitative results, 21% of increase in tuber number and a 22% decrease in tuber weight as seen in full dose of Bionur compared to chemical fertilizer and also tuber yield values are almost the same. As for qualitative results, an 8% increase in sphericity, a 6% fold decrease in distortion, a doubled increase in shelf life, decrease in wart disease damage from 33% to 2% and also increase in resistance to other diseases from 49% to 100% are seen in full doses of Bionur compared to chemical fertilizer. Moreover other doses of bionur almost got the same results mostly in the qualitative parameters [8].

II.Yield and Crop Quality

The effects of bio-fertilizers which can be used in field agriculture, on the yield and quality of various cultivated plants were determined. Two years plant development and nourishment trial report of Bionur™ Microbial effectiveness on potatoes. Plant nourishment and development effects of Bionur Microbial on potatoes: significant increase in tuber yield, enables longer vegetation period was observed over 2 years [9].

The Effects of bio-fertilizers which can be used in field agriculture, on the yield and quality of various cultivated plants were determined. The: one year plant development and nourishment trial report of Bionur Microbial effectiveness on sugar-cane. Plant nourishment and development effects of Bionur Microbial on sugar-cane strengthened root and stem significantly increased yield [10].

The effects of fertilizers which can be used in organic agriculture, on the yield and quality of various cultivated plants were determined. The Effects of Bionur Microbial on the yield and quality of various crops such as potatoes, tomatoes, spinach, cauliflower, corn, sunflowers, carrots, lettuce, and sugar cane has been researched at Suleyman Demirel University for a period of four years between 2005 and 2008. Fallowing results are defined [11].

In the trials conducted in 2006 on Silion cucumbers the application of Bionur™ Microbial increased yield by 31% compared to control and by 24% when compared to conventional. It also increased the number of fruit by 26% compared to control and by 22% compared to conventional. In the trials conducted on Ilke cucumbers in 2007 the application of Bionur™ Microbial increased yield by 71% compared to control and 68% compared to conventional. It increased number of fruit by 51% compared to control and by 65% compared to conventional. Plus the application of Bionur increased the weight of the fruit by 12% compared to control and 2% compared to conventional ($P<0.01$).

The trials conducted on sugar cane showed that the application of Bionur increased yield by 64% compared to control and by 29.8% compared to conventional fertilizers, average root length by 31.8% compared to control and 15.3% compared to conventional fertilizers ($P<0.01$). It is also worth noting that there was a significant improvement in color and aroma [11].

Furthermore the effects of fertilizers which can be used in organic agriculture, on the yield and quality of various cultivated plants were also determined. These are followed: In the trials conducted in 2007 the application of Bionur™ Microbial on Lital lettuce increased yield by 49% compared to control and by 14% compared to conventional; on carrots it increased yield by 96% compared to control and by 59% compared to conventional; on spinach it increased yield by 88% compared to control and by 179% compared to conventional; on cauliflower it increased yield by 42% compared to control and no difference was observed when compared to conventional; on Carlita potatoes, compared to control it increased yield by 45%, number of tubers by 33%, weight of tubers by 56%, total carbohydrates by 28%, free sugar by 162% and starch by 19%. ($P<0.01$) [12].

Effects of Various Plant Activators which are used in Organic Agriculture, on the Quality and Yield of Tomatoes were investigated[1].

Effects of various plant activators which are used in organic tomato cultivation, on nutrient elements were researched. Turkey's 6th Congress on Garden Plants, 4-8 October, Şanlıurfa [14].

The Effects of Plant Activators on the Yield, Quality and Disease Resilience of Tomatoes Cultivated in Field and Greenhouse Conditions were defined at the Department of Horticulture of Agricultural Faculty of Suleyman Demirel University in Isparta. SDÜ BAP Project no: 38 0M 06, 2006, Project supervisor (completed) [15].

The Effects of Plant Activators on the Yield, Quality and Disease Resilience of Tomatoes Cultivated in Field and Greenhouse Conditions were studied as a Master Thesis at

1 Turkey's 6th Congress on Garden Plants, 4-8 October, Şanlıurfa [13].

Department of Horticulture, Faculty of Agricultural, Suleyman Demirel University in Isparta [16].

III. Antifreeze

Tiryakioğlu, Y., 2006. Ms C. Thesis. The Effects of Some Frost-Protective Preperats Applications on Low Temperature Resistance, Yield and Quality in Greenhouse-Grown Carnations (*Dianthus caryophyllus L.).* Suleyman Demirel University Faculty of agriculture Department of Horticulture Project number: 1130 YL 05. According to a masters thesis studied by Tiryakioğlu in 2006; the effects of some frost-protective specimens on frost resistance, yield and quality in carnation were investigated. Carnation Evita cultivar as plant material and seven different commercial products including Glacier, Anti-stress 2000, Ekofer Zinc, Ekofer Potassium, EAP, Bionur and Antistress as the frost-protectives were used in the study. In the artificial frost test, the least damage was observed in Bionur Microbial treatment (17.67 %) at -5 ^{o}C followed by Antistres (31,40 %), EAP (31,73 %), Ekofer Potassium (32,34 %), Glacier (33,40 %) respectively. The most increase in carnation flower stem length was found from Bionur (71,31 cm), Ekofer Zinc (71,10 cm) and Ekofer Potassium (70,51 cm) treatments [17].

Conclusion

Due to all the qualities that Bionur possesses we believe that it may be a solution to many agricultural problems the world is faced with today. It has the potential to change the philosophy of conventional and commercial agriculture while managing diseases and boosting supply and quality within a sustainable framework. It seems to be a revolutionary tool and it should definitely be looked into by the scientific community to conduct further research on this product and discover the many wonders it has to offer.

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ALGAE TO ZEA MAYS: THE CURRENT STATUS OF BIOFUELS DEVELOPMENT IN THE UNITED STATES

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Abstract. Since 1980, production of bio-renewable energy in the USA has been growing considerably representing 4.5% of all energy sources. This consists predominantly of ethanol production from corn/maize (*Zea mays*) starch. The arena of biofuel production research and development in the United States is dynamic, with many technologies currently under study and development. This is largely due to an economic climate where tax and other government incentives favor the development of advanced biofuels over traditional first generation food crop-based biofuels, and because efficiencies of production have steadily been improving, making biofuels more competitive in the marketplace.

Key words: biofuels, bioethanol, biodiesel, US goals, government policy

Introduction

The Energy Independence and Security Act of 2007 established a new and high Renewable Fuel Standard. This established a goal of producing 110 million metric tonnes of ethanol equivalent biofuels plus 3.1 million metric tonnes of biodiesel by 2022. There remains a considerable gap between the cost-effectiveness of biofuels vs. fossil fuels, but the gap is closing. Current incentives by academia, government and industry in the United States of America are stimulating the research necessary to advance development of biofuel technologies to make it more competitive against all other less environmentally and long-term economically sound energy sources. Economic, human, and environmental issues connected with the use of advanced cellulosic (feedstocks such as corn stover, grasses and wood chips) and other non-food crop based fuels (e.g. produced by cyanobacteria and algae) can and will be solved with a strong and consistent commitment to continuing research and development.

The United States of America has become dependent upon plentiful and inexpensive energy to support its economy and the lifestyle of its people. In recent years, the sustainability of high consumption of non-renewable energy has been increasingly questioned as has the environmental consequences. The USA imports about 55 % of its consumption of crude oil (40% net considering US oil exports) [1]. There are additional concerns about the security of supply. Therefore, significant efforts are being made to find alternatives to the current pathway, including the following:

– Greater energy efficiency,
– Use of energy sources with lower greenhouse-gas (GHG) net emissions such as nuclear and renewable sources.

The latter includes solar, wind, geothermal, and biofuels. This communication discusses the current state of US biofuel development and addresses the economic and environmental consequences of increasing biofuel production in the USA.

Historic US Development and Production of Biofuels

The use of renewable energy in the United States is not new. More than 150 years ago, wood, a form of biomass, supplied up to 90% of energy used in the USA [2]. As the use of coal, petroleum, and natural gas expanded, the USA became progressively less reliant on wood as a percentage of its energy usage. More recently, emphasis has been placed on the development and production of the biofuels - ethanol and biodiesel [3].

Attention to biofuels can be considered to have begun in the 1970s with the passage of the National Energy Conservation Policy Act of 1978 [4]. This established the first biofuel subsidy applied to ethanol produced from corn grain. The corn-grain ethanol industry grew relatively slowly between 1980 and 2003. From 2003 to 2007, ethanol production grew rapidly as ethanol replaced methyl tertiary butyl ether as an “oxygenate” in gasoline to reduce carbon monoxide emission. Interest in providing other incentives for biofuels increased because of rising oil prices. The Energy Independence and Security Act of 2007 established a new and much larger Renewable Fuel Standard and set in motion the drive toward 110 million metric tonnes of ethanol equivalent biofuels plus 3.1 million metric tonnes of biodiesel by 2022 [5].

In 2011, 81% U.S. energy consumption came from fossil sources, namely coal, petroleum/oil and natural gas (figure 1). Renewable energy sources represent 9% of all energy used (9 quadrillion Btu) (figure 1). Biofuels are 21% of renewable energy sources used [6]. Biofuels can be divided into two basic categories, namely ethanol and biodiesel together with other biomass conversions such as biogas. The main U.S. biofuel is ethanol derived from corn/maize (*Zea mays*) produced by converting the starch to sugars and to ethanol through fermentation. Ethanol derived from sorghum and biodiesel derived from soybeans comprise a very small fraction of U.S. biofuels.

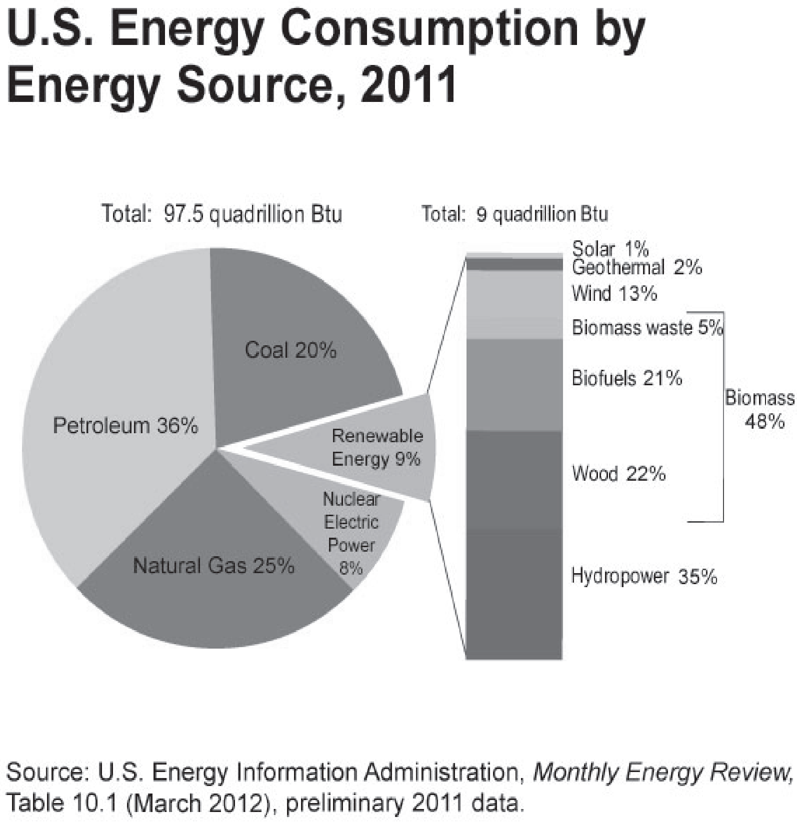
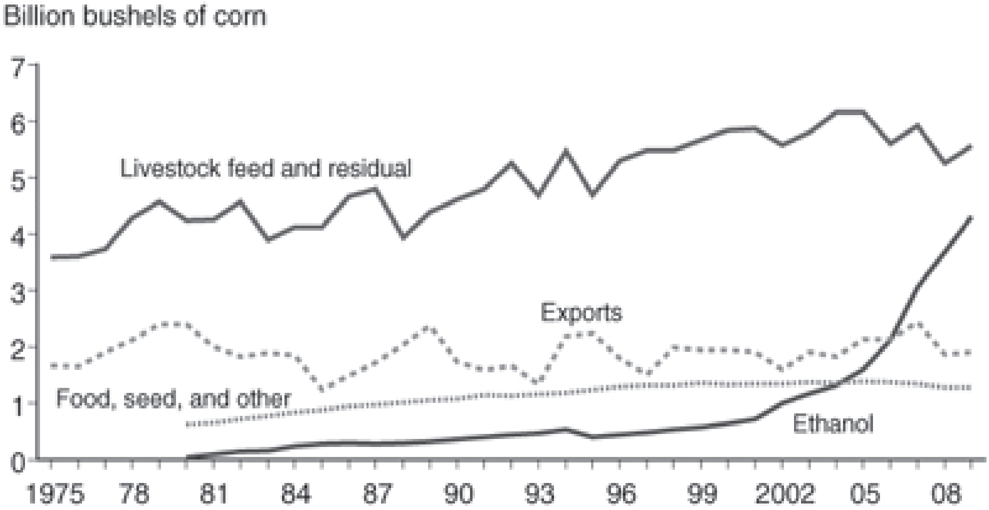


Figure 1. Contribution of different energy sources to US energy consumption

Current Emphases of Development and Production

Ethanol

Production of ethanol from corn, dominates U.S. biofuel production, accounting for over 85% of total U.S. biofuels production in 2013. Current tax incentives for biofuel production, including corn-based ethanol, were extended through 2014 in the American Taxpayer Relief Act of 2012 (7). The production of ethanol from corn is economically advantageous to U.S. farmers with increased prices paid for corn due to an increasing utilization of the annual corn crop for ethanol production [8]. Moreover, the co-products are being utilized for livestock and poultry production. Selected rural communities have experienced economic revitalization with ethanol production facilities.



Notes: Corn used for ethanol was not tracked separately prior to 1980. Corn used for the "food, seed, and other" category was split between several categories prior to 1980.

Source: USDA, Economic Research Service Feed Grains Database.

Figure 2. Primary uses of U.S. corn

However, it has been argued that the utilization of corn for ethanol production has resulted in an adverse impact on availability of the U.S. corn supply for human food, livestock feed, seed, and other non-ethanol uses because of increased U.S. corn prices [9]. According to some scholars, the current US Ethanol Mandate has had a direct role in driving up U.S. corn prices [10]. The International Food Policy Research Institute (IFPRI, 2008)[11] and the OECD (2008)[12] have both asserted that biofuels were responsible for a significant proportion of the corn price increase during the 2007–08 commodity boom.

As can be seen in the graph of US ethanol production (Figure 3) the overall volume of ethanol produced has declined in recent years. While a portion of this trend may be attributable to climate variability in recent years [13], indicators point to an increase in the price of corn commensurate with increase in demand. Profitability of corn-based ethanol production has been reduced to a point where other feedstocks have become more economically attractive to producers, despite their lower ethanol conversion efficiency [14].

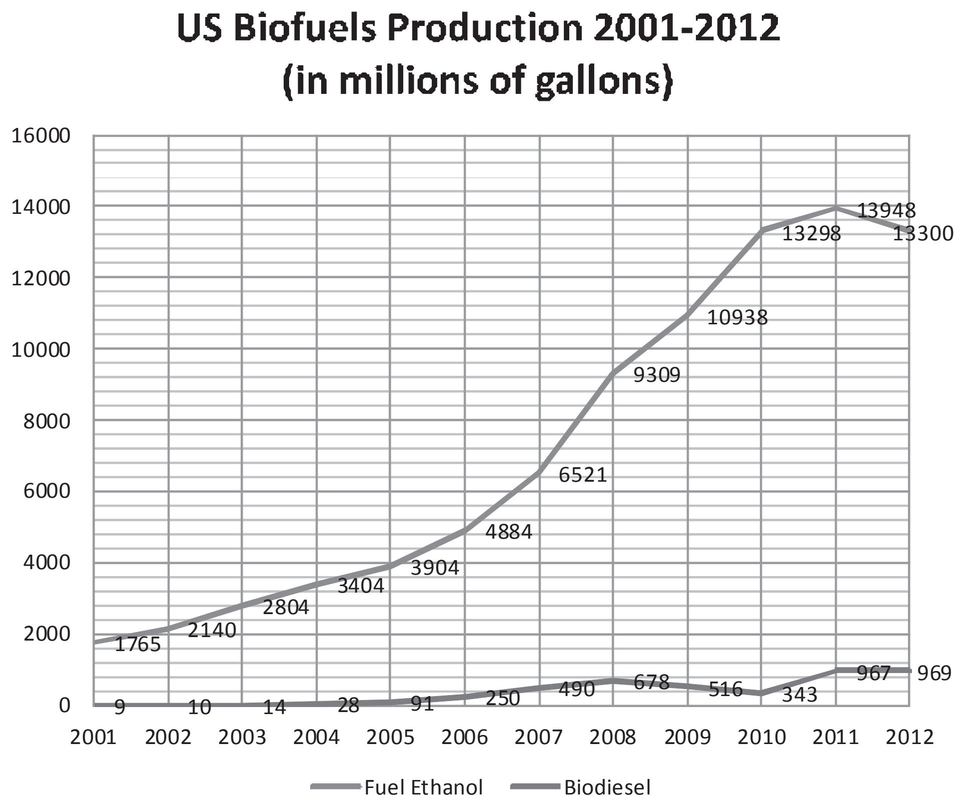


Figure 3. Comparison of fuel ethanol vs biodiesel production – 2001 to 2012

Cellulosic feedstocks currently comprise a small percentage of ethanol production in the USA (Figure 3), largely due to the energy demands and expense of converting cellulose into usable sugars for fermentation into ethanol. The USA is actively promoting development of the domestic cellulosic ethanol market through the use of incentives and grants. Grant programs in excess of $22 million have been established by the U.S. Department of Energy to stimulate development of commercial-scale cellulosic ethanol plants in the USA [15]. With this assistance, several companies have set up pilot and demonstration facilities and several commercial plants targeted to be commissioned in late 2013 [16].

In addition, the fuel blend mandates contained the recent 2013 Renewable Fuels Standard specify the addition of 10% ethanol in gasoline fuel, setting steady domestic demand for the industry, while certain recently released cars are able to run on a 85% ethanol, 15% gasoline "flex fuel" mix. The combination of such government mandates and financial incentives has spurred a variety of new technologies involving cellulosic ethanol [17].

While business plans for lignocellulosic ethanol production in the United States are as yet developing, signs of consolidation in the young US biofuel industry are already evident. Recent projects illustrate this clear trend of moving away from first-generation biofuels derived from food crops such as corn, sugarcane and oilseed, and toward the next generation, made from more plentiful cellulosic feedstocks such as corn stover, grasses and wood chips.

Research at the USDA National Center for Agricultural Utilization Research currently explores the use of yeast cultures to more efficiently release and digest sugars in corn cob waste through enzymatic action, thus improving fermentation efficiency and reducing production costs [18]. Similar efforts include the use of other fungi combined with pretreatment to increase yield in hydrolyzing and fermenting corn stover [19]. In each case, the efficiency gained from these processes, combined with the lower raw materials cost of cellulosic feedstocks, support a stronger business case to compete more effectively with traditional first generation biofuels based on food crops.

Other potential sources of materials under study in the United States for use in ethanolic biofuel production include short-rotation woody crops such as poplar and willow; and perennial grasses, such as switchgrass (*Panicum virgatum)* and *Miscanthus,* a giant perennial grass. Scientists from the University of Illinois at Urbana Champaign have recently developed a more economic and environmentally friendly pretreatment methodology for *Miscanthus*, using butadiene sulfone to break down cellulose and lignins more effectively [20]**.** While the energy yield per pound of biomass is lower in these feedstocks, the fast growth rate of grasses, in particular, increases overall yields, making this technology competitive in the biofuels market.

Biodiesel

While currently comprising only a small fraction of total annual US biofuels production, biodiesel is also experiencing a large increase in research and development activity in the United States. This is largely due to the wide variety of inexpensive feedstocks available in the US suitable for conversion [21]:

- animal fats, vegetable oils, and recycled greases
- agricultural and forestry residues such as manure and cellulosic waste
- aquatic products such as algae and seaweed
- municipal waste such as sewage sludge or solid waste

Each feedstock, however, carries its own set of challenges in use as a biodiesel feedstock, for example, glycerin as a major byproduct of the esterification process, trading one waste stream for another. Considerable efforts are being spent in developing more efficient conversion to reduce these waste streams, as well as exploration of cleaner catalytic processes for conversion with virtual elimination of waste byproducts [22].

Although other vegetable oils can be used for biodiesel, soybean oil is almost always the lowest priced of all major vegetable oils except palm oil. Given the readily available supply of this oil in the United States, soybean oil currently is the preferred biodiesel feedstock in the US.

Development of Advanced Biofuels

There are 159 companies working to produce advanced biofuels in the U.S. and Canada. This number remains nearly constant from 2011 and 2012. Some companies have shifted to fuel production from fossil-based natural gas, and a few others have otherwise left the biofuel market. Most companies, however, continue to assess ways to enter the advanced biofuel market and scale up production, although they may pursue other revenue streams for short-term growth [23].

Algae

A variety of feedstocks and technologies are being evaluated for use in advanced biofuels in the US. Of these, micro-algae is receiving a great deal of attention in the United States for a variety of applications, including the production of oil for conversion to biodiesel and for development of other advanced biofuels [24]. It has clear advantages over other potential feedstocks in that it does not require the use of cropland, grows rapidly for maximum production, can be genetically tailored to specific applications, and recent research has established that algae can be produced in a variety of diverse environments, including salt water, potentially expanding the types of conditions and locations where it can be effectively employed [25].

Photosynthesis by micro-algae can be employed both to "capture" carbon dioxide from the atmosphere and from power stations and to generate biofuels; namely methane, hydrogen and biodiesel, from trans-esterification of algal triglyceride [26]. Municipal, agricultural and industrial wastewater can also be used to provide nutrients together with heat for the growth of algae for biofuels [27, 28]. Moreover, the residue from algae after removal of the oils can be employed as a fertilizer for crop production.

Estimates of the potential for biofuel production are 50% of dry weight microalgae [29]. Production of biofuels from microalgae produces per unit area of land is dramatically higher than for biofuel crops [29]. Estimates of the potential yield of biodiesel range from 14 to 255 metric tonnes per hectare for microalgae compared to 1-2.5 for soy beans [30]. Production of microalgae requires the inputs of nitrogen and phosphate; respectively 88 kg nitrogen and 12 kg of phosphorus per metric ton of dried algae produced [29, 31]. Were algal biofuels to meet even the lowest projections of their potential, this would the equivalent of 44% of present US consumption of nitrogen fertilizers and 20% of phosphate usage [29].

Example algal biofuels projects currently in the USA:

- Use of carbon to catalyze increased algal biofuel production (Brookhaven National Laboratory)[32]
- Development of algal based jet fuels (National Renewable Energy Laboratories)[33]
- Development of new microalgal strains suited to biofuels production (NREL) [33]
- Use of cyanobacteria to more efficiently generate biodiesel (NREL) [33]

One of the current controversies in U.S. algal biofuels development involves open vs. closed system algal cultivation. Costs of construction and operations of open raceway or pool systems are significantly less than those closed systems, but greater process control, less evaporative loss and higher productivity of closed systems provide increased revenue and counterbalance the economic advantage of open systems [24]. Research and development in both systems of cultivation may be found in the United States, although the most recent trend is in the area of open raceway systems, integrated with other processes, making them more economically feasible.

For example, California Polytechnic University, in cooperation with the City of San Luis Obispo, has been awarded $1.3 million by the U.S. Department of Energy to develop an open raceway algal biofuels system, using this city's municipal waste water stream as the primary nutrient source [35]. Collaborative systems such as this provide both economic and environmental benefits, providing effective water purification, while generating income from the production of biofuels and fertilizer from the co-products of the process. According to some scholars, systems that integrate multiple processes and generate multiple revenue streams have the greatest potential for long-term economic viability.

Algae does represent significant potential for being a long-term solution for biofuels production, but it has been argued by some that, with current technology, algal biofuel production is not sustainable and scalable to production levels. Moreover, there is concern in the environmental community over the demands that large scale algae biofuel production would place on existing land and water resources [36].

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Bioenergy and Other Renewable Energy Technologies and Systems 27-32

THE CONCEPT OF THE ANALYSIS SYSTEM OF RENEWABLE ENERGY POTENTIAL IN AGRICULTURAL PRODUCTION

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Abstract: The concept of the analysis system of renewable energy potential in agricultural production was presented. The system will be designed for agricultural producers who run agricultural business activity, who have potential concerning renewable energy sources. The prepared concept constitutes an element of the advisory system which allows farmers to use the resources for renewable energy.

Key words: advisory system, renewable energy, computer programme, agricultural producers

Introduction

One of the challenges of Poland in the nearest future is ensuring safety in the field of extensively understood natural environment. It also concerns limitation of air pollution emission and increase of the use of renewable energy sources. The strategy of proceeding with regard to the ecological safety and the use of ecology principles assumes balancing the results of economic development and improvement of the energy safety level, particularly based on considerably higher level of use of renewable energy resources (RES). Increase of the RES use as a significant component of the cohesion policy 2014-2020 is a crucial factor which favours implementation of one of the main purposes of the strategy "Europe 2020" - sustainable growth which means inter alia the support of environment friendly economy [1,2,3,4,5].

Agricultural producers, who, when properly motivated and informed, may have in future a considerable share in the energy production from renewable sources, are the subjects who have a considerable potential concerning clean energy sources. Clean energy, which they produce, may be used for their needs and its excess may be transferred to other economy branches [6]. Therefore, energy production may be for these subjects a basic income source or significant completion of the production which they carry out. Presently, agricultural producers do not have sufficient knowledge and skills for implementation of the above mentioned purposes. Thus, it is necessary to carry out suitable informative activities and preparation of modern informative solutions, which through proper computer simulations will allow determination of energy potential of a specific agricultural producer. Consequently, knowledge on clean energy technologies in connection with a universal access to information will give synergy effect allowing optimal use of the possessed potential.

Materials and methods

The system which has been drawn up may enable the use of farmers' possibilities concerning renewable energy. Advantages from the use of resources concerning renewable energy sources may differ depending on the type of production and farm resources. In special cases, shift of the whole farm production and orienting it to energy production may be recommended. Agricultural producers have potential for production of clean energy which includes, inter alia:

- photovoltaic systems,
- solar collectors,
- cultivation and utilization biogas works,
- geothermal heating plant,
- biodiesel plants,
- geothermal heat pumps,
- small wind power stations,
- biomass heat and power stations,
- small biomass boilers,
- small hydro power plants,
- and others.

Additionally, agricultural farms may constitute main source of raw material (e.g. biomass) for big enterprises which produce energy in different forms [7, 8].

Presently, despite numerous suggestions of software for industry, there are not many IT solutions, basing on the scientific research results and which are designed for agricultural producers, which enable conducting proper calculations. Such calculations require specialist knowledge and are labour consuming. Thus farms' owners do not use specialist services on account of the expertise cost. There are no programmes on the market which would clearly allow listing indispensable indexes and which would enable their correct interpretation - giving recommendations for the application programme users concerning reasonable changes in the farm management system.

The suggested solution takes the empty place on the market. The project covering the drawing up of the concept of the system for renewable energy potential analysis in the agricultural production becomes a key technology in two areas: that is clean energy technologies and a universal access to information. The concept of the system will provide basis for creating IT solution, which upon implementation and popularization will increase the level of knowledge of application programme users (agricultural producers and other interested parties). Consequently, through showing the users notable effects, it will increase production of clean energy in agriculture. It will allow the use of resources, which are presently not used and consequently may improve Poland's balance in regard to the use of RES. In further perspective, it will indirectly positively influence meeting by Poland requirements towards EU concerning the use of RES in total energy production. Higher share of renewable energy will also increase energy safety of our country.

The suggested concept will be based on many years - lasting research and analysis, the use of clean energy technologies in the agricultural sector and the use of IT technology for obtaining an universal access to information for agricultural producers and subjects related to agricultural and food branch. Research in the Institute of Agricultural Engineering and Informatics of the University of Agriculture in Kraków concerned inter alia the use of energy plants (e.g. energy willow and others), biofuels, biogas and solar energy. The author of this paper created computer programmes (Plantene, Plantene-2) enabling listing willow biomass demands for heating purposes on a farm, using calculation algorithm worked out at the University of Agriculture (original in majority) [9]. He is also the author of a few programmes supporting farm management, including OTR-6, OTR-7 (Organizator Techniki Rolniczej 6 and 7), DoZem-2, Agregat-2, Bilenero, Gekko programmes and others. Application programmes were implemented and popularized [10]. The worked out concept is a logical connection of experiences related to the use of clean energy in agriculture with practical use of information technologies. Consequently, research results concerning the use of renewable energy sources and author's experience in developing software for agricultural producers will be used.

Biobkalkulator programme worked out in the Institute of Agricultural Engineering and Informatics (in cooperation with other scientific units) is an example of an application of calculation programme related to the use of RES which is functionally similar, although of different scope of use. The paper was worked out within the Research Project "Modern technologies of energy use of biomass and biodegradable waste - conversion of biomass and biodegradable waste for energy gas fuels", task titled "Computer calculation and advisory system concerning substitution of conventional energy carriers with biomass". Its purpose was to prepare a computer calculation and advisory system concerning substitution of conventional energy carriers with biomass. The programme was implemented and made available for uses [11].

The concept presented in the article is based on calculation algorithms used in existing original computer programmes and on the scientific research results related to renewable energy sources obtained in the Institute of Agricultural Engineering and Informatics. The applied solutions include the newest achievements of the national and world science.

Results and discussion

The analysis system of the renewable energy potential in agricultural energy must be based on the analysis of the resources of the farm (fig. 1). Not used potentials of energy production will be searched for on their basis. Solutions, which may be implemented in the analysed facility, will be determined in connection with the data of the existing solutions base.

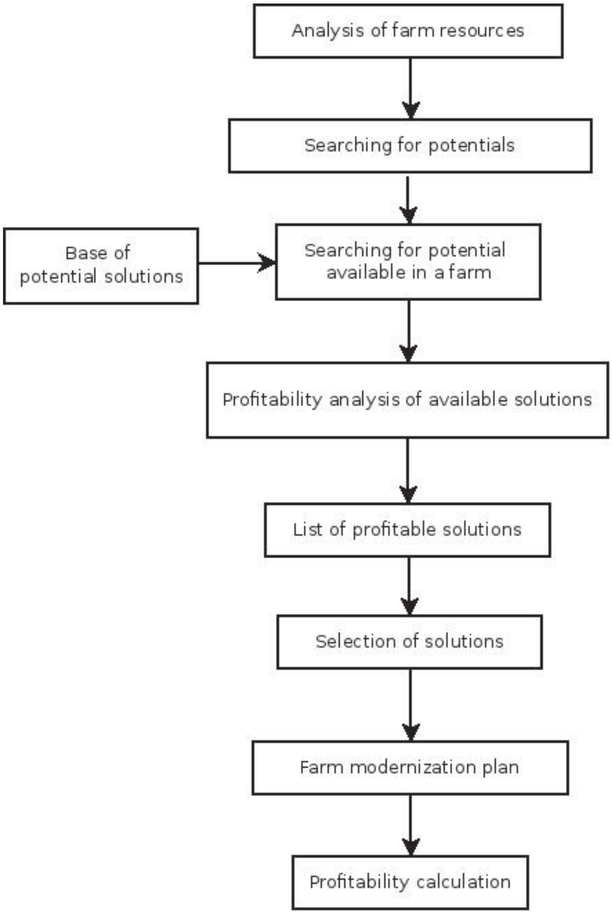

Figure 1. Proceeding scheme at drawing up an implementation plan of renewable energy production in a farm

From among solutions available in given conditions, a part of them will not be economically justified - these will be rejected by the system. The remaining, profitable will be presented to the user of the system for assessment and after his/her approval will constitute basis for drawing a farm modernization plan on account of renewable energy production. Consequently, calculation of profitability of the suggested modernization will provide answer to the question what advantages will a farmer have in a short and long term perspective. The programme will calculate the size of necessary investments and will suggest ready solutions (e.g. purchase of specific equipment, possibilities of crediting, the amount of funding etc.).

Simplified scheme of the designed system (fig. 2) assumes equipping it with a few data bases including inter alia information on various systems of agricultural production, agricultural equipment, machines and devices catalogue for renewable energy production and a base of available solutions. Except for the above mentioned, the application programme may also include other bases indispensable for implementation of the assumed objectives. The system will include four basic calculation modules, using data collected in the bases and three modules of programme management for users with different level of licences. Calculation modules carry out tasks related to the procedures of analysis, selection and calculation in the programme. Possibility of their modification along with new methods and techniques of solving problems is assumed. Module of communication with enterprises will allow introduction of new energy devices into the base when they appear in the producer's or the seller's offer. Module of communication with a user must be equipped with a friendly interface and developed help system. It should also include information which explains usefulness of the suggested solutions and extensive instructions of their introduction.

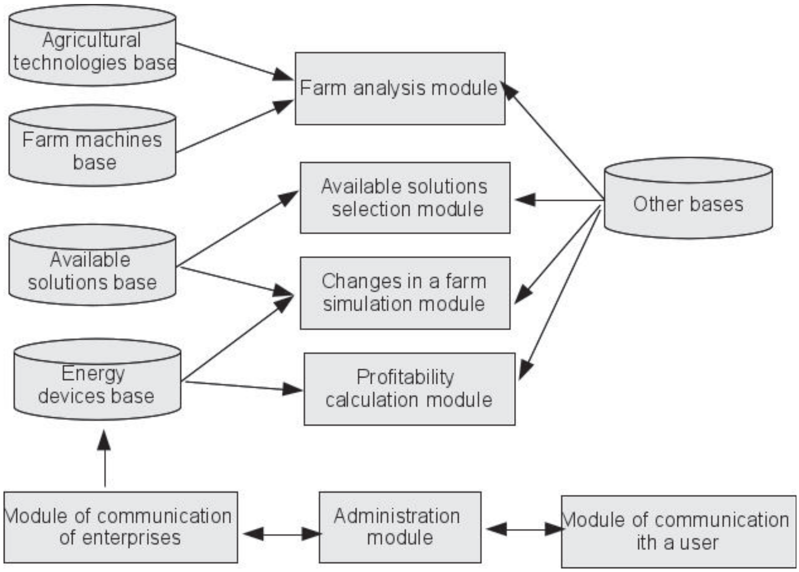

Figure 2. Simplified scheme of the system

The whole system will be placed on the server, which would be available from the level of internet browser. Public, multi-level access to the system makes it necessary to introduce: safe methods of authorization, securing the system against non-authorised access and making regular copies of safety.

Conclusion

The suggested solution is of a process innovation nature concerning implementation of clean energy technology in the sector of agricultural production. The formed system will allow practical use of IT technologies for analysis of production processes in agriculture and as a result will allow a universal access to information. The system, which ultimately is going to be designed as a result of the developed concept, will constitute product innovativeness. The suggested solution is of organization innovativeness nature; allowing analysis of various options of production organization it will enable selection of the most advantageous option in a given situation. A potential use of the concept will find its place in the agricultural sector and agricultural producers, enterprises and institutions related to the service of the sector will be recipients. The application of this system will help to indicate not used energy potential, which can be found in agriculture.

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SMALL SCALE CSP LAYOUT OPTIMIZATION FOR SOLAR RADIATION IN POLAND

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Abstract. Current development in Concentrated Solar Power (CSP) heads towards huge scale installations to lower total costs of ownership. Geographically such installations are located in near-equator areas like south Europe and southern states in the USA or northern Africa. In our opinion, even small scale CSP installations, used mainly for thermal energy gathering may be successfully installed in Central European countries. This paper presents an approach to set up small scale CSP installation optimization principles for gathering maximum sun power from flat panel array mirrors on the limited land surface. The goal is to provide a mathematical model for such calculations for dynamic parameters like land area, mirrors size and locations. The main problem to be resolved is shading and blocking of the sun rays and the limited land area. The proposed small scale CSP due to its low total cost may be freely extended if the thermal energy demand is raised in a given period. In Poland, such increased periods occur mostly during spring and autumn months.

Key words: concentrated solar power, CSP, modeling, solar energy, renewable energy

Introduction

CSP is a proven means of solar power generation and new technologies are lowering its cost curve, but a common characteristic of current CSP technologies is the use of steam turbines for power generation. Steam turbines, although well understood, consume large amounts of water and require extensive balance-of-plant equipment. CSP works best in regions with a lot of sun year-round, and these tend to be desert areas where water is in short supply and permission to use water may be difficult or impossible to obtain.

Concentrating solar power plants use mirrors or lenses to focus a large amount of sunlight onto a heat absorbing target, called a receiver [13]. On typical plants, the receiver heat exchanger creates high pressure steam, which then drives a turbine to power an electric generator. Spray water cooling is typically used to condense the steam. These CSP power plants require economies of scale to be cost effective, and are often rated at 50MW of power or more.

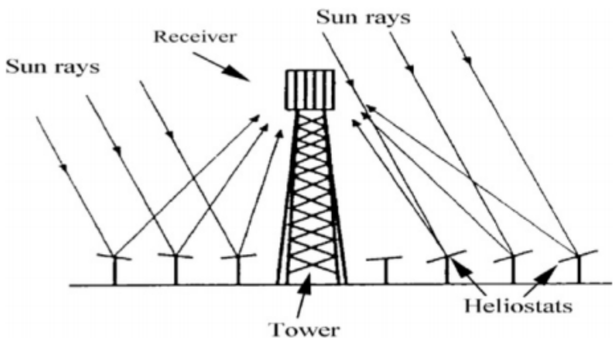

Figure 1. Conceptual model of concentrating solar system [13]

The most recent CSP technology to emerge into commercial utility was the heliostat field collector design. This expensive, powerful design has so far been incorporated in relatively few locations around the world. The 10 MW Solar One (1981) and Solar Two (1995) were the first HFC plants to be demonstrated, built in the Mojave Desert of California. They have since been decommissioned. Other plants, such as the 11 MW PS10 and 20 MW PS20 in Spain, and the 5 MW Sierra SunTower in California, were recently completed

The heliostat field collector design features a large array of flat mirrors distributed around a central receiver mounted on a (solar) tower. Each heliostat sits on a two-axis tracking mount, and has a surface area ranging from 50 to 150 m^2. Using slightly concave mirror segments on heliostats can increase the solar flux they reflect, though this elevates manufacturing costs. Every heliostat is individually oriented to reflect incident light directly onto the central receiving unit. Mounting the receiver on a tall tower decreases the distance mirrors must be placed from one another to avoid shading. Solar towers typically stand about 75–150 m height. A fluid circulating in a closed-loop system passes through the central receiver, absorbing thermal energy for power production and storage. An advantage of HFCs is the large amount of radiation focused on a single receiver (200–1000 kW/m2), which minimizes heat losses and simplifies heat transport and storage requirements. Power productionis often implemented by steam and turbine generators. The single-receiver scheme provides for uncomplicated integration with fossil-fuel power generators (hybrid plants).

Problem definition

Cheapness has never been the primary goal before. Specifically, it was never the primary goal of the big companies who designed the first heliostats to manufacture a cheap, low-tech system by the millions and then exploit it to make electricity. They were being paid with government money to do research and it was more important to have a big, impressive, high-tech system to show.

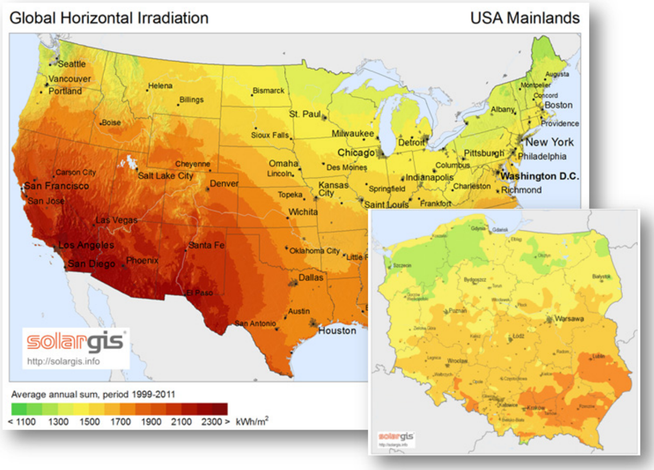

Figure 2. Global Horizontal Irradiation in Poland vs. USA [11]

Poland located in the Central Europe has far less sunlinght power than Spain or Nevada in the USA [11].

Although, the sun power available in southern Poland in most cases exceeds 1000W/m^2 during summer.

Proposed solution

A proposed, small scale CSP system, consisting of 50-100 one square meter heliostats, could finally provide a heat power of 25-50kW. This amount of heat would be enough to heat up to 400 sqm building or store the heat in a water container for late usage.

Figure 3. eSolar field layout [15]

Of course, during the summertime, such amount of heat is usually not needed in small to medium farms. The autumn and spring moths are the time, the most heat is needed. Poland as a growing economy is currently the fastest growing market for solar panels [12]. The problems for flat plate or evacuated tube panels like overheating and delivery of heat where it is really not needed could be solved by more sophisticated, small scale concentrated systems. Such CSP systems are usually computer-controlled [14], and allow to independently control each heliostat, allowing to concentrate more sunlight when most heat is needed and de-focus them during hot weather.

The first step in such system construction is the selection of the field layout. There are various solutions for that problem. The proposed layout will mark the one implemented by American company eSolar [15], which located all heliostats in rectangular arrays.

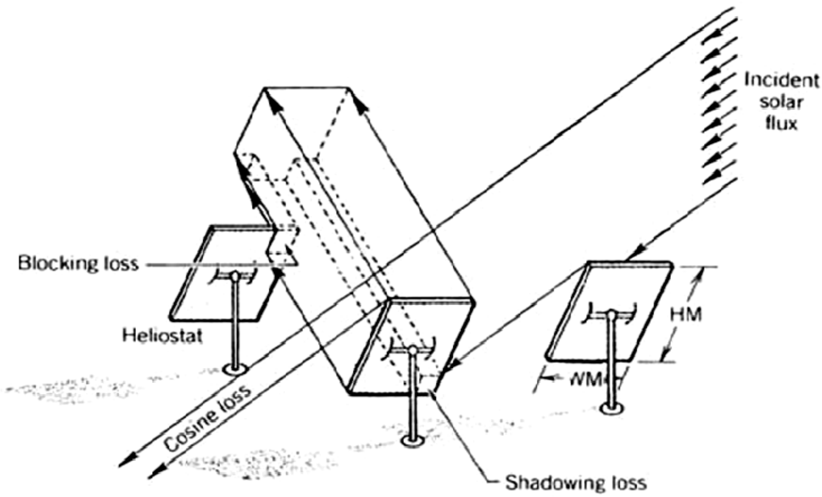

Figure 4. Blocking and shadowing problem during heliostat positioning [1]

This layout will simplify the heliostat location and maintenance. In future, it will also add possibility to expand the system, if needed.

In such configuration, the main problem is blocking the sunrays that are reaching the heliostat by other heliostat on the way. Another, similar problem is shadowing, which means: blocking reflected sunrays by another heliostat [1]. The location in Poland also do not help in mitigating this issue. Sun elevation in winter month is really low over the horizon, making blocking the issue number one. To calculate the layout and distances between small scale heliostats, a Google HOpS software was used [16]. As a input parameters, the following values were used:

- Layout: rectangular array, 10 rows by 10 mirrors, located evenly with 2 meters distance.
- Geographical location: Krakow, Poland (50,06° N,19,93° E)
- Tower with receiver, 15m high

Based on such values and using HOpS as a calculator and solar position equations published by U.S. Department of Commerce, National Oceanic & Atmospheric Administration [17] the effectiveness of such model was modeled and visualized. Unfortunately, the selected computer modeling solution does not provide blocking and shadowing results, so we can only receive irradiance of the receiver, as a effectiveness of the model (Figure 5.).

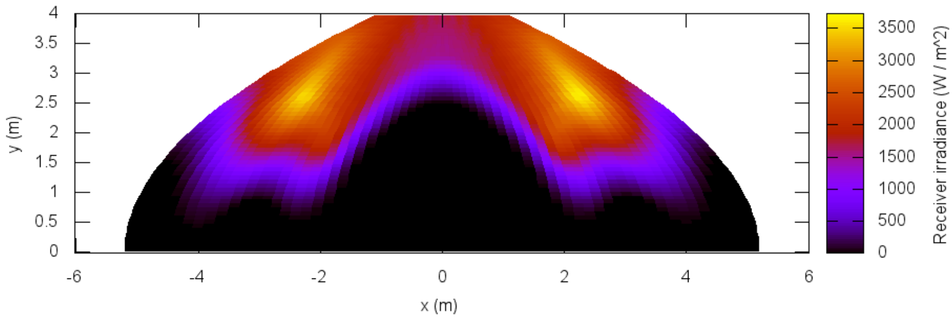

Figure 5. Receiver irradiance

Conclusion

Using the given tool that allows us to choose from two different, predefined layout types (rectangular, evenly distributed array and tower-centric) would not be sufficient to perform enough calculations for optimization. Based on computer based simulation in CAD/CAM system Alibre Design, seems like the non-linear distribution of heliostats would be more feasible for the proposed location in Poland. As the sun elevation is low in such location, the heliostats must be distributed unevenly, possibli in non-linear way. Authors plan to continue layout placement calculations for various locations and distributions of heliostats to get the biggest reflective surface that will reach receiver, especially during winter months.

This article is a starting point in research of concentrated solar systems application in Poland. Very high acceptance of renewable energy solutions in Polish homes focus only in subsidised flat panels. Other ways of gathering solar thermal power is almost completely unknown or not considered. Next generation of solar panels using evacuated glass tubes is being installed in Poland, but nothing more sophisticated or revolutionary. The conference where this article is going to be presented would be one of best ways to present new approach to use solar thermal power to the Polish scientists and entrepreneurs.

By using HOpS we could model only limited configurations of the concentrated solar systems. Authors experienced too much restrictions and limitations of this system during its usage. The further calculations of this and similar models will require to use other computer systems like SolTrace or TRNsys and compare results between them.

Authors consider also modeling of other types of CSP installations, like parabolic-through or Fresnel. They are more cost-effective, although having also some limitations.

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THE INFLUENCE OF THE DEGREE OF FRAGMENTATION CHOSEN BIOMASS OF WOODY PLANTS ON THE QUALITY PARAMETERS OF BRIQUETTE

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Abstract. Energy plant species, are plants characterized by a high annual growth, resistance to disease and pests, small habitat requirements and adaptation to the Polish climatic conditions. This species diversity causes that the properties of biomass vary widely and have a significant impact on the stages of solid biofuels production technology and quality parameters of the final product. The aim of the research was to determine the influence of material fragmentation degree on the selected quality parameters of briquette from willow, alder and black locust biomass. Briquetting was conducted at a pressure of agglomeration: 27 MPa, 37 MPa, 47 MPa. Three years old shoots of research material were pre-chipped and then milled into hammer mill using a sieve with a diameter of holes: ø15, 10 and 4 mm. Obtained briquette quality was assessed according to guidelines included in norms PN-EN 15150:2012 and PN-EN 15210-2:2011. Accordance with these requirements determined the specific density and mechanical durability of the briquette. It has been shown that the influence of degree of material fragmentation causes an increase of investigated quality parameters and can be described by the mathematical models

Key words: energy plants, biomass, solid biofuels quality, briquetting

Introduction

Biomass is still considered as the primary source of renewable energy in Poland. Energy derived from biomass constiutes 15% of the global energy consumption, whereby this share is even higher in the developing countries. The main advantage of biomass is lower sulphur dioxide emission during combustion as compared to fossil fuels, and lower ash content. Furthermore, the carbon dioxide balance during combustion equals zero, since the plants absorb it through photosynthesis [1].

The main source of biomass for production of low-processed solid biofuels, such as logs or chips, and highly-processed [compacted] ones i.e. pellets or briquettes are energy plantations. In Poland, the growers have a wide range of plants available to match the plants being grown to the water and soil characteristics of the habitat. This maximises biomass yield while minimising the effort on setting up and managing a plantation. The ongoing research gradually expands the list of energy species [2;3;4;5;6;].

From the perspective of biomass conversion to solid biofuels, the diversity of species mentioned results in that the properties of the material [biomass] vary and considerably affect the individual production processes and quality parameters of the end product [7;8;9].

The hierarchical system of biomass classification [PN-EN 14961:2011] includes four types of biomass: wood, herbaceous [grass and perennials], fruit and mixed ones. The best parameters offers the wood biomass [in relation to other biomass types it has a higher caloric value, bulk and specific density and lower ash content].

On energy plantations are planted: willow, alder, black locust, poplar and other. However, there has been no research carried out into the briquetting of fine biomass of those species, and into the quality of briquette obtained, therefore the objective of this study is to determine the effect of fineness of the selected woody biomass [willow, alder and black locust] on the quality of briquettes made of it.

Materials and methods

Material from the local department's experimental plantation of fast growing trees within the Energy Crop Collection was used for the study. Three-year old shoots of willow, alder and black locust, after cutting, were bunched and aged under roof. After natural reduction of moisture to 14%, the material was processed with a drum chipper to the theoretical length of chips 20 mm.

Moisture of the test material at individual stages of the study was measured with the dryer method according to the standard [PN-EN 14774-1:2010].

At the following stage, the chips were ground with POR ECOMEC hammer mill models C120-E/A. In the machine, a drum with rigid beaters was installed, operating with an interchangeable aperture sieve. With the interchangeable sieves of different aperture diameter, it is possible to achieve various fineness of the material. Sieves with 4, 10 and 15 mm mesh size were used for the study. The machine features gravity material output and a system of worm conveyors for handling the ground material.

Grain size composition of the material obtained was measured with an LPzE-4e Morek Multiserw shaker, with a set of sieves with round holes with diameters 45; 16; 8 and 3.15mm, and braided sieves with square holes 2.8; 2; 1.6; 1.4; 1; 0.5; and 0.25mm [PN-EN 15149:2011]. Moreover, bulk density of the material obtained was determined according to the standard [PN-EN 15103:2010].

So prepared material, after achieving 12% moisture content, was subjected to briquetting process. In the study presented, hydraulically driven piston briquetting machine manufactured by POR ECOMEC Junior model was used. This briquetting machine represents a large group of machines available in the Polish market and produces briquettes with diameter 50 mm and length from several to a dozen centimetres. The briquette length is related to the size of material batch briquetted in a single cycle. In case of material of low bulk density, relatively small quantity of material enters the pre-compacting chamber, which results in the shortest briquettes. For material with high bulk density, the pre-compacting chamber is optimally filled, and the highest briquette length is achieved, from 5 to 7 cm. POR ECOMEC press allows the adjustment of operating pressure, so it was possible to agglomerate the material at three pressures: 27, 37, 47 MPa. The briquette obtained was evaluated for quality according to the guidelines of the standard [PN-EN 14961:2011]. According to those requirements, specific density of a briquette was determined, using a kit for determining specific density RADWAG model WPS 510/C/1 according to standard [PN-EN 15150:2012].

Furthermore, the durability of the briquettes was determined. The measurement was performed according to the standard [PN-EN 15210-2:2011]. A sample weighing 2 kg [± 0.1 kg] was placed in the tester drum with a special shelf for faster crushing of the briquettes. According to the standard, the drum was rotating at the speed 21 rpm, and test duration was 5 min. After completion of the test, the briquette was screened through a sieve with mesh diameter 35 mm. The sieve residue was weighed on a laboratory scale with accuracy 0.1g, and the *DU* briquette mechanical durability was calculated from formula [1]:

$$DU = \frac{m_A}{m_E} \cdot 100 \qquad (1)$$

Where:

DU – briquette durability (%);
m_A – sample weight before test (g);
m_E – sample weight after test (g).

The durability of briquettes is understood as the resistance to external dynamical factors causing damage. It is one of the features critical for the ease of transport, storage and feeding such biofuel. Although the current normative regulations (PN-EN 14961:2011) do not set an obligation on marking durability, it was taken into account in the present study, as it is of extreme importance, in particular to the individual customers.

Results and discussion

In addition to the planned moisture content, in the initial tests, material briquetting was performed with the moisture content above 15%. The quality tests of the granules obtained proved clearly that this moisture content causes that the density and durability of briquettes falls within ranges above normative valued (density below 800 kg·m^{-3}, durability below 80%).

Determining the effect of grain size composition on the compacting process is made difficult, since it is described with several values.

For the needs of the study, an evaluation index of biomass fineness was applied, defined as:

$$S_g = \int_a^b f(x)dx \qquad (2)$$

where:

S_g – fineness index
$f_{(x)}$ – grain size composition cumulative curve
a – low limit of particle size;
b – high limit of particle size.

The analysis of grain size composition made it possible to determine the limits of *a* and *b* ranges, used for calculating the fineness index (2). The lower limit a = 0.5 corresponds to the most abundant fraction of small particles present in the range dust – 1.6 mm, and the upper limit b = 3.14 mm is the value of the most abundant fraction of large particles in the range 2 – 8 mm. A proper share of those fraction in the mixture being compacted will affect the process and parameters of the granulate obtained

Based on the grain size composition data recorded, cumulative curves were drawn for the materials tested with integration limits 0.5 and 3.14 mm marked. Then, fineness indexes were determined, and the results compiled in table 1.

Analysing the fineness index data, it can be found that black locust has the lowest S_g, which proves that it is the least grindable material. The highest S_g values were observed for alder with the highest share of fine fractions in the mixture, thus showing the highest grindability. Willow has similar properties to alder.

Table 1
Fineness index S_g of research material

Material	Mesh size of sieves (mm)	Fineness index Sg (-)
Willow	4	648,87
	10	306,59
	15	181,26
Alder	4	661,41
	10	314,95
	15	189,44
Black locust	4	613,78
	10	303,48
	15	162,19

(Source: own studies)

According to the valid standards (CEN/TS 14961) specific density of briquettes is one of the main values used for quality assessment. Briquettes meeting the quality requirements must be characterised, among others, by specific density above 800 kg/m^3.

The statistical analysis performed proved that bulk density of the material before agglomeration ρ_u, fineness index S_g and compaction pressure p significantly affect the specific density of the briquette.

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The statistical analysis performed proved that bulk density of the material before agglomeration ρ_u, fineness index S_g and compaction pressure p significantly affect the specific density of the briquette.

Statistical analysis performed with Statistica 9.0 software allowed non-linear estimation in order to find a mathematical function describing the above relationships. The highest match fidelity between a mathematical model and test results, assessed based on the determination factor, was obtained for the following relationship:

$$\rho=a\cdot\rho_u^{b}\cdot S_g^{c}\cdot p^{d} \tag{3}$$

where:

ρ – briquette specific density (kg·m^{-3});
ρ_u – bulk density of briquetted material (kg·m^{-3});
S_g – fineness index (-);
p – compaction pressure (MPa);
a, b, c, d – model constants.

Results of the estimation carried out are presented in table 2.

Table 2
Non-linear estimation results for the model $\rho=a\cdot\rho_u^{b}\cdot S_g^{c}\cdot p^{d}$, $R^2 = 0.84$

Parameter	Value	Standard error	p	Value T df =140	Low confidence limit	High confidence limit
A	462,003	49,06277	0,000000	9,41658	365,0037	559,0032
B	0,090	0,01901	0,000006	4,7206	0,1273	0,0521
C	0,015	0,00649	0,04001	1,8257	-0,0013	0,0323
D	0,260	0,00989	0,000000	26,277	0,2404	0,2795

(Source: own studies)

Analysing the effect of individual model parameters on the specific density ρ, it can be concluded that:

- positive value of the *b* and *c* exponent indicate that, as the specific density ρ value grows along with the growth of bulk density ρ_u and fineness index S_g values. This is a typical relationship while compacting not only biological materials.
- power exponent, present at the compacting pressure *d*, indicates that the increase of pressure *p* causes an increase of the specific density ρ.

Durability of briquettes understood as the resistance to external damaging factors is one of the features critical for the ease of transport, storage and feeding of this biofuel. Although the current normative regulations (PN-EN 14961:2011) do not set an obligation on marking durability, in the present study, while compacting a broad range of materials and with different operating settings of the briquetting machine, determining the durability was necessary for a comprehensive characteristics of the briquettes obtained.

The statistical analysis carried out proved that the fineness index S_g and compaction pressure *p* significantly affect the durability of briquettes.

With the Statistica 9.0 software, non-linear estimation was performed to find a mathematical function describing the relationships between the S_g index, agglomeration pressure *p* and briquette durability *DU*. The highest match fidelity between a mathematical model and test results, assessed based on the determination factor, was obtained for the following relationship:

$$DU = a \cdot p^{b} \cdot S_g^{c} \tag{4}$$

where:

DU – briquette durability
p – compaction pressure (MPa);
Sg – fineness index (-);
a, b, c – model constants.

Results of the estimation carried out are presented in table 3.

Table 3
Non-linear estimation results for the model $DU = a \cdot p^{b} \cdot S_g^{c}$, $R^2 = 0.76$

Parameter	Value	Standard error	p	Value T df =140	Low confidence limit	High confidence limit
a	40,978	2,879	14,232	0,0000	35,286	46,670
b	0,010	0,010	0,994	0,0322	0,010	0,030
c	0,196	0,009	20,600	0,0000	0,177	0,215

(Source: own studies)

Analysing the effect of individual model parameters on the briquette durability *DU*, it can be concluded that the value of the *b* and *c* exponents cause that the increase of the compaction pressure *p* and S_g fineness index increase the durability *DU*. This effect is quite obvious. A increase of the fineness index is caused by the increased amount of small particles, causing the increase of the contact area and increased number of contact points. In addition to that, the increased compaction pressure leads to the increased mechanical durability of briquettes.

Conclusion

To conclude the results of the study, it was proven that the increase of pressure and fineness of material described with the S_g index improves the quality parameters i.e. the specific density and durability. In case of the specific density, a significant positive effect of the material bulk density was also proven. The statistical analysis performed enabled description of the above relations with the following mathematical relationships ($\rho = a \cdot \rho_u^b \cdot S_g^c \cdot p^d$ and $DU = a \cdot p^b \cdot S_g^c$), with the degree of matching R^2 0.84 and 0.76 respectively.

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EXAMINATION OF ENERGETIC INDEXES OF AIR TO WATER HEAT PUMP

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Abstract: The spread of heat pump applications is due to the fact that we realized that these are also renewable energy sources; at least to the extent that the COP value (Coefficient of Performance) is visible and clear. Public assessment of heat pump would be improved in cases of applications utilizing renewable energy sources for input power. The application of air-to-water heat pumps are growing and nowadays are capable of heating residential or commercial building spaces and hot water supplies during all seasons. It is known that the performance of an air-to-water heat pump depends on the outside temperature, so the general COP values can be evaluated as instantaneous data. The definition and introduction of the SPF (Seasonal Performance Factor) has already proven to be a more useful energetic index for applications. It is considered as a weighted average, which gives a more accurate picture of the power consumption and the applicability conditions. In case of outdoor pools, which can be enjoyed the summer season only (for example: hotels, pensions, summer camps and homes). Air-to-water heat pump systems can be used effectively for heating and temperature regulation of the pool water. However, even in this limited application area we can prove that an optimal period of operation exists which is indicated by energetic indexes.

Key words: air to water heat pump, COP, SPF

Introduction

Heat pumps are effective solutions to heating and cooling applications for all types of domestic, commercial and food industry applications. This well-proven technology has been in use for decades and heat pumps are at work all over the world providing safe, reliable heating and cooling at affordable prices. Reserves of conventional fossil fuels are finite and emissions of carbon dioxide and other greenhouse gases add increasingly to the effects of climate change. As a low carbon technology, heat pumps can significantly reduce the Carbon Dioxide emissions (8).

A worldwide milestone was the installation of a heat pump in 1937/38 to replace single room wood stoves in Zurich City Hall. The heat source of the system was the Limmat River. Today, many heat pump systems operate in office buildings, baths, public institutions such as the Germany's Bundestag (2, 7).

At the heart of a modern heat pump is a refrigeration system. Paradoxically, the refrigeration cycle is an efficient provider of heat. There are two principle locations in the transfer of heat; the point where heat is absorbed, (the source) and where it is rejected (the destination). The compressor in a refrigeration system also produces waste heat, and a significant proportion of this can be recovered, thereby reducing running costs and the ultimate release of CO_2 (1, 4, 6). The easiest way in which to understand how a heat pump works is to look at Figure 1.

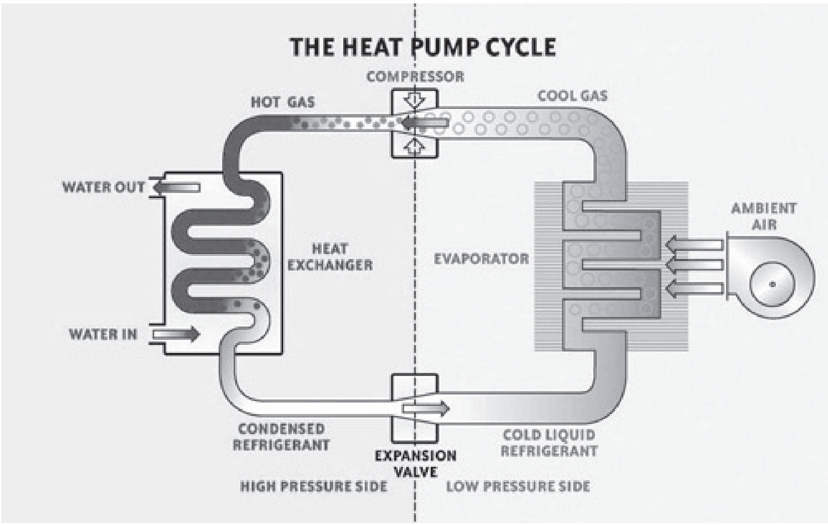

Figure 1. Operation principle of heat pump. Source: (9)

The first step in the cycle is evaporation, where the coolant circulating in the heat pump system collects heat from the air, water or the ground. This process causes the coolant to evaporate and change to a gaseous state. The second step is the compression. The heat pump's compressor rapidly compresses the coolant, which is now in a gaseous state and several degrees warmer. Thanks to the laws of physics behind the compression process, which cause the temperature of the compressed medium to increase with pressure, the compression elevates the otherwise low potential heat of the coolant to a higher level –

approximately 80°C. After that, the next step is condensation, where through the use of a second heat exchanger, the heat from the heated coolant is transferred to water circulating through the radiators. This causes the coolant to drop in temperature and condense back into a liquid state. The radiators distribute the heat provided into the heated areas. The chilled water in the heat loop then travels back into the second heat exchanger, where it is heated again. The final step is expansion, where by passing through the expansion valve, the coolant travels back to the first heat exchanger to be heated once again. This cycle keeps repeating itself over and over again (3, 5) The resulting heat can be used for space heating or to prepare hot water.

The efficiency of a heat pump can be expressed with COP (coefficient of performance) value, which is the ratio of heat output to the amount of energy input of a heat pump.

$$COP = \frac{\dot{Q}_h}{P_w} \qquad (1)$$

where

$\dot{Q}_h$ – heat output (W)

P_w – electrical input energy (W)

However, the COP value is influenced by the temperature of the evaporator and the condenser. In cases of swimming pool applications, these parameters are the ambient air and the water temperature of the pool. The same heat pump operates with lower COP value at lower ambient temperatures or higher water temperature of pool. This can be seen in table 1.

Table 1

COP of Microwell HP700 as a function of air and water temperatures

COP		T_{air} (°C)		
		15	20	24
T_{water} (°C)	15	5,34	5,81	6,29
	20	5,12	5,5	5,73
	25	4,83	5,21	5,55

Source: Microwell Hungary Ltd.

Accordingly, the COP value is not a reliable property in respect to the operation of the heat pump. That is the reason why researchers try to define better factors – for example SPF (Seasonal Performance Factor) or SCOP (Seasonal Coefficient of Performance) – for characterization of the heat pump. We would like to show the average value of COP of a heat pump in swimming pool applications.

Materials and methods

The measurements were carried out in Budapest at an 8.0 x 4.0 x 1.40 meter overflow system private pool at the start of the season just a few days after filling the pool. There are two alternative solutions in use for the heating of the water. One of them is a solar cover, where the heating effect is caused by the improved absorption of solar radiation and the inhibition of evaporative heat loss. The other is a HP500 type air to water heat pump (7 kW nominal heat output), which is installed on the filter-circulation system. It is capable of ambient air cooling and heating of the pool water.

The pool technology is presented in Figure 2. We indicate the measurement points, which make it possible to determine the actual COP value. The COP can be calculated with equation 1. The heat output can be determined from the change in water temperature (eq.2). It can be measured immediately before and following the heat pump directly.

$$\dot{Q}_h = c_p \cdot \dot{V} \cdot \rho \cdot \Delta T_{heatpump} \tag{2}$$

where

c_p – specific heat capacity ($J \cdot kg^{-1} \cdot K^{-1}$),

$\dot{V}$ – volume flow of the water pump ($m^3 \cdot s^{-1}$),

ρ – density of water ($kg \cdot m^{-3}$),

$\Delta T_{heatpump} = T_{out} - T_{in}$ – water temperature difference of heat pump (K).

The water temperatures were measured in the pool and before and after heat pump with an ALMEMO 2590-9 temperature measuring instrument (Ahlborn, Holzkirchen, Germany) and K type NiCr-Ni thermocouple. The volume flow ($\dot{V}$ = 6$m^3 \cdot h^{-1}$) was set by opening of the bypass line and checked by measuring the amount of water. The specific heat (c_p=4,182-4,184kJ) and density values (ρ = 997,7-998,5 $kg \cdot m^{-3}$) were obtained from table of literature (10) as a function of temperature of the water (T_{water}=18,5-22,1°C). The electrical power consumption (P_w=1,41±0,03kW) was measured with an Actaris SL7000 (Ganz Mérőgyár Kft., Gödöllő, Hungary) power meter. Figure 3 shows the measurement site of the heat pump.

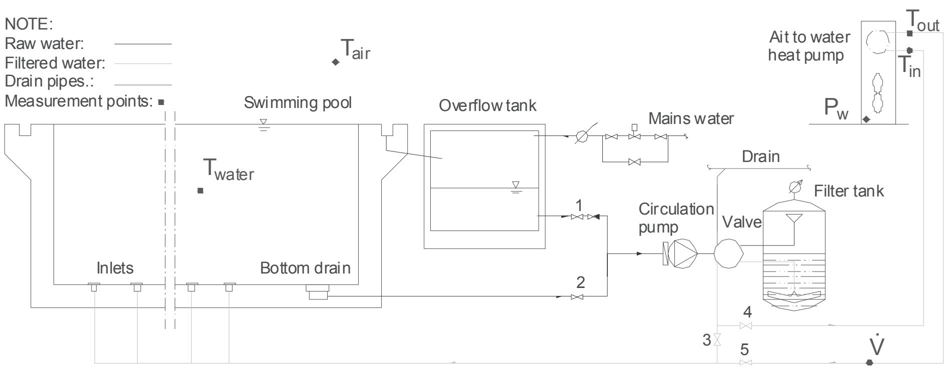

Figure 2. Technology flow diagrams. Source: Kerex Óbuda Ltd.

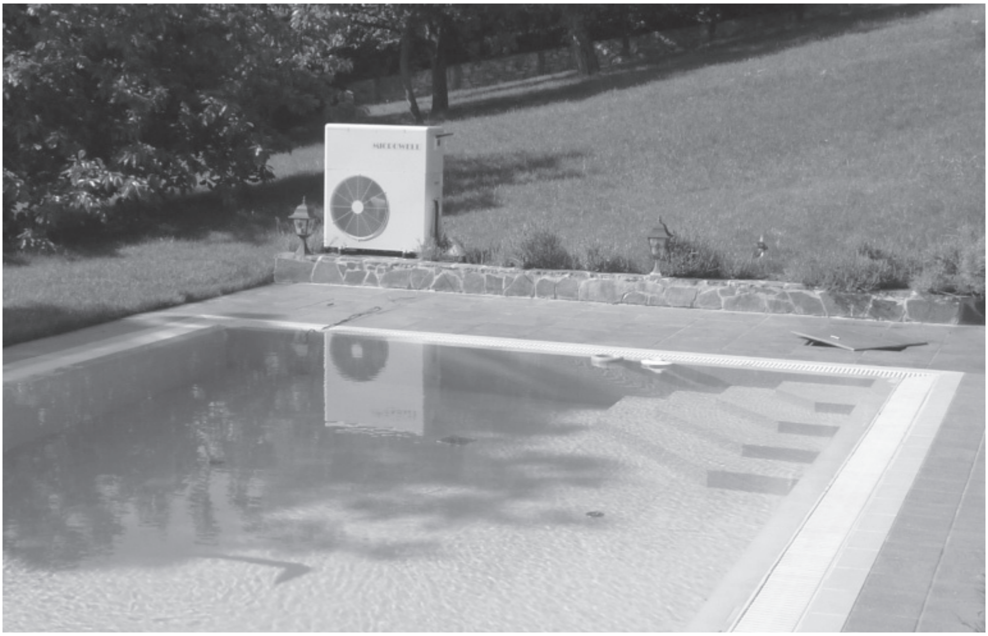

Figure 3. Private swimming pool, site of the heat pump

Results and discussion

The measurement results of 10th May are presented on Figure 4. The surface of the pool was open, the solar cover was not used. The water circulation and heat pump operation started at 8:00 and lasted until 20:00. The measurement was not disturbed by rain and the average humidity was 50.52%. It can be seen in Figure 4 that the pool water temperature is constantly rising when the heat pump is operating. The change of the curve's slope shows the COP change, too.

The current COP – determined by measuring of parameters for equations 1 and 2 and counting – are shown on Figure 5. The current value varies between 3.54 and 5.56 depending on the environmental conditions. The HP500 heat pump can characterized as having $COP_{ekvivalents}$=4.94 in the illustrated 12 hour period.

The operation of the heat pump is demonstrated in Figure 6 by thermal photography. The heat pump increased the temperature of the flowing water with $\Delta T_{heatpump}$≈1°C at $\dot{V}$= 6m^3·h^{-1} volume flow. This results in 3.7°C temperature raising of 46 m^3 of water considering the continuous heat losses.

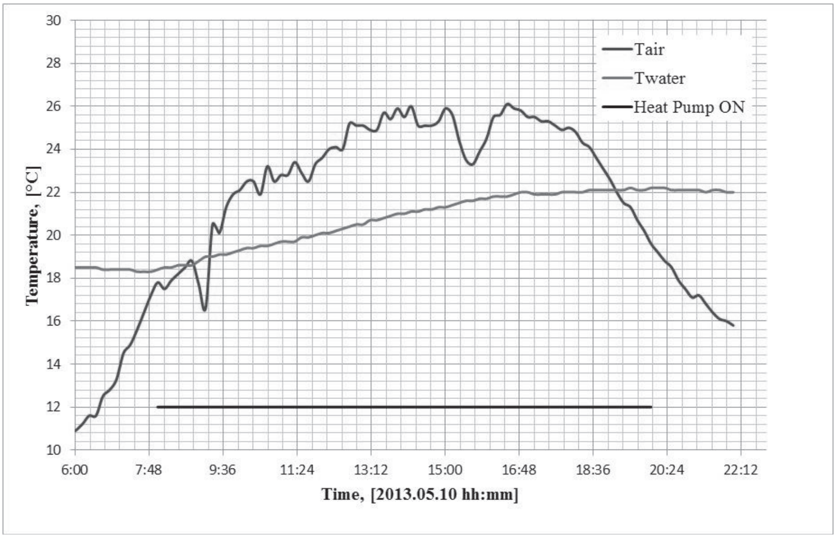

Figure 4. Air and pool water temperature as a function of time from 6 am until 22 pm.

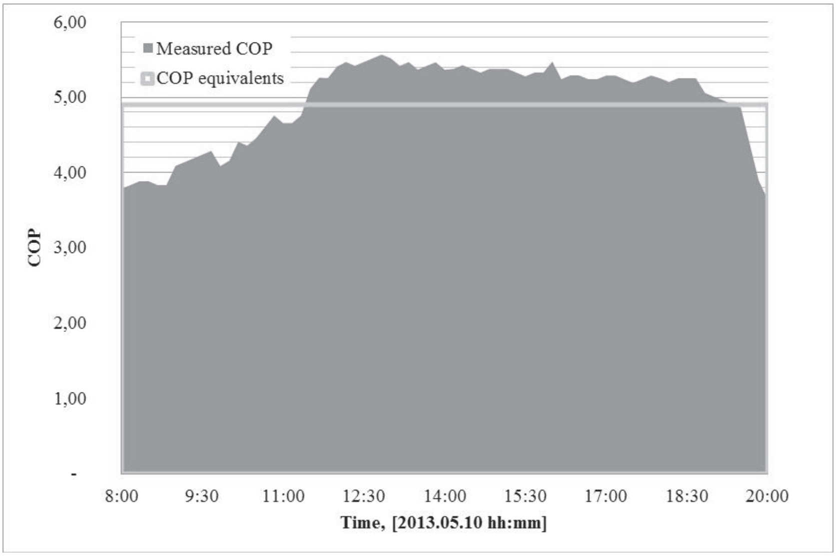

Figure 5. COP value of HP500 in case of heating of swimming pool

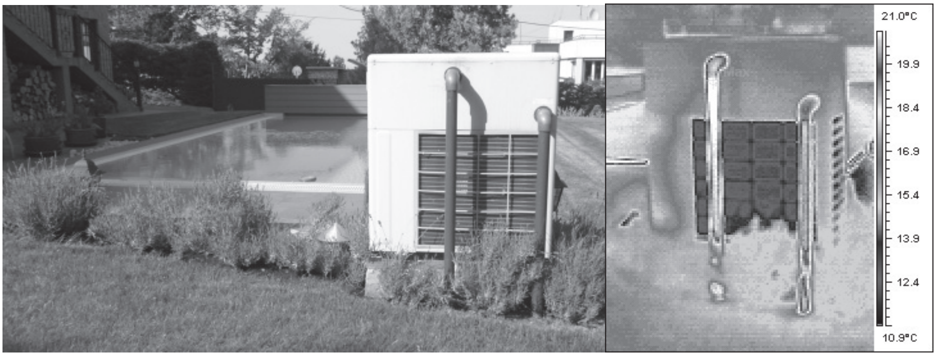

Figure 6. Thermal photography of heat pump

Conclusion

The applications of air-to-water heat pumps are almost ideal for heating of swimming pool water. During the summer period, the air temperature (evaporation temperature) is high enough (T>20°C) and the temperature of swimming pool water (condenser temperature) is low enough (T<30°C) in the case of an outdoor swimming pool for optimal heat pump operation. Despite the fact that COP is constantly changing – due to the environmental conditions and the achieved heating effect – the $COP_{equivalents}$ demonstrates well the efficiency of heat pump during the examined period. In this paper we examined a 12 hour application of a heat pump in which 16.8 kWh of electric energy was used to produce 82.9 kWh of thermal energy. We would have reached same result with ~9m^3 natural gas combustion. This means ~ 30% savings at the current prices in Hungary, but perhaps more importantly resulting in nearly 50% reduction in CO_2 emissions. (Calculated emissions with 0.56 kgCO2·kWh^{-1} and 1.96 kgCO_2·m^{-3} natural gas.)

Acknowledgments

This work was financially supported by TÁMOP 4.2.1.B-11/2/KMR-2011-0003 Improvement of Research and Education Standard of Szent István University project.

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INTERNATIONAL SCIENTIFIC CONFERENCE, SEPTEMBER 16-18, 2013, KRAKOW, POLAND

Bioenergy and Other Renewable Energy Technologies and Systems 55-65

ENERGY ASSESSMENT OF DIESEL FUEL AND B10 BIOFUELS IN SHAPING OF THE TRACTION INDICATORS OF VEHICLES EQUIPPED WITH DIESEL ENGINES

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Abstract. The article presents the most important information concerning energetic evaluation of diesel fuel and B10 biofuel in shaping of the traction indicators of vehicles equipped with diesel engines. An important segment of this evaluation are road tests on vehicle dynamics, control and operational fuel consumption as well as engine starting capability.

Key words: energy assessment, biofuels, road tests

Introduction

The most important purpose of a diesel engine fuel is to provide the engine with the best possible functionalities and operational efficiency with the lowest possible level of toxic ingredients in formed emissions [6]. Optimal combustion process in a diesel engine depends on various factors. Among them the most important are:

– constructional parameters;
– type and parameters of fuel injection process;
– type and properties of fuel.

In the following article the authors focus on fuel's type and properties that have significant influence on combustion process and constitute ecological and traction assessment of a drive unit [8].

Recently, the main type of fuel for diesel engine fuels are diesel fuels in the form of liquid hydrocarbons with boiling point of 150-360^{0}C and ennobled with specific additives. The ongoing process of depletion of oil resources, its unstable prices and lessening of the greenhouse effect resulting in CO_2 emission force to search alternative fuels derived from renewable energy sources [11]. One of the tendencies aiming to alter conventional fuels in combustion engines is possibility to use biofuels [1]. Within the Europa 2020 for smart, sustainable and inclusive growth there are 5 main goals defining development stages, which the European Union should reach in 2020 [2]. The member states declared that by 2020 they will have limited emissions of greenhouse gases by 20%, will have enhanced amount of renewable energy within energy mix by 20% and to implement energy efficiency on the same level [2]. Recent world realized it has been facing the serious ecological threat resulting from emission of CO_2 that to great extent comes from exploitation of vehicle transportation and agricultural machinery. It should be underlined that biofuels of first generation, obtained from food and oil products, have recently reached the level of economic production that means their production and consumption will be continued, but their participation in meeting demand needs for energy in transportation and agricultural branches will remain limited because of rivalry with food production industry [3].

Energy assessment of diesel fuel engine fed with diesel fuel and B10 biofuel in traction conditions

Apart from physicochemical properties of mentioned fuels, engine investigation was the basic tool for energy assessment [4] Basic physicochemical properties of Ekodiesel Ultra B diesel fuel and B10 biofuel were presented in tables 1-2.

Table 1.
The results of diesel fuel Ekodiesel Ultra B properties investigation

No.	Properties	Unit	Quantified value for fuel Ekodiesel Ultra B	Requirements according to ZN/ORLEN-4:2006	
				Min.	Max.
1.	Cetane number according to PN-EN ISO 5165		**52.1**	51.0	
2.	Cetane index according to PN-EN ISO 4264		**52.9**	46.0	
3.	Density at 15°C according to PN-EN ISO 3675	$(kg \cdot m^{-3})$	**834**	820	845
4.	Sulphur content according to PN-EN ISO 20846	$(mg \cdot kg^{-1})$	**5.6**		10.0
5.	Flash point according to PN-EN ISO2719	(°C)	**64.5**	56	

No.	Properties	Unit	Quantified value for fuel Ekodiesel Ultra B	Requirements according to ZN/ORLEN-4:2006	
				Min.	Max.
6.	Residues after carbonization from 10% of residues after distillation according to PN-EN ISO 10370	% $(m\cdot m^{-1})$	**0.01**	-	0.30
7.	Residues after cineration according to PN-EN ISO 6245	% $(m\cdot m^{-1})$	**0,001**	-	0,01
8.	Water content according to PN-EN ISO12937	$(mg\cdot kg^{-1})$	**60**	-	200
9.	Solid pollution content according to PN-EN 12662	$(mg\cdot kg^{-1})$	**12**	-	24
10.	Corrosive effect investigation on a copper plate (50^{o}C, 3 h) according to PN-EN ISO 2160	Corrosion level	**1**	1	
11.	Oxidation resistance, total insoluble residues according to PN ISO 12205	$(g\cdot m^{-3})$	**5.0**	-	25
12.	Lubricity, corrected diameter of use trace (WS1,4) at temperature of 60^{o}C according to PN-EN ISO 12156-1	μm	**348**	-	460
13.	Kinematic viscosity at 40°C according to PN-EN ISO 3104	$(mm^{2}\cdot s^{-1})$	**2.59**	2.00	4.50
14.	Distillation: - up to temp. 250°C it is distilled - up to temp. 350°C it is distilled - 95%(v/v) is distilled up to temp. according to PN-EN ISO 3405	% $(V\cdot V^{-1})$ (°C)	**42.0** **94.2** **352.5**	85	65 360
15.	Cold filter plugging point according to PN-EN 116	(°C)	**- 9**	-	0
16.	Corrosive effect on steel according to ASTM D 665A (38°C,5 h)	st. korozji	**Moderate corrosion**	-	-

Table 2

Basic physicochemical parameters of B10 biofuel

Parameter	Unit	B10 biofuel		Specification[1)]		Investigation method
		11/02/08	14/04/08	min.	max.	
FAME	% ($V \cdot V^{-1}$)	**10.3**	**10.1**	10±0.5		PN-EN 14103
Cetane number		**54.6**	**52.5**	51.0	-	PN-EN ISO 5165
Cetane index		**53.1**	**53.7**	46.0	-	PN-EN ISO 4264
Density at temp. 15°C	($kg \cdot m^{-3}$)	**833**	**833**	820	860	PN-EN ISO 12185
Distillation	(°C)					PN-EN ISO 3405
Beginning of boiling point		**171.0**	**173.5**			
5% distilled to		**200.0**	**201.5**			
10% distilled to		**210.5**	**209.5**			
20% distilled to		**224.0**	**224.5**			
30% distilled to		**238.5**	**239.5**			
40% distilled to		**253.0**	**255.0**			
50% distilled to		**267.5**	**270.0**			
60% distilled to		**282.0**	**284.5**			
70% distilled to		**295.5**	**298.5**			
80% distilled to		**310.5**	**313.0**			
90% distilled to		**325.5**	**327.5**			
95% distilled to		**334.5**	**338.0**		360	
end of distillation		**341.5**	**342.5**			
up to 250°C it was distilled	% ($V \cdot V^{-1}$)	**37.7**	**37.9**	-	65	
up to 350°C it was distilled	% ($V \cdot V^{-1}$)	**-**	**-**	85	-	
Sulhpur content	($mg \cdot kg^{-1}$)	**9.5**	**9.2**	-	10	PN-EN ISO 20884
Solid pollution content	($mg \cdot kg^{-1}$)	**38.2**	**54.8**	-	24	PN-EN 12662
Oxidation resistance	($g \cdot m^{-3}$)	**23**	**13**	-	25	PN-EN 12205
Kinematic viscosity at temp. 40°C	($mm^2 \cdot s^{-1}$)	**2.42**	**2.54**	2.00	4.50	PN-EN 3104
Acid value	mg ($KOH \cdot g^{-1}$)	**0.09**	**0.12**	-	0.2	PN-EN 14104
CFPP	(°C)	**-28**	**-18**	-	-10[2)] -20[3)]	PN-EN 116
Cloud point	(°C)	**-14**	**-7**	-	-	PN ISO 3015
Foaming properties[4)] - foam volume - foam decay duration	(cm^3) (s)	**62** **9.2**	**96** **14**		100 15	NF M 07-075
Anti-corrosive properties[4)] (on a steel arbor)	Corrosion level	**B+ moderate**	**B+ moderate**		B++ traces	ASTM D 665A, assessment according to wg NACE

Among many physicochemical properties of diesel engine fuels the most universal criterium of their usefulness is the value of a cetane number (CN). It should be underlined that a cetane number is a universal comparative indicator and not a fuel physical parameter with specified absolute value depending on chemical composition, viscosity, density, volatility and surface tension [7]. Its value indicates that one fuel is better to apply in a diesel engine from another.

Different chemical composition of diesel oil derived from oil and fuels of plant origin points out different autoignition characteristics of these fuels and necessity to correct CN values. In case of the B10 biofuel differences are hardly seen (CN comparative values) [5] [9].

According to European standards road (traction) tests are the most objective tool for energy and usefulness assessment of engine fuels. The subject of investigation were two vehicle engines with engine displacement of 2.0 dm^3, fed with Common Rail injectors meeting environmental protection EURO 4 requirements.

The tests of parallel tractions consists of:

- test of intensity of acceleration by changing gears according to PN-S-77500,
- measurement of fuel consumption at stable speeds of 90 and 120 km/h according to Rules of UNECE no. 84,
- measurement of exploitation consumption in urban, motorway and mountainous driving according to BOSMAL /I-7-12/03 instruction,
- car start-up ability at temperature of $+30^0$C; -25^0C cold-test chamber – according to BOSMAL /I-8-12/03 instruction,

Road tests were conducted using Correvit EEP-2 device for vehicle movement parameters investigation (tool accuracy ±0,5%). Measurements of fuel consumption at stable speeds were corrected according to requirements of Rules of UNECE no. 84, considering:

- fuel temperature,
- atmospheric conditions (ambient temperature, atmospheric pressure),
- rolling and aerodynamic resistance.

Corrected fuel consumption was calculated on the basis of the following equation:

$$Q_{zr1} = Q \times [1 + \alpha \times (t_o - t_p)] \tag{1}$$

where:

Q_{zr1} – corrected fuel consumption ($l \cdot 100\ km^{-1}$),

Q – fuel consumption measured at temperature of fuel during measurements ($dm^3 \cdot 100\ km^{-1}$),

α – gasoline cubical expansion rate: 0.001 ($1 \cdot {}^oC^{-1}$),

t_0 – reference fuel temperature: 20ºC,

t_p – fuel temperature at given measurement speed (ºC).

Moreover, results of fuel consumption measurements were corrected considering external reference conditions (100 kPa and 20^{o}C):

$$Q_{zr2} = K \times Q_{zr1} \tag{2}$$

where:

- Q_{zr2} – fuel consumption in $l \cdot 100\ km^{-1}$
- K – correction coefficient
- Q_{zr1} – fuel consumption in $l \cdot 100\ km^{-1}$ measured at ambient conditions during investigation (after reduction considering fuel temperature)

$$K = \frac{R_R}{R_{AERO}} \cdot \left[1 + K_R(t - t_o)\right] + \frac{R_{AERO}}{R_T} \cdot \frac{\rho_o}{\rho} \tag{3}$$

where:

- R_R – rolling resistance at investigation speed
- R_{AERO} – aerodynamic resistance at investigation speed
- R_T – total movement resistance $R_R = R_R + R_{AERO}$
- t – ambient temperature in ^oC during investigation
- t_o – reference ambient temperature (20^oC)
- K_R – correction coefficient considering influence of temperature on rolling resistance ($3.6 \cdot 10^{-3}\ \ 1 \cdot {}^oC^{-1}$)
- ρ – air density at investigation conditions
- ρ_o – air density at reference conditions

Measurements accuracy was calculated on the basis of the following equation:

$$d = k \cdot \frac{\sqrt{\dfrac{(C_i - \overline{C_i})^2}{n-2}} \cdot \sqrt{\dfrac{1}{n} \cdot \dfrac{(V_{ref} - \bar{V})^2}{(V_i - \bar{V})^2}}}{C} \cdot 100 \tag{4}$$

where:

- C_i – fuel consumption measured at V_i,
- $\overline{C_i}$ – fuel consumption at V_i speed, calculated by means of the regression equation,
- C – fuel consumption at V reference Speer, calculated by means of the regression equation,
- V_{ref} – reference speed,
- V_i – real speed during ith measurement,
- $\overline{V}$ – average speed $\overline{V} = \dfrac{\sum V_i}{n}$,
- n – number of tests,
- k – coefficient provided in the table from the rules no. 84.

Results of intensity of acceleration by changing gears in test vehicles powered with oil and the B10 biofuel were shown at fig. 1-4. (4).

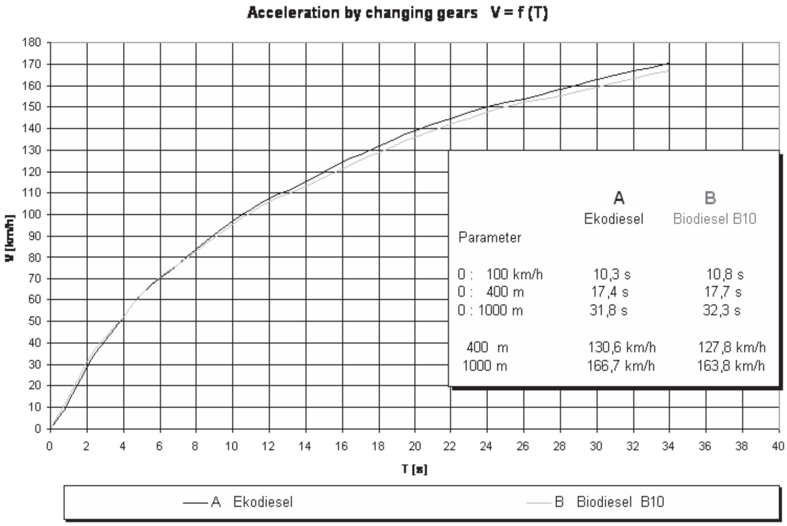

Figure 1. Acceleration of the test vehicle by changing gears in the function of time

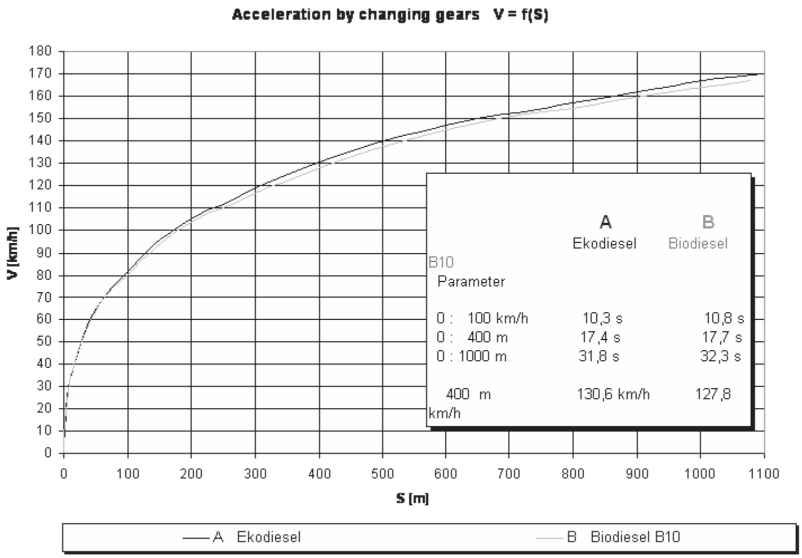

Figure 2. Acceleration of the test vehicle by changing gears in the function of road distance

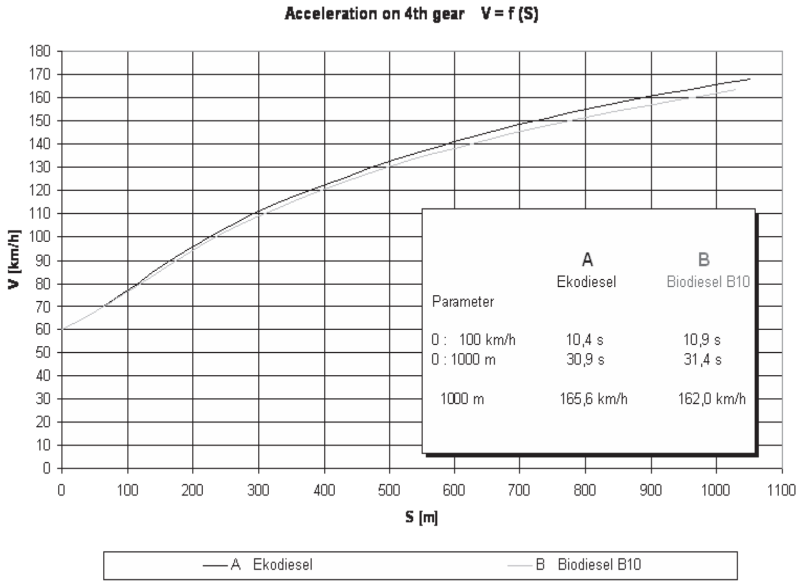

Figure 3. Acceleration of the test vehicle on the 4th gear in the function of road distance

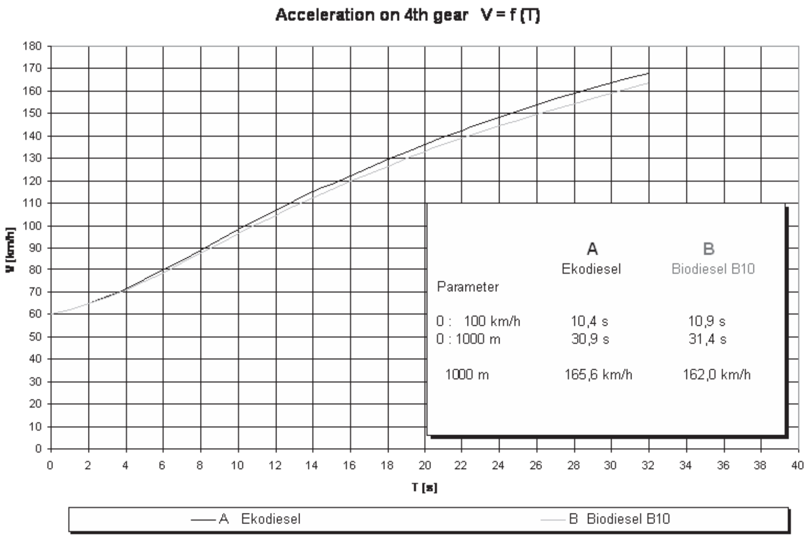

Figure 4. Acceleration of the test vehicle on 4th gear in the function of time

Results of control measurement of fuel consumption on the 5th gear and exploitation consumption were show at fig. 5-6, while engines start-up ability was shown in table 3.

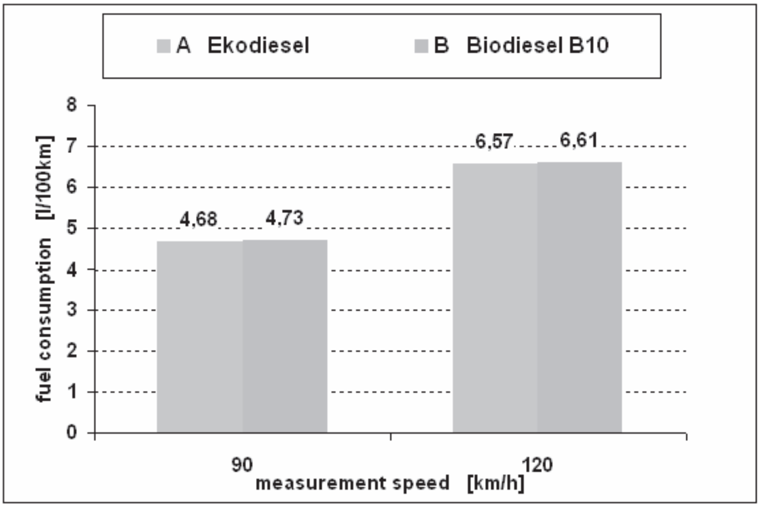

Figure 5. The results of fuel consumption on 5th gear

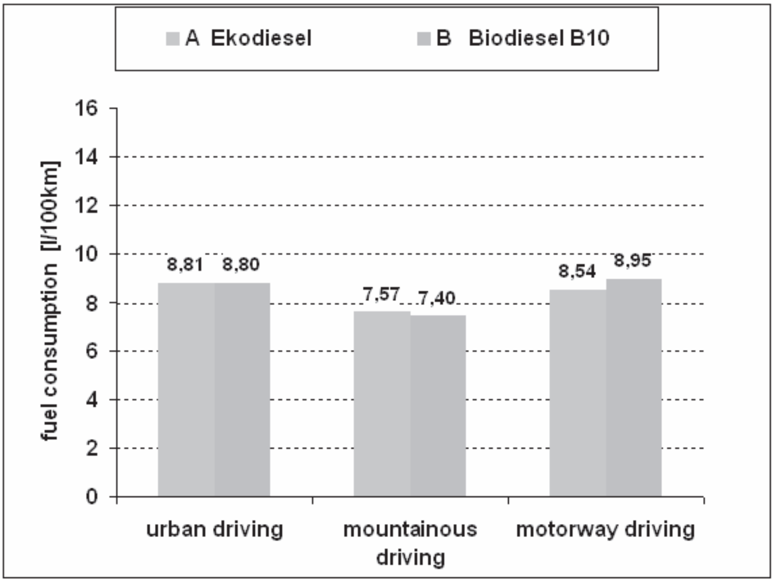

Fig. 6. The results of exploitation fuel consumption measurements

Table 3.
The results of the research of vehicle start-up ability powered with investigated fuels

<table>
<tr><td>Start-up conditions
• ambient temperature
* temperature of oil in an engine
(°C)</td><td>A
Ekodiesel</td><td>B
Biodiesel B10</td></tr>
<tr><td>• + 30
. + 30</td><td colspan="2">Correct start-up – start-up duration ca. 1 sec.
Engine operation after start-up at parking position
and when driving is correct.</td></tr>
<tr><td>• 0
* 0</td><td colspan="2">Correct start-up – start-up duration ca. 1.5 sec.
Engine operation after start-up at parking position
and when driving is correct</td></tr>
<tr><td>• - 20
* - 20</td><td>Correct start-up
– start-up duration ca. 2 sec.
Directly after start-up (for ca. 10 sec.) there were unstable engine revolutions and loudness (metallic bumps). Then engine operation at parking position and when driving was correct.</td><td>Correct start-up
– start-up duration ca. 3 sec.
Directly after start-up (for ca. 15 sec.) engine operated in an irregular mode and there were unstable engine revolutions, also metallic bumps could be heard (significantly louder than in the KR 025EJ vehicle.
Then engine operation at parking position and when driving was correct.</td></tr>
<tr><td>• - 25
* - 25</td><td>Start-up unsuccessful,
start-up duration ca. 20 sec. (3x).</td><td>Start-up unsuccessful,
start-up duration ca. 20 sec. (3x).</td></tr>
</table>

Tests results review

On the basis of parallel traction tests it could be concluded that in comparison to the vehicle (A) fed with Ekodiesel Ultra diesel fuel, the vehicle (B) fed with the B10 biofuel was characterized with following properties:

a) similar fuel consumption at stable speeds (90 and 120 km/h) and during urban and mountainous driving and slightly higher fuel consumption during motorway driving (by ca. 4.8%).

b) slightly poorer acceleration performance, by:

– 1.6 ÷ 4.9%, when accelerating by changing gears from standing start,
– 1.5 ÷ 8.6%, when accelerating on the 4^{th} gear from speed of 40 km/h and 60 km/h,
– 1.6 ÷ 7.4%, when accelerating on the 5^{th} gear from speed of 60 km/h and 80 km/h.

c) similar start-up abilities at ambient temperatures from -20 ^{o}C to +30 ^{o}C, however, engine operation (directly after start-up at temperature of -20 ^{o}C) in the vehicle powered with the B10 biofuel was louder and lasted a bit longer (by few seconds), when compared to the engine powered with Ekodiesel Ultra fuel.

d) subjective assessment of driving smoothness during urban, mountainous and motorway driving was similar.

Summary

Biofuels contained in diesel fuel play an important role in increase of Polish energy balance.

Until recently, application of biofuels as energy resources for vehicles was one of the most significant research problems as requirements specified for hydrocarbon fuels had not been met. Energy assessment of test cars' engines powered with diesel fuel and the B10 biofuel, expressed with fuel consumption during measurement on 5th gear and in exploitation conditions (urban and motorway driving), was similar to ON's.

It should be underlined that biofuels can be successful at the market of energy carriers for car vehicles and agricultural machinery, only if they are widely available and competitive in comparison to hydrocarbon fuels.

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ANALYSIS OF SOLAR RADIATION FOR THE PURPOSE OF IMPLEMENTATION OF PHOTOVOLTAIC SYSTEMS IN MUNICIPAL FACILITIES

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Abstract. This study provides an analysis of insolation, as well as determines the fluctuation of its parameters depending on the solar radiation flux density. These properties have established the basis for the definition of the scope of minimum density of solar energy flux at which a photovoltaic plant is able to cover the current power demand of a municipal waste water treatment plant. Therefore, three variants of a photovoltaic farm as a supporting power source of the waste water treatment plant have been developed.

Key words: solar energy, radiation flux density, insolation, photovoltaic cell

Introduction

Renewable power generation is a considerable branch of industry in a number of countries and it keeps developing at a very rapid pace. Its growth leads to new scientific problems of an increasingly complex nature necessitating the application of sophisticated mathematical modelling methods. Renewable energy is currently one of the youngest scientific disciplines which nevertheless covers a very broad scope of research with solar energy as one of its basic areas, the theoretical foundations of which were formed in the second half of the 20th century [1-4]. Solar power research deals with the estimation of solar energy potential and its fluctuation for the needs of solar power systems [5], growing of crops, including energy crops, and promotion of agrotourism [6-10]. In terms of research of solar power systems one may distinguish field [11] and laboratory surveys. Field surveys in Poland most frequently focus on the application possibilities of the existing solutions of thermal solar power systems for low-temperature heating purposes, such as hot tap water installations in particular. On the other hand, a certain market niche may be noticed in the field of applying photovoltaic farms for powering of concrete projects or providing power supplies to the power grid itself. Certain practical experience in Poland may be drawn from the only photovoltaic farm in Poland located in Wierzchosławice near Tarnów. On this site however, microelectronic systems have operated for less than two years, so it is difficult to find any reports on its operating effects. This gives rise to another question: why so few of such installations have been established nationwide in spite of the fact that EU directives force Poland to promote renewable energy. One of possible answers is a lack of a stable state policy in this respect or programmes supporting investments in photovoltaics. In these considerations one should also ask whether power generation in such systems is profitable within the current conditions. The article entitled 'Mult-Criterion Optimisation of Passive Photovoltaic Systems of Municipal Facilities', featuring a comprehensive overview of photovoltaic power applications, is an attempt to provide an answer to such a question. This part of the study provides a an analysis report of solar energy resources, performed at the location of a potential photovoltaic farm.

The objective of this section is to analyse the solar energy resources at the photovoltaic farm location which is intended to generate electric power for a waste water treatment plant situated in the South of Poland. In the course of research also the size of the farm has been determined.

Research method and scope

In order to determine the resources of solar energy and their fluctuation, hourly statistical data collected for a typical reference year and regarding the total flux of solar energy have been used, as recorded at the nearest weather station of the planned photovoltaic farm site. A typical reference year for ISO energy calculations was developed by the International Organization for Standardization and accepted by CEN as standard EN ISO 15927-4. The analysis also covers the determination of fluctuation of solar energy per absorption surface at different angles and southern azimuth.

The area of the photovoltaic farm was defined on basis of the following relation (1) [12]:

$$P_P = \beta_{PV} \cdot U_{PP} \cdot I \cdot A_{PV} \tag{1}$$

where:

- β_{PV} – proportionality rate for PV module ($A \cdot W^{-1}$),
- P_P – power of PV farm at operating point (W),
- U_{PP} – voltage at operating point (V),
- I – intensity of solar radiation per PV area ($W \cdot m^{-2}$),
- A_{PV} – PV module area (m^2),

where as the proportionality rate for selected silicon structures of cells was determined on basis of relation (2) provided in the study [12]:

$$\beta_{pv} = \frac{I_{SC}}{I \cdot A_{pv}} \tag{2}$$

where:

- I_{SC} – through fault current of a photovoltaic module (A), After substituting nominal data one can determine the proportionality rate of the panels for research purposes.

The equation of power generated by a module can be supplemented with the fluctuation of efficiency caused by dynamic cell temperature [13,14] relationship:

$$\eta_{PV}(T) = \eta_{PV}(300) \cdot (1 + \beta_T (T_{PV} - 300)) \quad (3)$$

where:

$\eta_{PV}(300)$ – photovoltaic cell efficiency rate at 300 (K),
β_T – temperature efficiency coefficient ($1 \cdot K^{-1}$),
T_{PV} – photovoltaic module temperature (K).

The area of a photovoltaic farm was determined on basis of relationship (1) of limit insolation value at which PV farm will cover the power demand of the waste water treatment plant with the consideration of cell efficiency fluctuation as a result of changing operating temperature (3). Also the relationship (1) supplemented with equation (3) was used to define the value of power generated by the farm after differentiating it.

Analysis of research results

The research data pertain to hourly parameters of total solar radiation intensity on a surface in a reference year calculated on basis of EN ISO 15927:4. On basis of these data, the total angle-dependent (0º, 30º, 45º, 60º) insolation of southward receiving surface was determined in the specific months, as presented on the diagram (fig. 1).

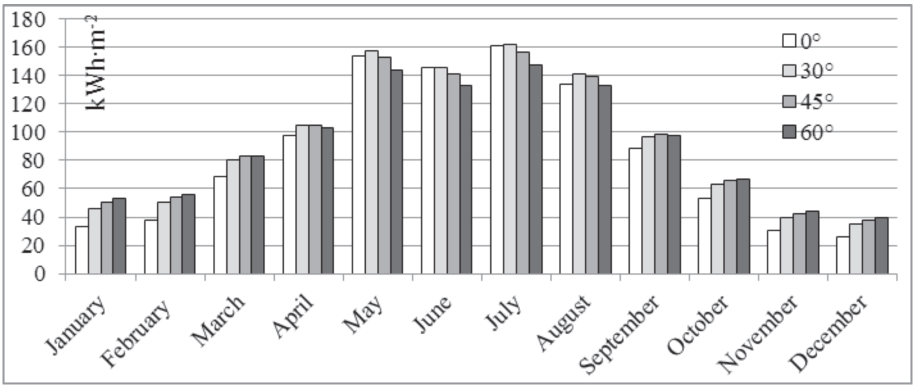

Figure 1. Monthly distribution of insolation depending on the angle of receiving surface

Insolation fluctuates strongly in the specific months between 25 $kWh \cdot m^{-2}$ in December and 161 $kWh \cdot m^{-2}$ in July (fig. 1). The insolation value is influenced by the angle of the receiving surface. Optimal tilt for the autumn-winter season (from October to March) should be 60º and 30º for other. However, within the whole year, the amplitude of insolation value is not so noticeable (table 1).

Table 1
Annual insolation value

Angle	Insolation $(kWh \cdot (m^2a)^{-1})$
0º	1026
30º	1118
45º	1122
60º	1096

The maximum insolation difference within a year between 45° and 60° is 28 $kWh \cdot (m^2\ a)^{-1}$, that is 2,5%, whereas the insolation difference between surfaces inclined at 30° and 45° is only 4 kWh, bearing no practical impact on power yield.

Also the distribution of insolation depending on the density of solar radiation (insolation) [14] is an important parameter, as presented in fig. 2 for the analysed area.

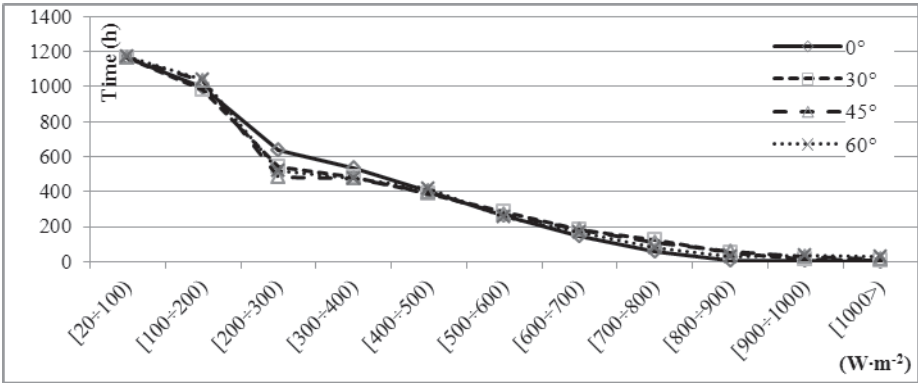

Figure 2. Distribution of insolation at selected angles of receiving surface as a function of insolation

The above diagram presents the insolation value as a function of insolation, with the latter presented below the diagram. As it is evident on basis of the chart (fig. 2), over 50% of daily time in a mean year ground is reached by a radiation flux density of 200 $W \cdot m^{-2}$. At such a small flux of solar energy, the efficiency of photovoltaic cell conversion efficiency must be considered in the calculations [14]. According to the presented diagram (fig. 2) one can notice that the optimal angle of the receiving surface in terms of small densities of solar radiation flux, that is 500 $W \cdot m^{-2}$, should amount to 0^O. Due to the fact that for this value of solar radiation, a horizontal alignment is optimal, one may conclude that diffused radiation makes up as much as 85% of the daily volume. Only above 500 $W \cdot m^{-2}$ should the angle of the receiving surface should be from 30º to 40º, so as to ensure the maximum capturing of solar radiation.

In order to determine the parameters of a photovoltaic farm, a detailed insolation analysis of the preselected actinometric station representing the site was performed. Figure 3 presents the distribution of insolation in the specific months depending on the density of solar energy flux and with the consideration of the optimal angle of the receiving surface. According to the diagram (fig. 3), the greatest yield of solar energy occurs in May, June, July and August at an angle of 30º (insolation distribution curves in the diagram align with each other). Furthermore, the distribution of insolation in April resembles the one in September, just as October and March, at an angle of 45º. In November, December and February, the distribution of insolation is virtually identical, whereas the number of hours where the density of solar energy flux is less than 200 W·m^{-2} does not exceed 80 per month.

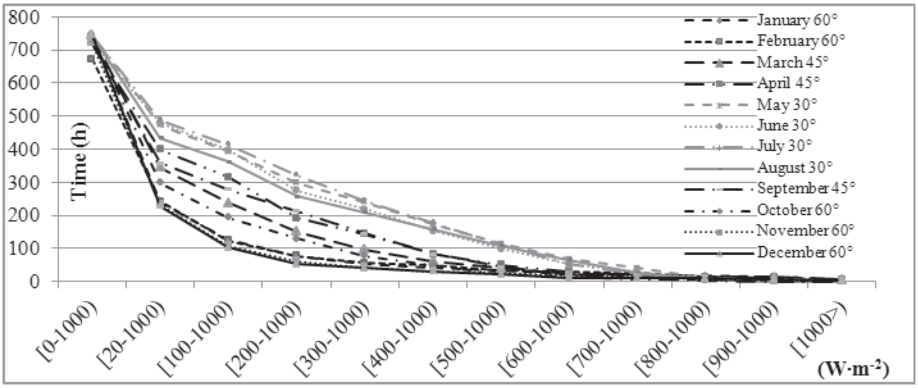

Figure 3. Monthly insolation values for optimal angle of the receiving surface

The annual insolation value analysis with its percentage values depending on the flux density is presented on the diagram (fig. 4). In the presented diagram it is evident that the (continuous) line marked as an optimum mostly forms an envelope of other curves, thus confirming that the amount of energy in the course of the year will be the highest, if the step-adjustment of the receiving surface angle is performed.

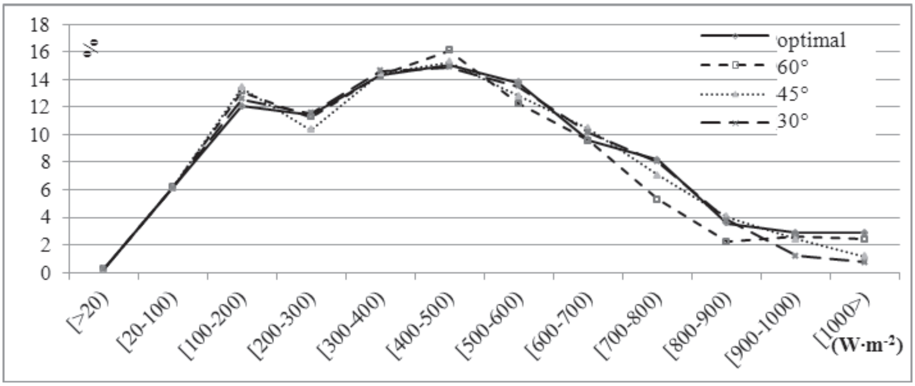

Figure 4. Percentage value depending on solar radiation flux density

Within a year, the greatest intensity of radiation reaching the surface, depending on the solar radiation flux density within 400-500 $W \cdot m^{-2}$, amounts to 15%. It is worth nothing that almost half of total energy reaching the ground has a flux density value of 300-600 $W \cdot m^{-2}$.

Thanks to the performed broad analysis of solar radiation energy at the location of the small photovoltaic farm intended as a supporting power source of the waste water treatment plant, it was possible to define the scope of solar radiation density flux values in which the power generated by the PV farm should cover the demand of the waste water treatment plant. This scope was determined as 200 $W \cdot m^{-2}$-350 $W \cdot m^{-2}$, whereas for the purpose of further analysis it was split into three variants: **W1** 200 $W \cdot m^{-2}$, **W2** 250 $W \cdot m^{-2}$ and **W3** 350 $W \cdot m^{-2}$.

In practical applications few types of photovoltaic cells may be distinguished, while the most frequently applied for power generation purposes are; monocrystalline, polycrystalline, amorphous cells.

For such types of photovoltaic cells, an analysis of the national market was performed, assuming the full availability of technical know-how on these modules, particularly regarding their operating point data, as compiled in table 2. On basis of relationship (2), the proportionality rate of each photovoltaic module was calculated, whereupon the rate was multiplied by the voltage value at peak power point, thus determining the efficiency of analysed modules as specified in table 2. Due to the neutral character of the research, no manufacturer data has been provided.

Table 2.
Specification of photovoltaic cells (mean values)

Label	PLN/Wp	Unit price $PLN \cdot m^{-2}$	Efficiency rate	Efficiency $Wp \cdot m^{-2}$
Monocrystalline	12,28	1597,56	13,9%	139,31
Polycrystalline	11,61	1517,76	13,1%	131,32
Amorphous	11,82	870,39	7,5%	75,32

On basis of market information specified in table 2 it was concluded that the monocrystalline cells have the highest efficiency rate and a similar unit price per Wp and m^2 of active surface compared to polycrystalline and amorphous cells. Therefore, monocrystalline cells have been adopted for further research.

The following criteria were used for the calculation of active surface of photovoltaic modules:

1. Maximum photovoltaic farm power should not exceed the maximum power subscribed with the power supplier, increased by the mean value of power demanded by electric devices installed at the waste water treatment plant.
2. Power generated by the PV farm should cover at least 90% of demand in the summer half of the year (April-September).
3. Points 1 and 2 should be fulfilled assuming that two reactors of the plant are operating; therefore, a growth of power consumption and power demand by electric devices of the waste water treatment plant by 62,26% was assumed.

4. The smallest photovoltaic farm to be considered in the analyses should meet the criterion 1 and 2 at current power and energy demand, that is operation of a single waste water treatment plant reactor.

On basis of the adopted criteria 1-4 and considering the limit values of solar radiation flux density from 200 $W \cdot m^{-2}$ to 350 $W \cdot m^{-2}$, three variants were developed: **W1** 200 $W \cdot m^{-2}$, **W2** 250 $W \cdot m^{-2}$, **W3** 350 $W \cdot m^{-2}$. Based on relationship (1) and the adopted criteria 1-4, the surface of photovoltaic modules was determined, as specified in table 3.

Table 3
Listing of photovoltaic plant parameters for three variants

Variant	**W1**	**W2**	**W3**
Mean power demand (kW)	30	30	30
Threshold flux density ($W \cdot m^{-2}$)	200	250	350
Required receiving module surface (m^2)	1100	860	620
Peak farm power (kWp)	153,06	120	85,72
Maximum farm power (W)	137,76	108	77,14

Summary

In order to determine the parameters of a photovoltaic farm, a detailed insolation analysis of the preselected actinometric station, regarded as a reference station for the site, was performed.

1. Insolation fluctuates strongly in the specific months between 25 $kWh \cdot m^2$ in December and 160 $kWh \cdot m^2$ in July. The insolation value is influenced by the angle of the receiving surface. Optimal tilt for the autumn-winter season (from October to March) should be 60º and 30º for other.
2. Within a year, the greatest intensity of radiation reaching the surface, depending on the solar radiation flux density within 400-500 $W \cdot m^{-2}$ amounts to 15%. It is also worth noting that almost half of total energy reaching the ground has a flux density value of 300-600 $W \cdot m^2$.
3. The performed solar radiation analysis at the photovoltaic farm location, in connection with the adopted functional and operating assumptions no. 1-4 allowed to develop three variants of such a PV farm which would cover the current power demand at such low solar radiation flux density as 200-350 $W \cdot m^{-2}$.
5. For variants **W1** 200 $W \cdot m^{-2}$, **W2** 250 $W \cdot m^{-2}$ and **W3** 350 $W \cdot m^{-2}$ the necessary area of photovoltaic monocrystalline modules was determined, together with other parameters of the PV farm, while a complete specification is provided in table 3.

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OPERATIONAL SAFETY OF BIOMASS CO-FIRING INSTALLATIONS

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Abstract. Biomass co-firing technology with conventional fuels is one of the easiest ways to produce renewable energy. It is also the easier process and requires smaller financial outlay than the other renewable technologies. Moreover, co-firing is currently the most economically advantageous form of the biomass use in the energy industry. Mixture co-firing can be carried out in the existing stoker-fired boilers, pulverized fuel boiler and grate boilers. However, the basic condition is to maintain optimal share of biomass in the fuel mix, taking into account both the nature and the type of furnace and physicochemical properties of the burned fuel. Blocks, where biomass is co-fired with conventional fuels has many power stations in Poland. The most renewable electricity in Poland is produced by biomass co-firing. Currently there are 41 power stations with biomass and fossil fuels co-firing. The aim of this paper is to analyze and evaluate the systems failure, where the biomass co-firing process is implemented. The analysis will identify the most important causes of threats and dangerous situations. The study was based on the research results, conducted in selected thermal power stations implementing biomass co-firing process. Dangerous developments associated with these processes (fires, explosions) were detailed analyzed.

Key words: biomass installations, co-firing, power plants

Introduction

According to the International Energy Agency, biomass is the fourth largest energy resource in the world after oil, coal and gas. It is estimate that by 2050 sustainable sources of biomass could be enough to supply the world with 10%-20% of its primary energy requirements. The EU has indicated that the use of biomass will double over the next few years and account for around a half of the total effort of reaching the EU's 20% renewable energy target by 2020 [1].

Biomass is burnt alongside coal in existing coal-fired power stations. This is a recognized renewable and carbon abatement technology. By substituting coal with biomass, emissions of CO_2 can be reduced significantly. Co-firing biomass to deliver up to 4% heat output requires relatively little capital expenditure and can be achieved with minor modifications to the existing facilities. Increasing the heat output to 20% and above requires quite significant capital expenditure on new biomass processing, handling and firing systems.

Biomass co-firing technology with conventional fuels is one of the easiest ways to produce renewable energy. It is also easier process and requires smaller financial outlay than the other renewable technologies [2,3] . Moreover, co-firing is currently the most economically advantageous form of the biomass use in the energy industry.

In order to reduce CO_2 emissions from existing plants with small capital investment, biomass co-firing with coal is the best possible option [4,5,6].

It is also a much simpler method than biomass combustion. Mixture co-firing can be carried out in the existing stoker-fired boilers, pulverized-fuel boiler and grate boilers. Biomass co-firing in existing coal-fired boilers has emerged as an option for voluntary reduction in CO_2 emissions to mitigate the global warming problem [6]. However, the basic condition is to maintain optimal share of biomass in the fuel mix, taking into account both the nature and the type of furnace and physico-chemical properties of the burned fuel [7,8]. Attention must be paid to increased deposit formation in the boiler and limitations in ash utilization due to constituents in biomass, especially alkali metals that may disable the use of ash in building materials. Due to undesired changes of ash compositions, the share of biomass is usually limited to approximately 10% of the fuel input [9].

Simultaneously, the process of biomass co-firing is accompanied by high fire-explosive, especially in connection with the operations of this process, ie.: storage compounds, preparation and transport, milling in the existing mill sets.

These threats are i.a. the result of the introduction of new fuel with different physico-chemical properties into the co-firing process in the energy installation.

The sharp increase in explosion risk of co-firing systems designed for wood pellets, straw, sunflower hulls and bran cereal is due the enlargement of used biomass assortment: cocoa shells, oil cakes, industrial wastewater. Dust from these pellets are classified to ST 2 explosion class, in contrast to previously mentioned, included into ST1 explosion class [10,11].

Table 1
Dust explosion classes according to K_{st} value

Dust explosion class	K_{St} value * ($bar\cdot m\cdot sec^{-1}$)	P_{max} (bar)
St 1	> 0 to 200	10
St 2	> 200 to 300	10
St 3	> 300	12

*The K_{st} value is calculated as the equivalent pressure in a 1 m^3 sphere from the cube law
(K_{st} value = cube root of volume x explosion pressure rise).

There are basically three options for co-combustion [7,10]:
- direct,
- indirect
- and parallel co-combustion.

Direct co-combustion is combustion of biomass together with fossil fuel in a single combustion chamber. Indirect co-combustion means combustion of fossil fuel with previously gasified biofuel, and parallel combustion requires at least two boilers as biomass is burned in one and fossil fuel in another [7,10,11].

Regarding low investment cost, most popular is the direct co-firing. As biofuel added to the carbon may be forest or agricultural biomass in the unprocessed or crushed form or compacted fuel (pellets, briquettes). However according to polish legislation the forest biomass used in the boiler should be withdraw by 2015 [13].

Current co-firing situation in Poland - overall approach

Blocks, where biomass is co-fired with conventional fuels have many power plants and thermal power stations in Poland. The most renewable electricity in Poland is produced by biomass co-firing. Currently there are 43 power stations with biomass and fossil fuels co-firing [14].

In the period 2006-2010, in Poland use of biomass in co-firing almost tripled increased, and in 2011, more than half of the consumed biomass (for energy purposes) was co-fired.

Table 2
Renewable energy resources trade in Poland in 2013

Investment	Number of Investments	
	No.	(%)
Biogas power plants	211	11,6
Solar power plants	12	0,7
Water-Power Plant	775	42,5
Biomass power plants	21	1,2
Wind Turbine	765	41,9
Power plant with co-firing processes	43	2,3

Source: based on [13]

The most common type of biomass for power plants and thermal power station in Poland are:
- agricultural waste such as straw pellets,
- forestry residues, and wood pellets from sawdust, wood chips,
- wastes biomass that are biodegradable, such as briquettes, sunflower hulls, husk grain or dried fruit.

Part of biomass used in installations in 2011-2012 was imported. Generally, the amount of biomass imported into Polish is growing, from 300 thousand tons in 2007 to more than 2 million tons in 2012.

Unfortunately, the process of biomass co-firing in Poland has many shortcomings. Inspections carried out by the Labor National Inspectorate in the period 2010 - 2011 showed that the majority of plants have started biomass and coal co-firing without adequate protection the carburizing drafts and mill installations [15].

In all controlled objects, irregularities of carburizing systems work were found, with particular emphasis on the biomass and coal co-milling process. Moreover, since 2005, in the vast majority of companies with biomass co-firing processes, the technology fires have occurred. First of all, the mill sets where the biomass and coal are co-milled are not adapted for this process. The coal mills for milling coal and other minerals are use for this purpose. Co-firing is realizing mainly in the oldest coal boilers (mainly in pulverized). The average boilers age in polish power and heat plants intended for biomass co-firing is 35 years [16].

Adding biomass to this fuel stream causes deposition of these materials – due to their adhesive properties - inside the devices creating the conditions for ignition.

The problems and irregularities are regarding also the electric devices, working in the potentially explosive atmospheres, in the carburetion systems of thermal and power plants.

Material and scope of analysis

The aim of this paper is to analyze and evaluate the systems failure, where the biomass co-firing process is implemented. The analysis will identify the most important causes of threats and dangerous situations. The study was based on the research results, conducted in selected heat and power plants in Poland implementing biomass co-firing process. Dangerous developments accompanying these processes (fires, explosions) were analyzed thoroughly. Special attention was paid to the explosion location in installation. There is attempted to identify the causes of the various explosions and crashes.

There were 10 larges polish power plants selected, where failures and explosions in period 2010-2013 were analyzed.

Results and discussion

There are no comprehensive statistics on dust explosions in industry, either nationally or internationally [17]. This data are very often an internal plants documentation and are not publicly available. There can be find only some information about fatal dust explosions and incidents that involved fatalities or serious injuries [18] .

That is way the acquired data about explosions and failures in the selected co-firing installation were analyzed thoroughly.

The detailed specification regarding the analyzed power plants (period 2010-2013) is presented on the fig.2.

Based on the collected data, it can be stated that the most often explosions are in mill installations. This is especially dangerous, because from this location may occur the propagation of fire or explosion on the carburizing gallery.

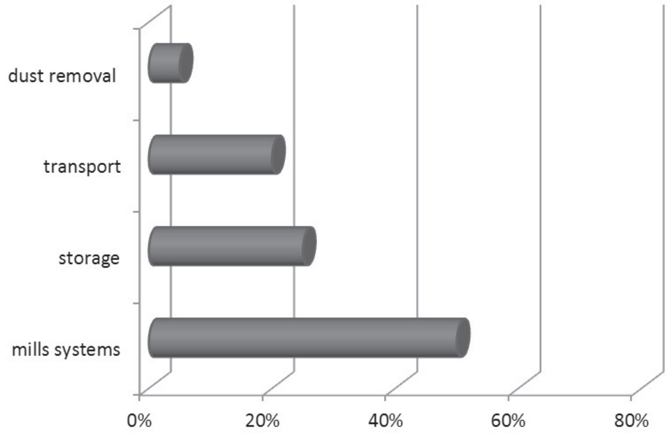

Figure 2. Explosions location

The basic problem results from not appropriate for co-firing mills construction. Bowl-ball mills are commonly used in the Polish power industry for coal milling purposes and recently for milling coal-biomass mixtures. Difficulties with ball mills (as designed for milling coal) are biomass presence – it has a substantially lower powder density and much lower minimum ignition energy (MIE). The large difference in powder densities leads to coal and biomass being dangerously separated as early as feeding the mill and inside the mill. The much lower MIE, on the other hand, causes the mixture to be far more susceptible to ignition, which is associated with a number of adverse effects when milling.

Another location of explosions in the installation is biomass storage areas (silo) and transportation systems.

The literature preview is confirming these explosion locations [19,20]. Also the problem of coal dust autoignition is important. Several authors have analyzed different materials suitable for biomass installation, with particular reference to autoignition [12,21,22]. Ramirez et.al.[23] have indicated prevention methods of dust ignition, for agricultural biomass including maize, wheat, barley, lucerne and soya.

The following biomass types are using in analyzed objects:

– forest biomass (waste wood chips and bark)
– agricultural (chips from energy crops (willow), straw pellets and briquettes),

The analysis of the accidents causes shows that the human factor is the most common cause of failures.

Similarly, according to statistic [24] more than 50% of accidents at work are caused by incorrect behavior of employees, and in half of them the insufficient concentration on duties is the factor. The failures of the biomass co-firing installations usually occur at night and on Saturdays and Sundays.

Table 3

Explosion location in the analyzed objects (period 2010-1013)

Object		Biomass Boilers type	Share of biomass in co-firing process (%)	Explosion location
1	Thermal power station A	pulverised-fuel boiler	10	Siloses
2	Power plant B	pulverised-fuel boiler	8	bucket elevators, boilers container, mills
3	Thermal power station C	pulverised-fuel boiler	10-15	mills systems
4	Thermal power station D	fluid bed boiler	100	transport system of biomass into the boiler
5	Power plant E	pulverised-fuel boiler	8	Silo, transport system
6	Power plant F	pulverised-fuel boiler fluid bed boiler	100	Bucket elevator
7	Power plant G	pulverised-fuel boiler	10	Mills systems
8	Power plant H	pulverised-fuel boiler	9	mills systems, dust removal system
9	Power plant H	pulverised-fuel boiler	10	Mills systems
10	Power plant I	pulverised-fuel boiler	10	dust removal system, backflow from boiler into transportation system

Summarizing results analysis, the main reasons of hazard situations by co-firing processes include:

- wrong equipment choice constituting a source of ignition,
- lack of or insufficient equipment for processes monitoring,
- lack of anti-explosive protection systems (explosion suppression and isolation),
- the use of different kinds of biomass not suitable/ complying with the design parameters, of installation (errors in the operation manuals and servicing),
- an excessive reduction of staff of staff operating the installations,
- contaminated biomass, lack of its quality monitoring (insufficient).

Conclusions

Due to the safety of people working in heat and power plants where the biomass is co-fired, and the state energy security of the country, the following things should be done:

- an adaptation of mills to co-milling coal and biomass by applying suppression or explosions decompression systems in coal mills
- an adaptation of electrical devices to the work in dust explosion zones (to eliminate the threat of the secretion of the exaggerated warmth quantity or arched shortings while electrical devices work
- a continuous control of biomass quality
- automation of some processes to avoid human errors

Dust explosions can lead to loss of life, injuries, property damage, environmental damage as well as consequential damage such as business interruption losses. Many dust explosions that occur in process plant are relatively small, leading to limited damage. However, under the right circumstances, even small explosions can escalate into major incidents.

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International Scientific Conference, September 16-18, 2013, Krakow, Poland

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ANALYSIS OF THERMAL EFFICIENCY OF VERTICAL GROUND EXCHANGERS COOPERATING WITH A COMPRESSOR HEAT PUMP

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Abstract. The paper presents results performance analysis of vertical ground heat exchangers (1xU and 2xU type) cooperating with compression heat pump. Proceeding from the overall depending determined thermal resistance between flowing circulating factor and the surrounding environment. Exchanger is divided into three segments, namely: horizontal section located in the ground and two vertical sections: one cooperating with the ground, and in direct contact with groundwater. In the next step, the theoretical thermal efficiency was calculated and compared with the results of experiments. It was a broad convergence the results with theoretical calculations.

Key words: heat pump compressor, thermal efficiency, heat ground

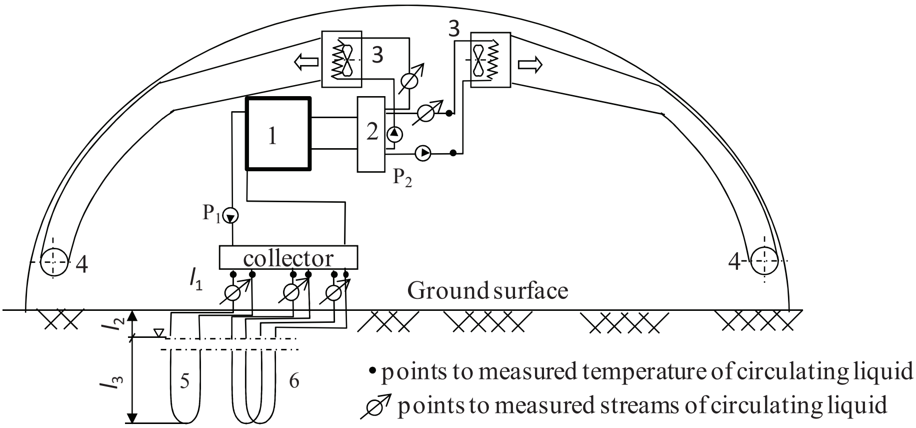
Introduction

Existing legal regulations, development of technology of producing devices for obtaining energy from renewable sources, increase of their efficiency, duration, resistance to climatic conditions causes that traditional devices for obtaining energy may be substituted to a higher extent by other devices, including a heat pump. It is known that efficiency to transfer heat from the so-called lower source (ground, water, air), besides investment costs, electric energy costs, decides on the profitability of its use. Intensity of the heat reception by exchangers, which constitute a lower source, depends on thermo-physical parameters of the surrounding environment and difference in temperature between this environment and the circulation factor flowing inside it. The issue concerning the analysis of heat exchange in this system element was the subject of the research which was carried out in many scientific centres. Thus, [2] presented a mathematical model of the heat transfer in the ground (exchangers located at the maximum depth of 100 m were considered), where the following were accepted as decisive variables: thermal and physical properties of the ground and a conduit of which plumbs were made, distances between exchangers and their depths, flow speeds of the circulation factor. The model was solved with numerical method and in conclusion (after conducting verification experiments) it was found that it is useful at designing installations. [9] developed a programme for optimization of the compressor heat pump operation along with the factor flow analysis. The results obtained by theoretical research were verified by them on a measurement stand with a multi-stage compressor, where throttling and compressing processes occur. It was concluded that the applied method may be used in the procedure of parameters optimization of the compressor pump impeller, minimization of losses related to the transformation of the thermodynamic factor and at rational control of its operation. [7] presented constructive solutions of the ground exchangers cooperating with compressor heat pumps, concluding that everywhere, where advantageous conditions occur (high level of aquifers), this device, due to possibilities of its application also for cooling buildings and effective use of electric energy (acc. to the author, the pump allows saving 30 to 40% of electric energy) is recommended in air conditioning solutions. [1] analysed the use of the heat pump for heating an experimental greenhouse. Ground exchangers (both horizontal as well as vertical) constituted a lower source. [8] analysed energy effects and carried out the procedure of optimization of economic indexes for stream heat pump cooperating with ground exchangers. [3] investigated the effects of using the heat pump cooperating with vertical heat exchangers used for heating a school determining the efficiency of work in the cooling cycle. The authors also compared the obtained effects with a heat pump, where air was used as a lower heat source. [10] analysed energy effects of a heat pump with a lower source in the form of an exchanger of liquid-air type used for heating an experimental greenhouse. [6] carried out simulation experiments in which they analysed operation efficiency of a heat pump cooperating with horizontal ground heat exchangers. Three different soils (sand, sandy clay and loamy clay) of varied humidity were assumed as input variables. It was found that the highest energy efficiency was obtained for sandy soil, moreover for all types of ground, relation of the researched parameter to its moisture was reported. [4] developed a nomogram for determination of structural and exploitation parameters of mono systems (the pump cooperated with ground exchangers) and bivalent (cooperation of the heat pump with the system of conversion of radiation into hot water) where the heat pump was used for heating a plastic tunnel. Significance of the research issue explicitly appears from the quoted literature review, as a consequence of which, the obtained results serve for improving the work efficiency of the heat pump.

Material and methods

The system presented schematically in fig.1 is the subject of analysis.

As it appears from the above, a part of the heat exchanger constitutes a horizontal segment (with length of l_1), whereas the part is located in the ground with or without the contact with the ground water (respectively length of the the segment l_2 i l_3). Total depth of the vertical borehole is 100 m.



1- heat pump; 2- buffer container; 3- liquid- air heat exchangers; 4- perforated pipes; 5- U-tube ground heat exchanger (type 1xU); 6- U-tube ground heat exchanger (type 2xU

Figure 1. Scheme of laboratory stand

The heat transport in the closest surrounding of the ground heat exchanger that is in the ground is an issue which is described as a function of space and time coordinates. It is also a problem linked to the liquid flow. The linking consists in the heat transport by means of convection from liquid to the wall of U-pipe and then by means of conduct through its wall to the ground. A three-dimensional model of heat exchange in ground (along with initial-border conditions) completed with equations describing the issue of movement and continuity of liquid flow and the heat exchange for the flow of circuit liquid should be applied for full theoretical description of thermal issues.

Upon accepting simplifying assumptions (bringing analysis to one dimension and for determined conditions), the considered issue of heat exchange in x direction is simplified to the form of:

$$q = -\lambda_{gr} \cdot \frac{\partial T}{\partial x} \tag{1}$$

where:

q	– heat stream (thermal power per an area unit) expressed,
W·m^{-2}; λ_{gr}	– thermal conductivity of ground expressed,
W·mK; ∂T	– temperature gradient,
K; ∂x	– distance gradient expressed in (m).

In this equation, temperature gradient (∂T) is a driving force of heat flow and it may be interpreted as a difference in temperature between outside temperature of the borehole and temperature in an undisturbed profile. In order to determine, which heat stream may be obtained from one meter of borehole made in the ground of a given diameter (in other words a linear exchanger efficiency) a border conditions needs to be accepted, which limits the considered case only in regard to what happens on the wall surface of the borehole and equation (1) must be multiplied by circumference of the borehole made in the ground.

Another alternative approach allowing determination of exchanger efficiency (q_t') is determination of thermal resistance and then using the relation in the following form [Zalewski, 2001]:

$$q_t' = \frac{T_{gr} - T_l}{R_t} \tag{2}$$

where:

T_{gr} – ground temperature in the profile undisturbed with pump activity (^oC),
T_l – circulation factor temperature (^oC),
R_t – total linear thermal resistance, ($mK \cdot W^{-1}$).

A calculated final of thermal efficiency of the exchanger was determined as a weighted average from particular segments featuring variable efficiency.

At solving the equation (2) determining an average efficiency of the exchanger sonde at the considered depth (z) knowledge of the ground temperature is indispensable. It was accepted in the analysis that the ground temperature changes at the average 3K/100m and dependence of this change as a function of depth is described by the following equation [5]:

$$t_{gr}(h) = t_a + G(y - h(y)) \tag{3}$$

In fig. 2 Scheme of conduit along with symbols accepted for analysis.

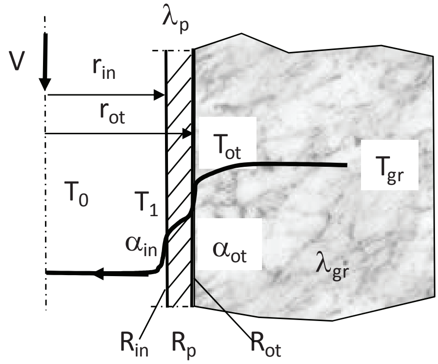


Figure 2. Scheme of the considered element along with the accepted symbols

Determination of the resistance of heat movement on the way: liquid-surrounding environment is an indispensable parameter occurring in the considered issue. Therefore, it may be written down as follows:

$$R_t = R_{in} + R_p + R_{ot} \tag{4}$$

Thermal resistance on the route: flowing liquid-the conduit wall (R_{in}) was determined from the relation:

$$R_{in} = \frac{1}{\pi \, d_{in} \alpha_{in}} \tag{4a}$$

where convectional coefficient of heat transfer (α_{in}) was determined from the correlation equation in the following form:

$$\mathrm{Nu} = 0{,}023 \cdot \mathrm{Re}^{0,8} \cdot \mathrm{Pr}^{0,4} \quad \text{(turbulent flow)} \tag{4a1}$$

or:

$$\mathrm{Nu} = 0{,}15 \cdot \varepsilon_l \, \mathrm{Re}^{0,33} \cdot \mathrm{Pr}^{0,43} \cdot \mathrm{Gr}^{0,1} \left(\frac{\mathrm{Pr}}{\mathrm{Pr}_w} \right)^{0,25} \quad \text{(laminar flow)} \tag{4a2}$$

Resistance of heat transfer through the conduit wall (R_p) was determined from the relation:

$$R_p = \frac{\frac{1}{\lambda_p} \ln \frac{d_{ot}}{d_{in}}}{2\pi} \tag{4b}$$

For calculation of the heat transfer resistance on the outside of the conduit (R_{ot}) the following relations were used:

a) for the horizontal part of the exchanger:

$$R_{ot-1} = \frac{1}{2\pi\lambda_{gr}} \ln \left[\frac{2s}{\pi \, d_{ot}} \sinh\left(2\pi \frac{h}{s} \right) \right] \tag{4c1}$$

b) for the vertical part of the exchanger (to the level of ground waters):

$$R_{ot-2} = \frac{\ln\left(\frac{r_{ot-b}}{r_z} \right)}{2 \cdot \pi \cdot \lambda_{gr}} \tag{4c2}$$

c) for the vertical part of the exchanger submersed in ground water:

$$R_{ot-3} = \frac{1}{\pi \, d_{ot}} \frac{\sqrt{\pi^3}}{4\sqrt{\left(\frac{1}{d_{ot}} \right)} \sqrt{k_f \, \varepsilon \, c_{pf} \, \rho_f \left[\lambda_{gr} (1 - P_0) + \lambda_f \, P_0 \right]}} \tag{4c3}$$

where, particular symbols mean:

- G – coefficient including the temperature growth at the ground depth ($K \cdot m^{-1}$),
- q_m – heat stream received from the exchanger plumb (W),
- $h(y)$ – considered depth (m),

m_{pc} – stream of the flowing circulation factor ($kg\cdot s^{-1}$),
λ_{gr} – coefficient of ground conductivity (W·mK),
d_{in} – inside diameter of the conduit (m),
α_{in} – coefficient of heat transfer at the connection: liquid in the exchanger - the conduit wall ($W\cdot m^{-2}K$),
Nu, Re, Pr, Pr_w – respectively: Nusselt's, Reynolds' and Prandtl's number and Prandtl's number for the mean temperature of the wall (Pr_w) (-),
ε – correction factor for laminar flow (as a function of the length and diameter of the exchanger) (-),
d_{ot} – outside diameter of the exchanger sonde (m),
h – location depth of the horizontal exchanger (m),
s – distance between the exchanger conduits (m),
k – coefficient of ground filtration (darcy),
r_f, c_{pf}, λ_f – density, specific heat and coefficient of soil water heat transfer, respectively: $kg\cdot m^{-3}$, $J\cdot kgK^{-1}$ oraz W·mK; P_0 - ground porosity coefficient, [-].

Verification research was carried out on the stand (fig.1) and based on the measured sizes (stream, temperature difference) linear thermal efficiency of the plumb was measured as:

$$q_m^{'} = \frac{m_{PC}\, c_l\, \Delta T}{l_p} \tag{5}$$

where:

m_{PC} – stream of the flowing factor in a given cycle ($kg\cdot s^{-1}$),
c_l – specific heat of the circulation factor ($J\cdot kgK^{-1}$),
l_p – total length of the exchanger (m).

Results and discussion

The tests were carried out in March when acc. to long-standing average temperature at the depth of 0.5 was 3°C. The following initial sizes were accepted in the analysis: λ_{gr}= 1.8; d_{in} – 0.037; α_{in} – coefficient of accepting heat at the connection: liquid in the exchanger- the conduit wall, $W\cdot m^{-2}K$; Nu, Re, Pr, Pr_w – respectively: Nusselt's, Reynolds' and Prandtl's number and Prandtl's number for average temperature of the wall (Pr_w) [-]; ε – correction factor for laminar flow (as a function of length and diameter of exchanger), [-]; d_{ot} – outside diameter of the exchanger pipe, m; h – depth of placing horizontal exchanger, m; s – distance between the exchanger conduits, m; k_f – coefficient of ground filtration, [darcy]; r_f, c_{pf}, λ_f – density, specific heat and coefficient of soil water heat transfer, respectively: $kg\cdot m^{-3}$, $J\cdot kgK^{-1}$ and W·mK; P_0 – ground porosity coefficient, [-]; G – coefficient including the temperature growth at the depth of ground, $K\cdot m^{-1}$; q_m – heat stream received from the exchanger plumb, W; $h(y)$ – considered depth, m; mpc – stream of flowing circulation factor, kg/s; c_l – specific heat of the circulation factor, t_l – length of the heat pump performance cycles. Fig. 2 presents the course of measured parameters for one of the daily performance cycle of the heat pump.

One may notice that during the considered operation time there were 9 cycles of the heating pump operation. The length of the cycle was within the range of 22.5 to 24 minutes. During this time, average volume of the factor, which was pressed through vertical exchangers in particular cycles of the pump operation was: type U1 0.34 whereas for the exchanger type U2 it was 0.51 and 0.34m^3. While, during the heating pump performance, average difference between the supply temperature and the return of the circulation factor in particular cycles was for the exchanger: U1 from 2.3 to 3.5 whereas for exchanger type U2 for particular U-pipes from 2.38 to 3.8 K and from 2.1. to 3.5K.

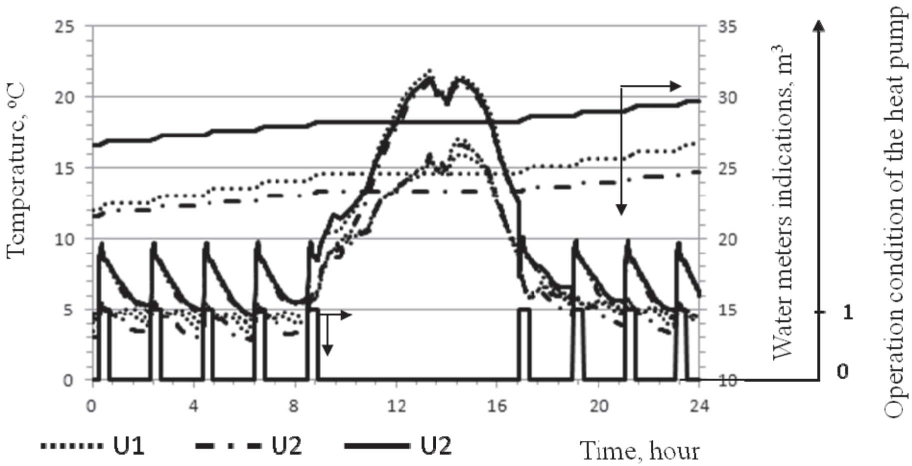


Figure 2. Daily course of the measured parameters during the heat pump performace

Fig. 3 presents the course of temperatures for one of 9 performance cycles of the heat pump.

As one may notice, only after approx. 20 minutes of the heat pump operation stabilization of temperature changes occurred in the analysed ground exchangers. Similar regularities were reported for the remaining operation cycles of the heat pump. Therefore, it may be assumed that during this time, a determined process of heat exchange between liquid in the exchanger and the surrounding ground occurred. Thus, a detailed analysis related to heat capacity of vertical ground heat exchangers was carried out for the established process.

Table 1 presents enumerated values of unitary resistance and temperature of the wall for one exemplary cycle, in which temperature of pressing the circulation factor for the established process was 5 and the return was 8^{o}C. Temperature of the wall was calculated by means of standard relations describing the heat movement by a ring partition.

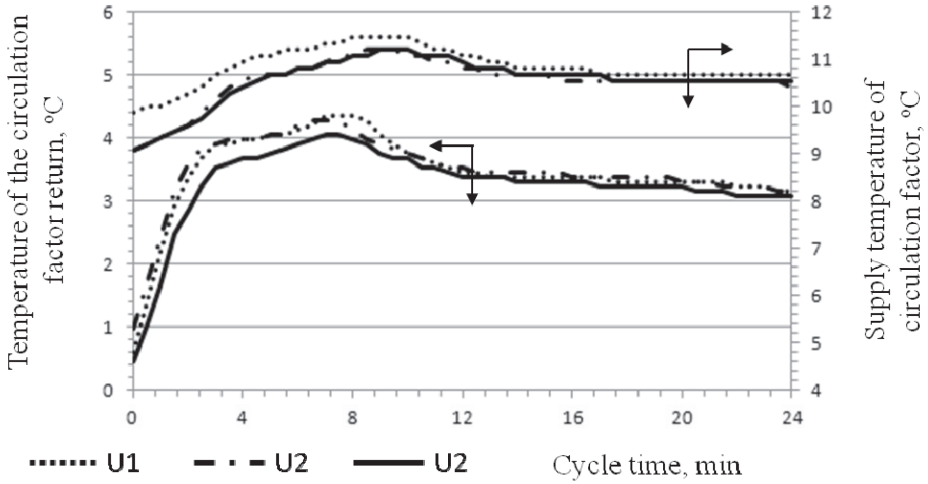


Figure 3. Course of supply temperature changes and return of the circulation factor of the selected operation cycle of the heat pump

Table 1.
Enumerated values of unitary resistance

Specification	Thermal resistance, $(mK \cdot W^{-1})$			External temperature of the exchanger wall (°C)	
	R_{in}	R_p	R_{ot}	$t_{ot\text{-}in}$	$t_{ot\text{-}out}$
Horizontal exchanger	0.29	0.059	0.67	5.1	8.1
Vertical exchanger (to the level of ground waters)	0.29	0.059	0.33		
Ground exchanger (in ground water)	0.29	0.059	0.16		

Linear capacity of the ground exchanger was carried out based on 50 performance cycles of the heat pump. From the analysis which was carried out, it appears that unit thermal efficiency of the considered exchangers is, for the exchanger type 1U -14.1 whereas for total efficiency for the exchanger type 2U 19.2 1W/running $m_{\text{of the conduit}}$. When comparing the unit capacity of the analysed exchangers one may say that total thermal efficiency of the exchanger type 2U is approx. 36% higher than exchanger type 1U in the researched operation cycles.

Fig. 4 presents results of the comparison of efficiency determined from the presented relation (q'_t) and measurements (q'_m) for the analysed ground exchangers.

Additionally, a calculated value of the relative error- e^{max} (calculated towards the measured value) and the value of the mean square error (σ) was marked.

As can be seen, the comparison is characterised by satisfying conformity whereas correlation coefficient (r) is within 0.78 to 0.81.

If one assumes that the ground exchanger was located directly at the place of locating the heat pump, then thermal capacity of the boreholes will be from 41.5 (exchanger type 1U) to 56.6W/running $m_{of\ borehole}$ for the exchanger type 2U.

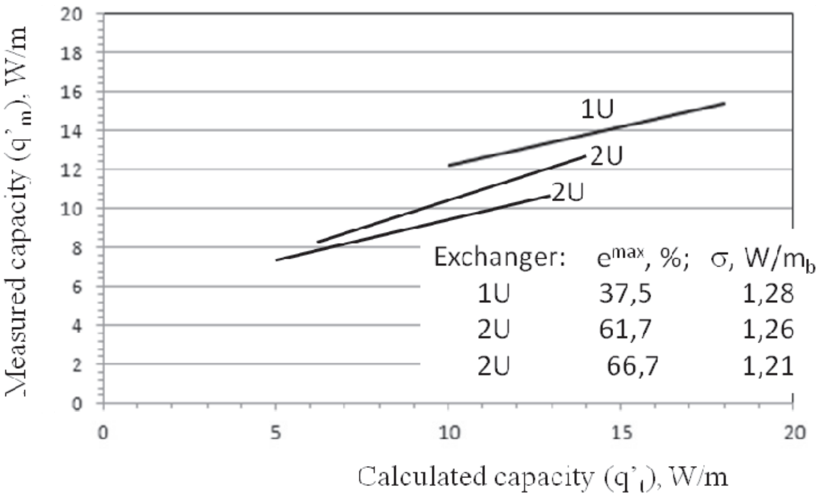


Figure 4. Comparison between calculated and measured unit efficiency of ground exchangers

Conclusions

1. Total thermal resistance of the analysed ground plumbs, depending on their geometrical location is within 0.51 to 1.02 $mK\cdot W^{-1}$.
2. Comparison between the measured and calculated unit efficiency of the exchanger conduit is characterized by conformity at the level: correlation coefficient (0.78 to 0.81), a range of the maximum relative error is within 37.5 to 66.7% whereas the range of mean square error is changing from 1.21 to 1.28 W/running $m_{of\ the\ conduit}$.
3. Mean unit thermal efficiency of the considered exchangers is, for the exchanger type 1U - 14.1 whereas for total efficiency for the exchanger type 2U 19.2 1W/running $m_{of\ the\ conduit}$.
4. In case of locating the heat pump directly next to the boreholes, then average thermal efficiency of the borehole where the exchanger type 1U is located is 41.5W whereas a borehole with the installed exchanger type 2U equals 56.6 W/running $m_{of\ borehole}$.

This research is founded by the Polish Ministry of Science and Higher Education, as a project: Energy and environmental aspects of renewable energy in horticultural object: N N313 445137.

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MECHANICAL DURABILITY OF PELLETS AND BRIQUETTES MADE FROM A MISCANTHUS MIXTURE WITHOUT AND WITH THE SEPARATION OF LONG PARTICLES

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Abstract: The aim of the study was to evaluate the separation of the mixture exceeding the requirements of the particle size limit of comminuted miscanthus material for the production of pellets and briquettes, using a coefficient of mechanical durability. From the cut and milled miscanthus material, with a maximum particle size 46.0 mm and 6.0 mm respectively, the long particles were separated on the sieve of hole size 8.98 mm and 3.34 mm respectively, where a relative proportion by weight amounted to 6.0% and 50.9% respectively. Particle size distributions were approximated by Rosin-Rammler-Sperling-Bennett model setting the parameters for the cut and milled mixture, which allowed to predict the separation of biomass matching the particle size of the mixture for the pellets and briquettes production. These were made at a pressure of 53.5 ±4.5 MPa and 52.0 ±5.0 MPa respectively. On the basis of comparative values of the mechanical durability of the pellets (98%) and the pellets (87%) only the need for separation of long particles from miscanthus mixture for the production of briquettes was justified, because of their significant part in the basic mixture and the large differences in the dimensions of the long particles in relation to the required ones. The durability coefficient of briquettes made from a complete mixture amounted to 80% and after the separation of the long particles increased to 94%.

Key words: miscanthus, particle size, pellets, briquettes

Introduction

The basis for the compaction process is a connection of fine particles in the larger form of biomass of a predetermined shape and an adequate durability, which results in a substantial increase in the density of the material. The creation of intermolecular forces as a result of sufficient close up of the particles is a condition for agglomerate formation

Increasing the contact area between the particles results in creating forces of mutual attraction between particles, van der Waals and electrostatic forces [4, 5, 6]. The occurrence of a bonding mechanism in the agglomeration process may be the result of formation of solid bridges. They are formed by melting, concentration of the binder and melting and crystallization of the dissolved substance.

It is generally accepted that the biomass particle size is inversely proportional to the density of pellets or briquettes. This follows from the fact that during compaction the smaller particles have a greater surface of contact and are easier to pack and are characterized by higher binding energy per unit mass, regardless of their physicochemical properties [7; 8; 9; 10].

MacBain and Payne [11] found that small and medium-sized particles are desirable in the granulation process, because having a larger surface, they easily lend themselves to steam in the process of conditioning, which results in better gelatinization of starch. Moreover, they found that the smaller particles improve process efficiency and reduce granulation costs. They also found that very small particles can cause interference in the process of granulation due to clogging of the pelletiers die.

According to Kronbergs [12] during straw briquetting a change of the particles length from 20 mm to 1.5 mm contributed to increasing the density of briquettes by 25%.

Mani et al. [13] also indicate that the particle size has an influence on the mechanical properties of the pellets of straw from wheat, barley and corn.

Excessive fragmentation of the material requires increasing the outlay of energy, not only in the preparation stage of the mixture, but also in pressure agglomeration, as pointed out by Frączek et al. [14] in the manufacture of briquettes from willow material. The material comminuted on the 4 and 15 mm sieve was characterized by energy requirement of 37.5 and 35.3 $Wh \cdot kg^{-1}$ respectively at an agglomeration pressure of 47 MPa. At lower agglomeration pressures (17–37 MPa) energy inputs amounted to 20 $Wh \cdot kg^{-1}$on average.

The results of previous studies have become an inspiration to undertake our own research. The aim of the study was to evaluate the separation of the mixture exceeding the requirements of the particle size limit of comminuted miscanthus material for the production of pellets and briquettes, using a coefficient of mechanical durability.

Materials and methods

Miscanthus plants were harvested by a trailed forage harvester Z374 from plots at the Experimental Station in Skierniewice, which belongs to the Warsaw University of Life Sciences. The chopping unit of the forage harvester was equipped with 5 knives. The cutting disc rotational speed amounted to 1000 rpm. The set working parameters allowed for a cutting frequency 83 Hz and a theoretical length of chopped plant material particles of 8.8 mm. After natural drying, the cut mixture was milled in a beater mill equipped with a sieve of 15 mm holes.

For the purpose of evaluation of cut particle size distributions a sieve separator was used with horizontal sieve oscillation and research methodology in accordance with the requirements of ANSI/ASAE S424.1 [15], compatible with the European standard PN-EN 15149-1 [16]. For the evaluation of milled particle size distribution a sieve separator was used with vertical sieve vibration and research methodology in accordance with the requirements of PN-EN 15149-2 [17], compatible with ANSI/ASAE S319.4 [18].

For particle size distributions of comminuted material cumulative distributions were constructed which were approximated by Rosin-Rammler-Seprling-Bennett model – RRSB [19].

Moisture content (wet basis) was determined in accordance with standard ASAE S358.2 [20]. During harvesting and separation the moisture content of cut miscanthus material amounted to 45.4–47.5% and 45.0–47.2%, and during the milling and separation of the material – 4.5–7.7% and 4.9–7.1% respectively.

From the mixture of the cut and milled material of the maximum particle size of 46 mm and 6.0 mm respectively, long particles were separated by using a sieve with holes of 8.98 mm and 3.34 mm respectively.

From the mixture without separating long particles and after their separation, briquettes were made in the APT Alchemik hydraulic press and pellets on a Testmer pelletier with ring-type PD-1 type die.

To measure electricity consumption of the briquetting and pelleting machine, a TW TeamWare Wally IP measuring instrument was used. For the assumed mechanical efficiency of the drive system of the briquette press and pelletier of 0.85, electric motor of 0.90 and hydraulic pump, pressures of 0.80 the pressure during briquetting and pelleting were calculated, which amounted to 47–57 MPa and 49–58 MPa respectively. Measurement error was 4.5% and 4.8% respectively.

The assessment of the durability of pellets was carried out in accordance with the requirements of PN-EN 15210-1 [21], compatible with ASAE S269.4 [22], while the durability of briquettes – in accordance with the requirements of PN-EN 15210-2 [23].

In all studies, each test was performed for five trials. The samples were weighed on analytical balances with a precision which allowed to achieve a relative error not exceeding 1%. Data were analyzed by using statistical analysis and the statistical package Statistica v. 10.

Results and discussion

Particle size distribution of the miscanthus cut material was characterized by right-sided skewness (skewness coefficient amounted to 1.6) and was relatively leptokurtic (steep), with a kurtosis coefficient of 0.9 (Fig. 1a). Particle size distribution of the milled material was characterized by a slight right-sided skewness (skewness coefficient of 0.1) and was platokurtic (flat), with a negative kurtosis coefficient value (-1.2, Fig. 1b).

Particle size geometric mean values of the cut and milled miscanthus material amounted to 10.47 mm and 0.93 mm respectively, whereas the dimensionless standard deviation of these averages amounted to 1.86 and 0.52 respectively. The dimensional standard deviation of particle size geometric mean of the milled material was 1.40 mm (this value for the cut material was not calculated due to lack of guidelines in ANSI/ASAE S424.1 [15]).

On the basis of particle size distributions of comminuted material the calculated parameters of the cumulative distributions of the RRSB models are shown in Fig. 2. The RRSB models were used to calculate the amount of material for separation whose the particles are longer than 3.34 mm in a milled mixture and 8.98 mm in a cut mixture. From the milled mixture 6.5% (by weight), and from the cut one – 49.4% of the long particles was separated. In laboratory experiments, by using sieves with same size holes, from the milled mixture 6.0% (by weight), and from the cut mixture 50.9% of the long particles was separated. The relative prediction error is 8.3% and 2.9% respectively, and for this type of experiment it can be considered as not very high.

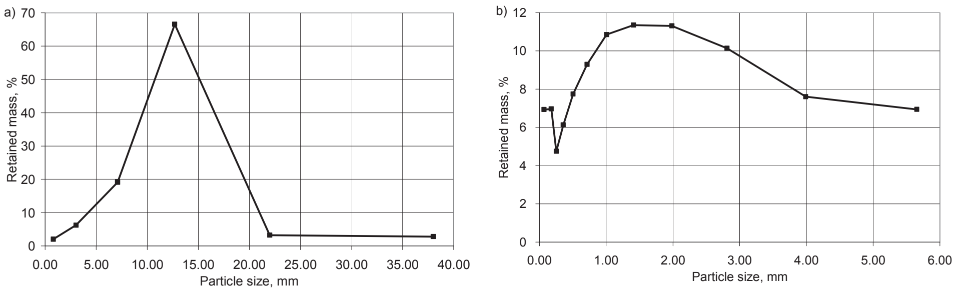

Figure 1. Particle size distribution of cut and milled miscanthus material

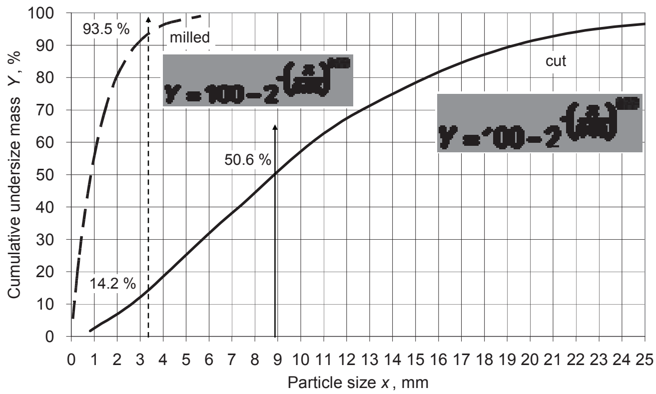

Figure 2. The cumulative frequency of cut and milled miscanthus material determined on the basis of the RRSB model (vertical lines with arrows mark boundary particle sizes; 3.34 mm – for pellets and 8.98 mm – for briquettes)

From the mixture without separation and after separation of the long particles, pellets and briquettes were produced, determining their durability coefficient for which a statistical analysis of variance was carried out (Tab. 1). Based on the results of this analysis, we can conclude that as well the form of solid fuel (pellets, briquettes) as the mixture type (without separation and after the separation of the long particles) had a statistically significant impact on the diversity of mechanical durability values of products. The interaction between the main factors was also highly statistically significant. The impact of these factors was found at a high significance level of less than 0.0001 (Tab. 1).

Overall pellets made from miscanthus material were characterized by much higher durability coefficient values than briquettes and amounted to 98.0% and 86.9% respectively. It follows that the pellets meet the requirements of the European standard CEN/TS 14961-6 [24] which specifies that the durability coefficient value for miscanthus pellets should be ≥97.5%.

The durability coefficient of the briquettes of plant biomass is not defined in the standard. On the basis of the literature review the durability of the briquettes should be greater than 80% [25]. Taking into account this recommendation, it can be concluded that the briquettes produced meet the practical requirements of durability. Such requirements are set by the power industry for briquettes, due to the need to preserve the tidiness and the ensuing fire safety. Lower durability of briquettes is a risk of increased fragmentation of solid fuel, ambient dust, dust cloud formation or deposition of a dust layer which may ignite at temperatures 450°C and 280°C [26] respectively.

The results of durability coefficients (Fig. 3) allow to conclude that the separation of large particles from a mixture intended to produce miscanthus pellets did not cause any effect in a statistically significant way on the diversity of durability products. The durability coefficient of pellets made from a mixture without separating large particles was 97.92%, and after the separation the value of the coefficient for the pellets increased to 98.04% only. This is due to a slight difference in the structure of the particle size distribution in the mixture without any separation, and after separation. From the complete milled mixture about 6% by weight of particles larger than the size of 3.34 mm was separated, and the largest particles were no more than 6 mm – taking into account the 95% range.

Table 1

The results of the analysis of variance of the factors affecting mechanical durability Ψ in% of briquettes and pellets made of miscanthus material

Source	Sum of squares	Degree of freedom	Mean square	Test F	p-value
Form: A	700.9	1	700.9	1132.6	<0.0001
Separation: B	258.1	1	258.1	417.1	<0.0001
Interaction: A × B	249.3	1	249.3	402.8	<0.0001
Error	13.0	21	0.6		

Fig. 3. Interaction of fuel forms with the separation of particles on the mechanical durability of briquettes and pellets made from miscanthus

The briquettes made from a mixture without separation of the large particles were characterized by a mechanical durability coefficient of 78.18–82.30%, and those made from a mixture free of large particles in the range of 93.03–94.10%. The absolute durability of briquettes made from a mixture consisting of more uniform particles and smaller dimensions is therefore increased by 13.3% (percentage points). The definitely positive effects of separating of the long particles from a cut mixture are due to the large weight fraction (50.9%) which was separated from the whole miscanthus mixture. The long particles had a much larger dimension than the holes of the sieve (8.98 mm) which was used for the separation. The size of long particles of the cut mixture was 46 mm (95% of range), but in the mixture occasionally even longer particles were found. This justifies the need to separate very long particles from a miscanthus mixture for briquette production, especially when the long dimension of the particles is well above the recommended value of 10–15 mm and the weight is large. Similar conclusions were formulated by Hebda and Złobecki [27], who found that the fraction of fine particles smaller than 3.15 mm allows to obtain briquettes with wheat, rye and rapeseed straw with the greatest durability (98%). Briquettes made from a mixture of particles greater than 16 mm were characterized by a significantly lower durability, less than 90%.

Conclusions

1. A mechanical durability coefficient of briquettes made from a miscanthus mixture, from which a large amount of 50.9% (by weight) of long particles, exceeding 8.98 mm, have been separated, is higher by 13.3% than briquettes made of a mixture without separating them, and amounts to 93.6% and 80.2% respectively. A slight separation of long particles (6% by weight), longer than 3.34 mm from the mixture for the production of pellets did not affect the durability of the products, because of the small differences in particle size distributions.
2. The concept of the separation of a mixture meeting the requirements of the preferred particle size may allow for further reducing the energy load of working units, especially the finer fractions contained contaminations in the form of sand and dust, which unnecessarily expose working elements of the beater mill or other biomass milling equipment to damage. The separation of long particles has a logical explanation for the high proportion of such particles in the mixture, and significant differences in long particle size in relation to the value recommended for pellets or briquettes, but the estimation of these parameters requires a different scope of studies.

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ELECTRIC POWER DEMAND IN A MUNICIPAL FACILITY

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Abstract. In this study, an analysis of active power load and electricity consumption dynamics is provided on the example of the examined municipal facility, in a monthly, daily and hourly view. A joint hourly load profile typical for all days of the week was developed, which was then used for the purpose of simulation of electricity consumption costs depending on the specific tariff group. In the course of the study it was checked how the distribution of daily load within the valid time sections influences upon the total cost of energy. Also the power and electricity demand was simulated after the planned expansion of the plant, together with the estimated electricity consumption costs.

Key words: electricity, tariff group, cost of energy, active power, load profile, load dynamics indicators

Introduction

Total capacity of commercial power plants in Poland amounted to 38,12 GW as per the 3rd quarter of 2012. 82% of them were power plants fired mainly with non-renewable resources, such as hard coal and brown coal. According to Polskie Sieci Elektroenergetyczne (Polish power grids), within the coming years, that is by 2020, approx. 6,6 GW will be disconnected and by 2028 - approx. 10 FW. Due to minor investments in new power capacity, both conventional and alternative, an issue of power shortage begins to come to the fore. Already in 2012 there was a short period of time when the power reserve amounted to as little as 1 GW, whereas due to security reasons it should amount to 3,5 - 4,5 GW. In the current situation all initiatives aiming at the establishment of new power sources both in the power industry and scattered local generation are well-reasoned [1-5].

Taking into account the limited availability of non-renewable energy sources, renewable sources begin to play an increasingly important role in the power industry. Both environmental and economic aspects provide another advantages supporting their development [6-11].

In the recent years very intensive works have been conducted on the creation of an efficient supporting system of renewable energy sources, as a development opportunity not only for local communities, but also local governments. Out of many available renewable energy sources, small photovoltaic installations attract ever larger interest of administrators of municipal buildings, as they may be used to cover their own power demand and to sell the excess of electric power [12,13]. Performance of the load changeability and power demand of a given facility [14-17], together with a field insolation survey are the basic tasks prior to the initiation of an investment project involving generation of electric power with renewable energy sources. The efficiency of the future photovoltaic farm relies greatly on the quality of these analyses, and it also impacts the financial effect achieved by its owner.

The objective of this study was to perform a dynamics analysis of electric power and energy analysis, as well as electricity consumption costs of the specific municipal facilities located in the Podkarpackie voivodeship.

Material and method

The study objective was accomplished on basis of own research performed at a switching station powering the municipal facility located in the Sanok province and monthly power consumption volume data within a yearly cycle. Own research consisted of permanent measurement and recording of active power load values averaged per 15 minutes and determination of power consumption in the specific periods of time. Own research was carried out by means of a specialist AS-3 plus grid parameter analyser manufactured by the Twelve Electric company from Warsaw. The performed research allowed to create a database including historical power consumption data in each hour of day and night. The collected data enabled the performance of yearly electricity cost simulations according to the selected tariff of a local provider.

Research results

Analysis of dynamics of power demand and electricity consumption

The total power of electric receivers installed within the municipal facility, as determined on basis of information provided in its Technical Process Plan, amounts to 120 kW. Asynchronous motors used to power treatment process devices are the most frequent type of receiver with a rated power of 1 to 18,5 kW. The total power demanded by receivers for the waste water treatment process amounts to 40 kW. In order to reflect the real operating conditions it was assumed that daily electric power consumption would amount to 0,5 MWh.

In the coming years, the facility is planned to be expanded, thus causing a growth of installed power and power demand of receivers up to 183 kW and 60 kW, respectively. This process will also cause an increase of daily power consumption up to approx. 0,9 MWh.

According to the performed calculations, the actual yearly power consumption by all receivers operating at the facility amounted to 150 MWh. The monthly power consumption value (E_m) has fluctuated from 10,32 [MWh] in September to 17,83 MWh in July, while on average it amounted to 12,47 MWh. The monthly power consumption variation rate amounted to 15%. This rate was greatly affected by the abnormal power consumption in July. Its main reason were very intensive and frequent rains in this period. When this phenomenon was excluded from the analysis, the variation rate fell below 8%, and also the average power consumption decreased below 12 MWh.

The load fluctuation in the consecutive hours of the specific days of the week was similar. Average active power load in the analysed facilities amounted to 17,89 kW, ranging in the specific days from 10,9 kW to 24,5 kW. The variation rate of the analysed daily diagram amounted to 18%. According to the performed analysis, no significant differences occur between the load values of the specific days of the week.

The maximum momentary active power load fluctuation recorded during the research reached almost triple value while ranging between 36,00 kW and 69,57 kW. Their variation rate was lower and it amounted to 11%. Also in the time series of maximum load no noticeable impact of the day of the week on value or course was observed.

Analysis of electricity costs

The examined municipal facility has a contract with the Rzeszowski Zakład Energetyki S.A. acting as part of Polska Grupa Energetyczna (PGE) S.A., covering the sales of electric power and combined with its distribution. On basis of information included in the application for the connection terms, the facility was classified as tariff C11 and thus its billing of power consumption was performed on basis of the respective tariff rates of the Sales and Distribution Company.

Power recipient is obliged to pay the following fees to the supplier and seller of electric power according to a framework agreement:
– constants associated with contractual power demand and permanent fee O_s,
– variables dependent on electricity consumption O_z.

According to the performed calculations the average electricity costs of the examined municipal facility operating currently within C11 tariff amounts to 8400 PLN. Another simulation of monthly electricity costs was performed considering the switching from C11 to one of the two tariffs available for customers not exceeding a contractual power demand of 40 kW. The proposed changes occurred to be reasonable, as they have reduced the electricity costs on average by 970 PLN in case of tariff group C12a and 330 PLN in case of C12b. In a yearly view, this would allow to reduce electricity costs by 11% and almost 4%, respectively. The reason for this is the fact that in within the expensive peak time zone of the proposed C12a tariff the facility uses as little as only 25% of its total power consumption.

According to the performed simulations, the selection of the C12a tariff group is a secure solution for the examined facility. The occurrence of non-typical days during the year with a different power consumption profile in the specific time zones should not cause a growth of monthly costs above the currently incurred expenses. At this moment, 25% of energy is used within the peak time zone. According to the results of analyses presented in figure 1, the costs incurred within C11 and C12a would be equal only when the consumption in the peak time zone exceeded 50% of total power consumption.

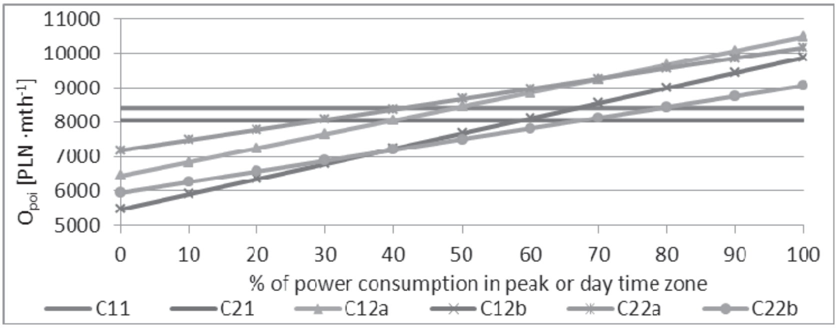

Figure 1. Impact of power consumption in the specific time zones on monthly electricity costs

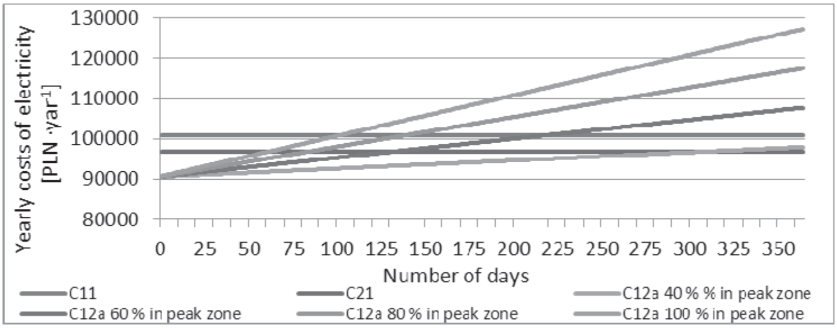

Figure 2. Impact of power consumption in the specific time zones on yearly electricity costs

In the worst scenario (fig. 2), the equalising of yearly electricity costs of tariff groups C11 and C12a would occur only after approx. 100 days in which all power would have to be supplied within peak time zone. Growth of electricity consumption in the peak zone from the current 25% to 40% regardless of its duration indicates that the selection of the C12a tariff group is economically reasonable.

In order to achieve further electricity cost reduction it is economically reasonable to change the tariff group and modify the daily operating schedule by initiating the entire treatment process 2 hours earlier. The load profile can be shifted thanks to the available buffer tank capacity. After moving to the C12a tariff group together with the modification of the operating profile, a 14% reduction of electricity consumption costs can be expected compared to the current consumption.

After the completion of the planned expansion of the facility it will be necessary to increase the contractual power demand assignment to approx. 60 kW and to change the tariff group. According to the performed analyses of electricity costs in tariff groups available for customers operating on low-voltage with a demand above 40 kW and unchanged load profile, the best solution would be the C22b tariff. After the increase of power demand by the examined facility the differences between the tariff groups of a single or double time zone would be limited to 1-2%.

Summary

Currently, the total power of electric receivers installed within the municipal facility amounts to 120 kW. The total power demanded by all receivers for the waste water treatment process amounts to 40 kW. In order to reflect the real operating conditions it was assumed that daily electric power consumption would amount to 0,5 MWh. After the planned expansion of the facility, one can expect a growth of installed power and power demand of receivers up to 183 kW and 60 kW, respectively. This process will also force an increase of daily power consumption up to approx. 0,9 MWh.

According to the performed research, the load fluctuation in the consecutive hours of the specific days of the week is similar. Average active power load in the analysed facilities amounted to 17,89 [kW], ranging from 10,9 kW to 24,5 kW. The maximum active power load fluctuation recorded during the research reached almost triple value while ranging between 36,00 [kW] and 69,57[kW.

According to the performed calculations, the average electricity costs of the examined municipal facility within C11 tariff amounts to 8400 PLN. The changes proposed in this study have reduced the electricity costs on average by 970 PLN in case of tariff group C12a and 330 PLN in case of C12b. In a yearly view, this allows to reduce electricity costs by 11% and almost 4%, respectively. Additionally, after moving to the C12a tariff group together with the modification of the daily operating profile, a 14% reduction of electricity consumption costs may be expected compared to the current consumption.

After the completion of the planned expansion of the facility it will be necessary to increase the contractual power demand assignment to approx. 60 kW and to change the tariff group. According to the performed analyses of electricity costs in tariff groups with a power demand above 40 kW and unchanged load profile the best solution is the C22b tariff.

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BIOFUELS: AN UKRAINIAN PERSPECTIVE WITHIN A EUROPEAN AND GLOBAL CONTEXT

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Abstract. Biofuel production and use worldwide is increasing. New technologies for production of the first, second and third generation biofuels have been introduced. Ukraine is one of the largest European Union exporters of the rapeseed for biodiesel production. In Ukraine, there are potentially emerging favorable conditions for the bioethanol fuels production. These include using existing but under-employed distillery factories and sugar factories employing the national scientific and technological infra-structure.

Key words: biofuels, bioethanol, biodiesel, Ukrainian assessment and opportunities

Introduction

Renewable energy contributes 2.7% of primary energy production presently in Ukraine composed of the following:
– Hydropower 2%
– Biomass 0.5%.

Domestic production of natural gas in Ukraine meets 35% of needs with the remaining 65% of needs covered by the imported gas, mainly from Russia. This issue, coupled with the large imports of oil, impacts a lack of energy independence and aggravates the energy insecurity. Strategies to address this problem include diversification of traditional energy sources and the development of renewable energy. The experience of the U.S. and the EU with renewable energy should be taken into account. The paper will address biofuels (biodiesel and bioethanol) together with biomass from a global, European and specifically Ukrainian viewpoint.

A. Biofuel The European Union (EU) adopted a directive establishing the goals of substituting liquid fuels with biofuels (bioethanol and biodiesel) – 2% in 2005, 5.75% in 2010 and 10% by 2020. The EU is ready to replace 10% of the market of motor fuel with biofuel, however the effective development of this market will require imports from states outside the EU.

B. Biodiesel Biodiesel is composed of long chain alkyl (or fatty) acids esterified with alcohol such as methanol, ethanol or propanol. It is produced from plants oil or animal fats or food waste. Marked increases are occurring in biodiesel production. Europe is the major producer of biodiesel in the world (figure 1).

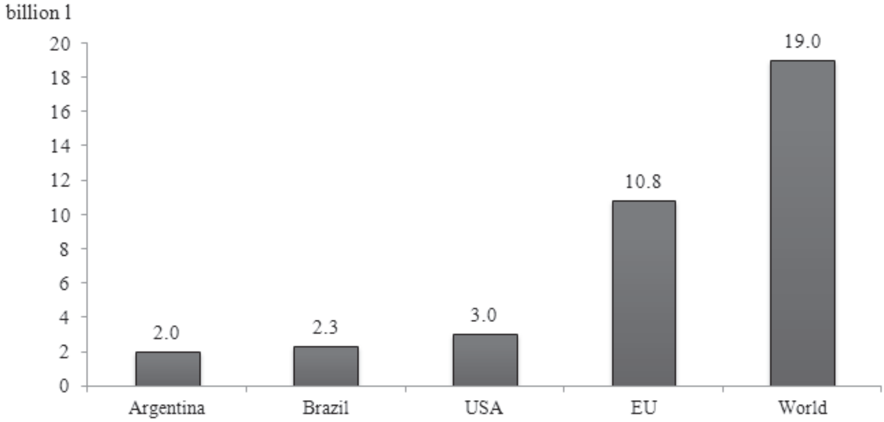

Figure 1. World production of biodiesel in 2010 [1]

Almost 80% of the European biodiesel is produced from rapeseed oil. Global rapeseed production, according to the US Department of Agriculture (USDA), is shown in Figure 2.

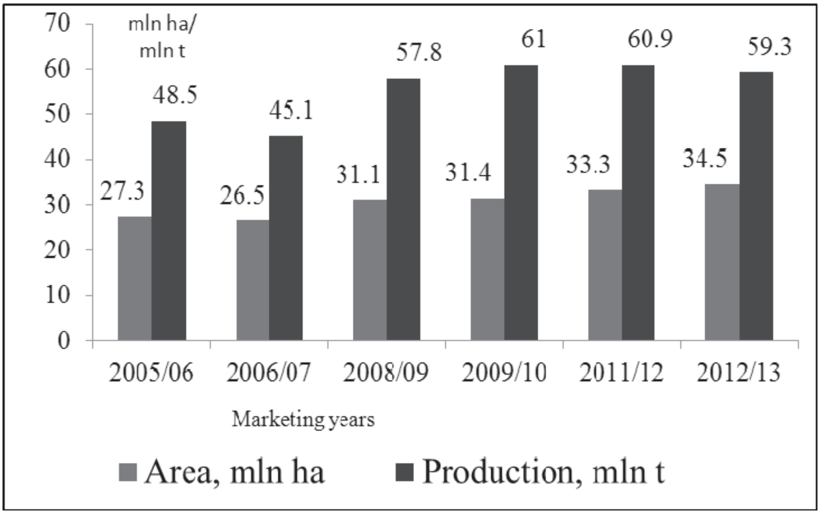

Figure 2. Dynamics of world production of rapeseed

Oil seed production

Soybeans are the major source of oil seeds globally. For details of oil seed production globally see below:

Global oilseed production 2012/2013 [2]

1. Soybeans 269 million tonnes
2. Rapeseed/canola 61.1 million tonnes
3. Cottonseed 45.3 million tonnes
4. Peanut 37.0 million tonnes
5. Sunflower 36.4 million tonnes
6. Palm kernel 14.5 million tonnes
7. Copra 6.0 million tonnes

Soybean oil [2]

Global 44 million tonnes

1. China 12 million tonnes
2. USA 8.8 million tonnes
3. Argentina 7.2 million tonnes
4. Brazil 7.1 million tonnes
5. European Union 2.2 million tonnes

Palm oil

Global 58 million tonnes

1. Indonesia 31 million tonnes
2. Malaysia 19 million tonnes
3. Thailand 2.1 million tonnes

In 2012-2013 marketing year USDA anticipates production of 59.3 million tonnes of rapeseed. The largest producer of rapeseed is the European Union with 18.9 million tonnes followed by Canada, China and India. Figure 3 illustrates the leading nations producing rapeseed.

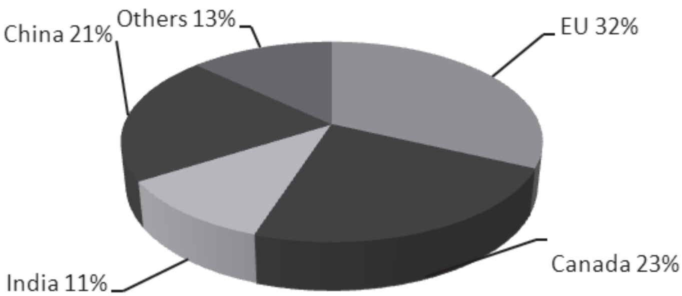

Figure 3. World production of rapeseed in 2012-2013 marketing year (4)

Ukraine, oilseeds and biofuels

Ukraine is a significant producer of oil grain including sunflower seed (8.7 million tonnes in 2011). Ukraine also has significant processing of sunflower seed to oil (3.1 million tonnes in 2011) [2]. Moreover, there is significant soybean production (2.3 million tonnes)[3]. In contrast, there was 1.4 million tonnes in 2011 production of rapeseed but with little processing of rapeseed. Ukraine is a major exporter of rapeseed to the European Union with a total of 1.2 million tonnes exported in 2010 [3]. The principal recipient countries are the following:

– The Netherlands 27%
– Belgium 20%
– France 17%,
– Poland 8%

Ukrainian production of rapeseed is summarized in figure 4.

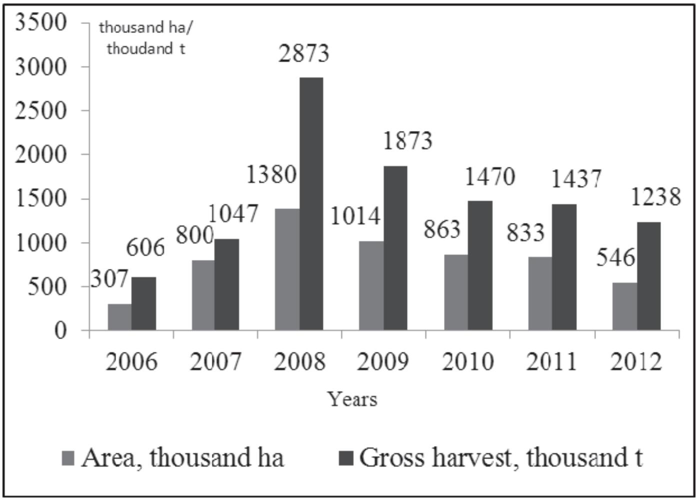

Figure 4. Rapeseed production in Ukraine

According to the State Statistics Committee of Ukraine, rapeseed producers received €100 million profit reaching an 32% level of profitability of this activity. Other possibilities include use of biodiesel

Bioethanol is an alternative liquid fuel capable of replacing gasoline. Over the last ten years bioethanol fuel production in the world has been growing rapidly (figure 5). According to the International Energy Agency, projections of ethanol production in 2020 vary between:

– 185.7 million tonnes
– 281.5 million tonnes.

Globally, the raw materials for bioethanol production are the following:
– Corn (55%),
– Sugar cane (34%),
– Molasses (6%),
– Wheat (3.5%) [4].

In August 2005, the US enacted the Energy Bill (Energy Policy Act of 2005) and a Renewable Fuels Standard. This Renewable Fuels Standard included mandates for annual production levels both for ethanol from crops (corn/maize) and from cellulose (corn stalks, rice straw, wood industry wastes etc.). This has led to the USA being the number 1 producer of ethanol. Other major producers are the following:

2. Brazil
3. EU
4. China
5. Canada.

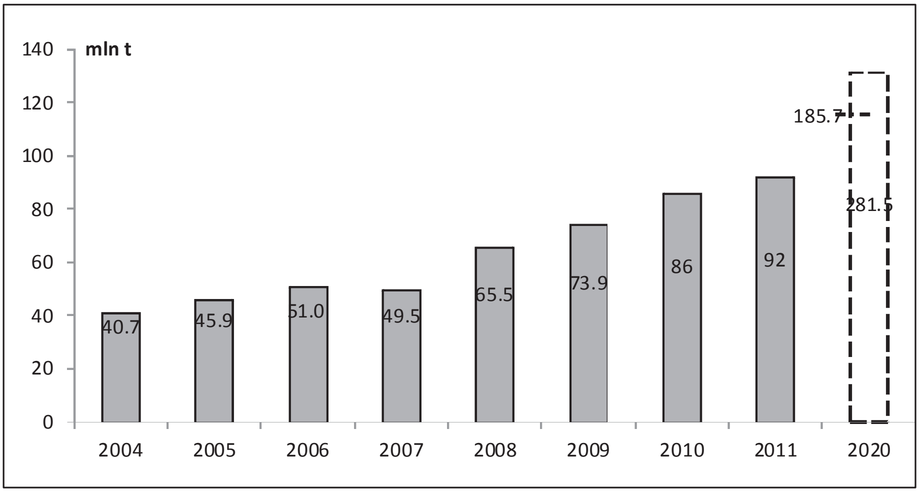

Figure 5. Growth of global bioethanol production

Ethanol in Ukraine

Ukraine uses 4.5 million tons of gasoline per annum. Domestic production of oil meets only 20% of this demand, with imported oil or gasoline is imported from neighboring states [5]. Despite the adoption of numerous legislative acts and programs promoting the production and use of biofuels, Ukraine has not yet established large-scale production of ethanol. However, considerable progress has occurred (see figure 6). In 2011 the bioethanol production was only 9,726.4 tonnes. However, this level was 15 fold that of 2010 (figure 6).

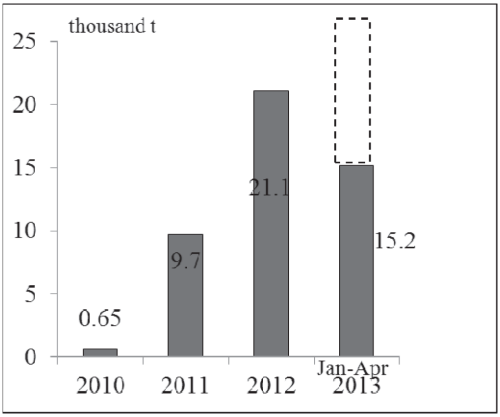

Figure 6. Bioethanol production in Ukraine in 2010-2013.

In 2012, norms for biocomponents in motor gasoline produced and/or sold within Ukraine were enacted. The mandatory content of biocomponents is the following:

- 2014-2015 5%,
- 2016 7%

This will require 370 thousand tonnes of bioethanol. Moreover, Ukraine has established export quotas for the supply of bioethanol to the EU as follows:

- 27 thousand tonnes in 2012
- 100 thousand tonnes in 2017 with a gradual increase during the period of 5 years to 100 thousand thousand annually.

A further substantial increase of the bioethanol production can be achieved by using the under-employed capabilities of Ukrainian distillation factories (present use versus capacity is estimated at 40%). The overall capacity of the alcohol industry potential would allow production of additional 320 thousand tonnes of bioethanol. This will require raw materials. In our opinion, one of the most promising approaches is for Ukraine to follow the French example of processing sugar beet into sugar and then ethanol. Significant bioethanol production has existed in France since 2003. In 2010, the ethanol production reached 2.4 million tons with sugar beet accounting for 45% of the feedstock for this. The Cristanol Plant factory in Bézancourt (France) is a complex with plants that produce sugar, bioethanol from sugar beet, fuel bioethanol from crops, alcohol for human consumption, livestock feedstuff (press cake) fertilizers made from the processing of molasses stillage (vinasse) and biogas [6,7]. The use of sugar beet and crops (wheat and corn) allows stable and efficient year-round production depending on market conditions. The Cristanol plant produces 9% sugar from sugar beet with 10% left in the "green molasses". Biogas production represents a useful co-product from sugar beet processing with an impact on the energy balance and costs. It is estimated that 5 million tonnes of sugar beet or 2 million tonnes of corn are used to produce 400 thousand tonnes of bioethanol. Calculations show (Table 1) that bioethanol produced from sugar beet in Ukraine can be a competitive commodity on the EU market.

Table 1.
Comparative cost of bioethanol [6]

State-producer	Cost of bioethanol, € / 100 l
USA (corn)	39.47
Germany (wheat)	54.97
Germany (sugar beet)	59.57
Brazil (sugar cane)	14.48
Ukraine (sugar beet)*	57.84

Ukraine has long experience with the cultivation and processing of sugar beet. However, sugar beet production has declined in Ukraine by over 70% over the past 25 years. It is obvious that Ukraine has the potential to at least restore production in the sugar sector increasing sugar beet production from 6 to 32 million tonnes per year. An additional component of this strategy could include use of corn/maize; Ukraine producing 22.8 million tonnes in 2011 [3].

B. Biomass

The 2009 EU Directive considered that 33% of electricity in 2020 should be generated from renewable energy. Biomass has the greatest potential to meet the need. Bioenergy development is highly relevant for Ukraine with its production of 24 million tonnes of oil equivalents per year [8]. Ukraine has multiple sources of biomass: agricultural waste (e.g. straw, manure), wood and wood waste, human waste and specialty energy crops. Solid biomass can be used for biopower by the following approaches:

– Direct combustion (e.g. of wood, straw, sapropel - organic deposits in the water reservoirs)
– Conversion to biogas (containing methane) by either fermentation or incomplete combustion
– Conversion to biofuel liquids by fermentation and chemical processes (esters of rapeseed and other oils or ethanol).

Liquid biofuels produced from biomass for the use in automobile engines are divided into three generations (Figure 7) [9]. The second and third generations are also known as “advanced” biofuels.

The most common types of biofuels are the biofuels of first generation: bioethanol (80% of total biofuel production), biodiesel, vegetable oils and biogas.

The EU started biodiesel production in 1992 and since that time it is the leader in this sphere (Fig. 6). In 2010 the world production of biodiesel increased by 12% compared to 2009 and reached 19 billion liters.

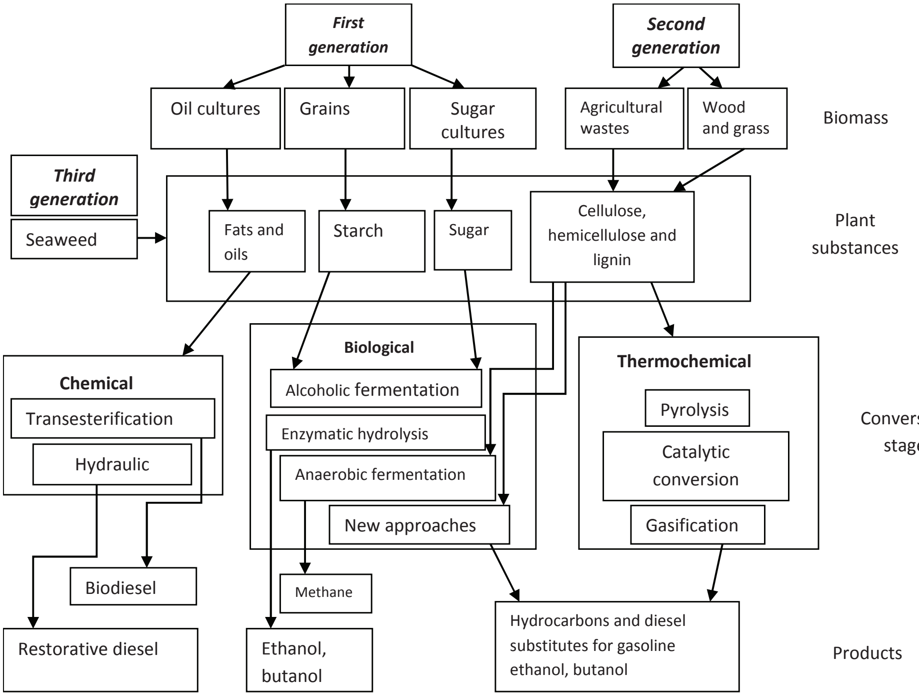

Figure 7. Processes for converting biomass into biofuels of the first, second and third generations [10]

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INTERNATIONAL SCIENTIFIC CONFERENCE, SEPTEMBER 16-18, 2013, KRAKOW, POLAND

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SMALL NUCLEAR REACTORS FOR DISTRIBUTED COGENERATION SYSTEMS

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Abstract. Current investments in nuclear sector are based only on big reactors, above 3000 MW thermal power, what is driven by the scale effect. However, the analysis has shown that this effect is not greater than in other fields. The unite equipped with a Small Modular Reactor, SMR, is expected to deliver between 50 and 300 MW electric power and the higher power limit is coming from the safety considerations. The inherent safety concept is common for all modern SMR designs. Within this concept even the hazards of high risk will be not controlled by the additional safety systems, but by the inherently safe reactor design and construction. The concept of using SMRs doesn't fit to the large nuclear power plants because the complex that comprises more than ten SMRs would have a complicated structure. On contrary the simplicity and inherent safety of the SMRs fits to the distributed energy systems. The suitable sites for SMR are in the vicinity to the industry, to deliver electricity and process heat (nuclear cogeneration). Currently only High Temperature gas cooled Reactor (HTR, HTGR) and integrated Pressurized Water Reactor (iPWR) reached high maturity level to construct the industrial prototypes within the next ten years.

Key words: SMR, inherent safety concept, nuclear cogeneration, HTR, iPWR

Introduction

Energy sector is dominated by a tendency to deploy units of larger and larger power. This trend, named scale effect, is common for all power technologies, including nuclear, coal and gas technologies and also windmills. Scale effect had stimulated the growth of the nuclear sector in the past. However, nowadays it seems that huge investment cost for a single nuclear power unit is one of the main obstacles for new constructions. This is stated in the strategic document, "Nuclear Energy Research and Development Roadmap" [1], published by the U.S. Department of Energy in 2010: "*The capital cost of new large plants* *is high and can challenge the ability of electric utilities to deploy new nuclear power plants."* Indeed, the cost of building the smallest today available nuclear power plant with a capacity of 1000 MW is estimated to be in the range between three and over five billion EUR which is a challenge even for the biggest companies.

Unfortunately any simple idea to scale down existing reactors design is not the best solution either. The comparison between the costs of a large power plant of 1340 MW and a cluster of four smaller units, each with a capacity of 335 MW, has been published in Ref. [2]. It was estimated that the capital cost of a cluster is 1.7 times higher than the cost of a single large unit. According to the analysis presented in Ref. [2] small reactors are capable to reach competitiveness but only after massive implementation, making profits from standardization, construction modularity, and first of all from the technological innovations. Concluding, it is difficult to initiate the construction of the first SMR and such a project cannot be simply a scaled down of a large reactor. It seems that SMR projects require public support at least for licensing of new designs. Currently the energy sector can consider SMR only as an option in a long term perspective since this sector requires not only mature technologies but also evidences of competitiveness against large power stations. In this context it is worth noting that energy systems powered by natural gas are commonly used in a very wide power range, from less than one megawatt to several hundred megawatts. Although the power industry is dominated by large units, small units are still available, mostly in order to supply the energy-intensive industry and district heating systems, generally for distributed cogeneration systems. It seems that this field is easier accessible by SMRs because here SMR must show competitiveness against others small power stations, and not against large nuclear power stations.

Scale effect: economics and safety

Competitiveness is a key factor in the SMRs development and the scale effect is strongly against SMRs. This problem is discussed in Ref. [2], but can be also illustrated by using a simplified model assuming that power, P, is proportional to the reactor volume, i.e. to R^3 and the cost, T, is proportional to the amount of used materials i.e. to the surface of the construction, to R^2. Within this assumptions:

$$\frac{dT}{dP} = 0.67 \cdot \frac{T}{P} \tag{1}$$

One can read from equation (1) the scale effect factor n = 0.67. This value fits to the results presented in Ref. [2] that shows n=0.62 and the range of this parameter between 0.5 and 0.7. Concluding, even an extremely simplified model gives a reasonable good estimation of the role of the scale effect and the magnitude of the scale effect for nuclear power plants is of the same order of magnitude as for other energy technologies.

However, what is more interesting, the scale effect shows also that SMRs are potentially safer than large reactors. The reactor safety greatly depends on the efficiency and reliability of emergency systems that remove heat from the core of the reactor in order to keep it in a safe condition. A lot of activities, particularly after Fukushima accident, are focused around this fundamental safety issue. In this context it should be pointed out that an inherently safe reactor should be able to get rid of the decay heat only by cooling the external surface of the reactor vessel, using only natural processes and passive systems. Thus the adequately small ratio between decay heat power and reactor vessel surface corresponds to the achievement of inherent safety opportunity. Decay heat power, P, is proportional to the reactor volume, i.e. to R^3, and reactor vessel surface, S, and so is proportional to R^2. Thus the ratio P/S depends on P like $P/S \sim P^{1/3}$. Comparing two reactor systems: one of 1340 MW and the second one of 335 MW as in Ref. [2] ones gets that amount of decay heat per vessel surface is 1.6 times smaller for the smaller reactor. Therefore the opportunity to achieve inherent safety is greater for smaller reactors. In some exaggeration, it can be defined that SMRs must have so small power that allows relaying on inherently safe systems to remove decay heat. It can be expected that inherently safe systems are not only more reliable, but they are also cheaper than any others systems what shows the path to achieve competitiveness by SMRs.

Recently, a number of reports on the competitiveness of the SMRs was published, as for example: „Small Modular Reactors - Key to Future Nuclear Power Generation in the U.S." [3] and „Economic viability of small nuclear reactors in future European cogeneration markets" [4]. Most of the publications shows the analysis from the perspective of the SMR technology providers [5], only part of them reflects a general energy policy perspective [3] and only few the energy consumers perception [4]. This tendency reflects the fact that the energy sector is the only one sector that has experience in nuclear energy. However, it seems that key partners for SMR emergence are companies having experience in the field of the distributed cogeneration systems.

SMR development status

Currently only High Temperature gas cooled Reactor (HTR or HTGR) and integrated Pressurized Water Reactor (iPWR) has reached high maturity level to construct the industrial prototypes within the next ten years [6].

The HTR technology promises to provide electricity and heat, firstly in the form of high temperature steam, 550 °C, that is used mainly by the chemical industry. The strongest programs are in Asia and they are based on the operating test reactors: HTTR in Japan and HTR-10 in China. It must be stressed that in China, the industrial program HTR-PM to build a prototype industrial installation is in progress. They restarted the construction on December 2012 which was stopped after the Japanese earthquake and tsunami in March 2011. The HTR-PM twin reactors system will deliver 200 MW electric power in 2017 and the estimated investment cost of the project is 476 million USD [7].

The group of companies "NGNP Industry Alliance" leaded by chemical concern DOW goal is to build a prototype installation in US [8]. Finally, nuclear cogeneration concept is also developed in Europe, but so far all activities are less advanced than in the U.S. The concept vision was formulated already a few years ago under the European initiative SNETP [9]. The reports from the EURATOM program "End-Users Requirements for industrial Process heat Applications with Innovative nuclear Reactors for Sustainable energy supply, EUROPAIRS" [10] are available. Currently the formation of a group of industrial partners "Nuclear Cogeneration Industrial Initiative" is in progress under SNETP initiative [9]. There are also some research activities in Europe, under the frame of EURATOM and there is a program "Development of high temperature reactors for industrial purposes, HTRPL" in Poland financed by NCBR [11] and coordinated by AGH University of Science and Technology. The main objective of the HTRPL project is to strengthen scientific and technical potential, assisting in the implementation of nuclear power program in Poland. Specifically, the objectives of the HTRPL project are:

- Analysis of the prospects for implementation in Poland HTR reactors in the next few years
- Theoretical studies in physics and nuclear engineering of HTR reactors
- Develop guidelines for the technologies for coupling between nuclear and chemical installations, including the prospects for nuclear-coal synergy.

The small integrated pressurized water reactors, iPWR are the other interesting SMR. It seems that iPWR is the most mature SMR technology [12]. Recently the new opportunity for SMR development, towards SMR prototype construction was announced in U.S. and iPWR technology developers shown their strong interest in this initiative. After the evaluation the project mPower was granted by U.S. Department of Energy on November 2012 [13].

Carrying out licensing procedures is another challenge for SMR technologies including HTR and iPWR technologies. Regulators have experience in the field of licensing for currently available reactors, but this knowledge cannot be applied directly for SMR licensing procedures. This issue is for example analyzed in the report published by ANS: "Interim Report of the American Nuclear Society President's Special Committee on Small and Medium Sized Reactor (SMR) Generic Licensing Issues" [14]. This report shows the major differences between currently used safety systems and safety systems for SMRs. It seems that most of the differences come from the adoption of the concept of inherent safety that is a common feature for SMR technologies.

Advantages of distributed nuclear cogeneration systems - case studies

Currently constructed nuclear plants, are large what cause some difficulties in power distribution. Huge quantity of energy produced in one place have to be distributed to consumers located in distant areas. Long power line network cause a number of disadvantage as [15]:

- Energy loss; in Poland it is 12% of total energy produced lost, what gives 18 TWh loses annually, assuming 1 MWh price ~300 PLN it cost about 5,4 billion PLN annually
- Investments in power lines; in Poland for 3,2 GW nuclear plant it is necessary to build 1500 km 400 kV line for about 1,5 billion EUR (~6 billion PLN)
- Difficulties during investment period - permits, arrangements etc.

In the end power lines makes countryside ugly, some land under them is useless, they are source of noise, and cause some electromagnetic danger. Second aspect of case is cogeneration. In big nuclear plant, such huge quantity of heat is produced, that can't be used for commercial purposes because there is no customer to buy it. Nuclear plant usually are located in remote areas where difficult to find a proper way to utilize generated heat it makes necessary to build huge cooling chimneys which are costly and cause environmental effects.

A new trend is, to develop distributed energy generation system, based on SMR units. Reactor can be located near electrical substation at the beginning or end of main power lines or in the vicinity to the energy-intensive industrial or agriculture biofuel areas, to deliver electricity and process heat to consumer (nuclear cogeneration) and only excess (shortage) of electricity will be send to (taken from) the grid reducing losses in electricity distribution. Also it is easier to finance 100 - 300 MW SMR project then thousands MW big nuclear station.

It is also possible to use SMR units as stabilization installation for other renewable sources as windmill or photovoltaic. As an example of possible application for HTR reactor in synergy with biofuel production, there is a concept [16]. Within this concept the hybrid system combines wind energy, nuclear energy, utilize heat to dry biomass and to produce biofuel from collected biomass. Wind farm is about 1 GW pick electric power and is connected to the grid via node assisted by "Dynamic Energy Switch" (DES) which balanced energy send to the grid in relation to output generated by wind. Variability, of the output oscillate with max. output of 1 GW electric power (wind + nuclear). The wind farm and nuclear installation SMR (HTR technology) are operated in parallel to deliver a combined output as close as possible to demand for electricity in the grid. When wind power production is lower, the nuclear reactor compensates it by supplying steam to the turbine to produce electrical power. As wind generation increases, the nuclear reactor reduces electricity production and supplies heat to the biomass processing plant. Nuclear plant installation with processing facilities, collect biomass which covers an area of 80 km radius around (it is about ~2 million hectares what is limited by transportation costs) it is assumed that this area deliver about 1 000 000 tons of dry biomass annually. The biomass is processed in three stages each with varying heat and electricity requirements. The system results in a torrefaction process product, converted to a pyrolized oil, then processed into to bio-diesel and bio-gasoline with the addition of hydrogen. Yields annually are about 218 000 m^3 bio-gas and 275 000 m^3 bio-diesel or about 218 000 m^3 of bio-gasoline. The nuclear reactor (HTR) was optimally sized at 347 MW of electric power (755 MW of thermal power) and operated at full capacity. Dynamic Energy Switch allows switching between heat and power production to compensate for power production changes from renewable energy sources. Heat is provided at two temperatures (200 and 500 ^oC). Hydrogen is produced by electrolysis when wind has high availability and/or during low electricity demand periods in the grid. The hydrogen is used in synfuel production and also is used to accumulate generated energy. About 23% of the electricity produced by the nuclear complex is used for hydrogen production.

Another site that could be consider for SMR is related to a new trend in biomass production which is based on aquaculture techniques as a principle. Watered biomass, algae, consume sun light, carbon dioxide, and in many cases waste water as a food. Algae growth very fast some kinds might even double their dry mass within five hours. To using algae in place of regular biomass within nuclear cogeneration concept seems to give several advantages:

– Space required - in regular conditions for Chlorella Vulgaris strain it is 1 kg dry mass yields daily from 1 m^3 watered environment. Suppose culture will be growing in 50 cm deep closed race pound, total net surface required for cultivation of 1 000 000 tons of dry biomass annually is at the range of 5 500 000 m^2 what is 550 ha, even added in addition place for roads and infrastructure spaces, whole production area come down to 720 - 750 ha (compare to 2 000 000 ha)

– Type of soil - there is no needs for arable land race pound might be constructed even on rocks
– Mechanical transportation - is not needed because watered biomass might be transported by pipelines and in last distance on conveyers
– Low parameter hit after draying of biomass and after pyrolysis might be used to keep race pound in proper cultivation temperature

It is worth mentioning also a very interesting publication "Bio-Fuel Production Assisted with High Temperature Steam Electrolysis" [17] in which the considered system in supplied by SMR (iPWR technology) that provide steam, 300^{o}C and electricity.

Conclusion

Since 2010 a quite big progress was done on the SMR developments mostly in China and US and prototypes are expected within the next 10 years. It seems that distributed cogeneration systems are the most promising sites for the SMRs, hoping also in Europe and in Poland.

Acknowledgements

This work was supported by the National Centre for Research and Development, Poland under the strategic project "Technologies Supporting Development of Safe Nuclear Power Engineering", task "Development of high temperature reactors for industrial purposes (HTRPL)", grant number SP/J/1/166183/12.

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International Scientific Conference, September 16-18, 2013, Krakow, Poland

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IDENTIFICATION OF GHG EMISSION SOURCES IN THE LIFE CYCLE OF MOTOR FUELS

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Abstract. In the article, issues concerning GHG (greenhouse gases) emission in the motor fuel life cycle have been discussed. The life cycle of fuels is divided into few stages: crude oil extraction, transport to a refinery, processing at the refinery to obtain motor fuels, fuel storage and distribution, and the final stage: combustion in a car engine. The specifics are different for each stage, therefore, for each of them there is a different GHG emission source. Individual GHG emission sources, separately for each stage, have been indicated and briefly discussed. In the article, apart from the GHG emission sources, the applied GHG emission reduction method has been presented. The document puts special emphasizes on the stages, where the fuel producer has the best capability of managing the GHG emission (stages of crude oil extraction and processing). It can be achieved through activities such as improvement of energy efficiency, changing of heating fuels, and reduction of flaring and venting GHG emission.

Key words Life cycle, GHG emission, motor fuels

Introduction

Directive 2009/30/EC of the European Parliament and the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC [1] is one of the most important legal acts for motor fuels manufactures. The said directive is commonly referred to as the FQD, which is the abbreviation for English phrase Fuel Quality Directive. The most significant changes which have been introduced, refer to increase of maximum content of biocomponent in motor fuel.

The aforementioned directive, apart from laying down a number of provisions, impose on the fuel suppliers an obligation to reduce greenhouse gases emission in the fuel life cycle. In particular, Article 7a(2) states as follows:

Member States shall require suppliers to reduce as gradually as possible life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied by up to 10 % by 31 December 2020, compared with the fuel baseline standard referred to in paragraph 5(b) of FQD. This reduction shall consist of:

a) 6 % by 31 December 2020. Member States may require suppliers, for this reduction, to comply with the following intermediate targets: 2 % by 31 December 2014 and 4 % by 31 December 2017;

b) an indicative additional target of 2 % by 31 December 2020, subject to Article 9(1)(h), to be achieved through one or both of the following methods:

– the supply of energy for transport supplied for use in any type of road vehicle, non-road mobile machinery (including inland waterway vessels), agricultural or forestry tractor or recreational craft;
– the use of any technology (including carbon capture and storage) capable of reducing life cycle greenhouse gas emissions per unit of energy from fuel or energy supplied;

c) an indicative additional target of 2 % by 31 December 2020, subject to Article 9(1)(i), to be achieved through the use of credits purchased through the Clean Development Mechanism of the Kyoto Protocol, under the conditions set out in Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community, for reductions in the fuel supply sector.

Out of the aforementioned three targets, the first target requiring emission reduction by at least 6% is an obligatory target, while the two others are additional targets. However, the said directive has not specified methods for calculating greenhouse gases emission, and only Article 7a(5) mentions necessity to specify all measures necessary for the implementation of that Article. Reduction index is to be calculated based on average European emission factor determined for the 2010 year, i.e. so called baseline fossil fuel greenhouse gas intensity, which is identical for all fuel suppliers, regardless of their technological advancement. The said directive obliged also the European Commission to develop methods for determining that level.

According to the provisions of the directive it is required that suppliers report GHG emission factor, amount, origin and place of purchase of fuel and supplied energy. Methodology for determining GHG emission factors should compensate for necessity to take exact measurements, minimise administrative procedures and at the same time encourage suppliers to take actions aimed at reduction of greenhouse gases emission.

Motor fuels life cycle

Product life cycle is defined in PN EN ISO 14044 standard [2] Environmental management -- Life cycle assessment -- Requirements and guidelines, the said standard specifies requirements and procedures necessary to assess life cycle (commonly referred to as LCA). According to the definition provided in this standard, life cycle means subsequent and related with each other stages of the manufacturing system, starting from product exploiting or manufacturing from natural resources, and ending with its final disposal. Life cycle assessment can be made for all types of products available on the market, not only for motor fuels. Product life cycle is schematically presented in the following figure 1.

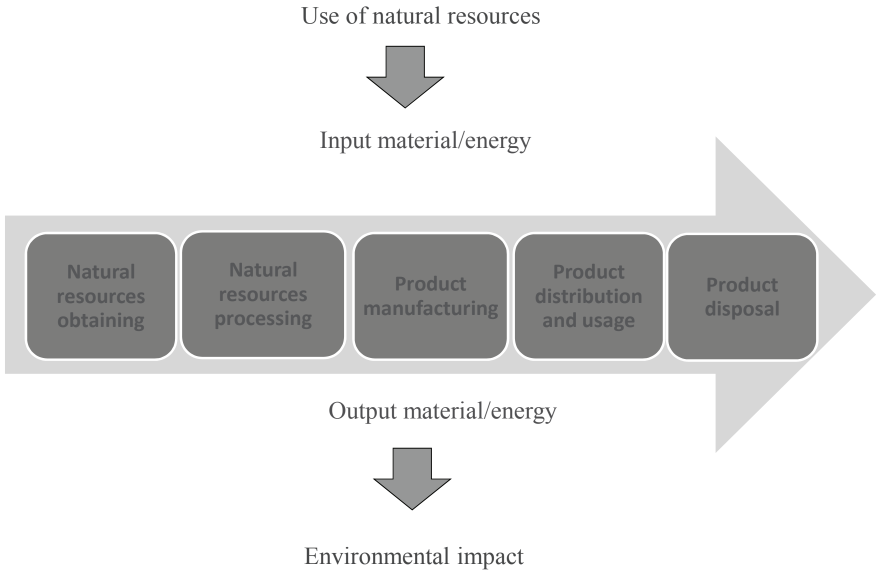

Figure 1 Product life cycle

Product life cycle starts when the resources are exploited in order to manufacture the product, but resources are often first treated, and only then assessed product is manufactured from such semi-finished products. However, product life cycle does not stop here; instead the following stages include product distribution and usage, whereas the last stage of the life cycle is product disposal. Each stage uses resources of the natural environment (use of fossil fuels, water, air, other materials), and these materials make input energy and input materials. Each stage exerts also environmental impact due to emission of different substances, including hazardous ones, as well as emission of noise to the natural environment. In case of conventional motor fuels chart presented in figure 1 above need to be modified as presented below in figure 2.

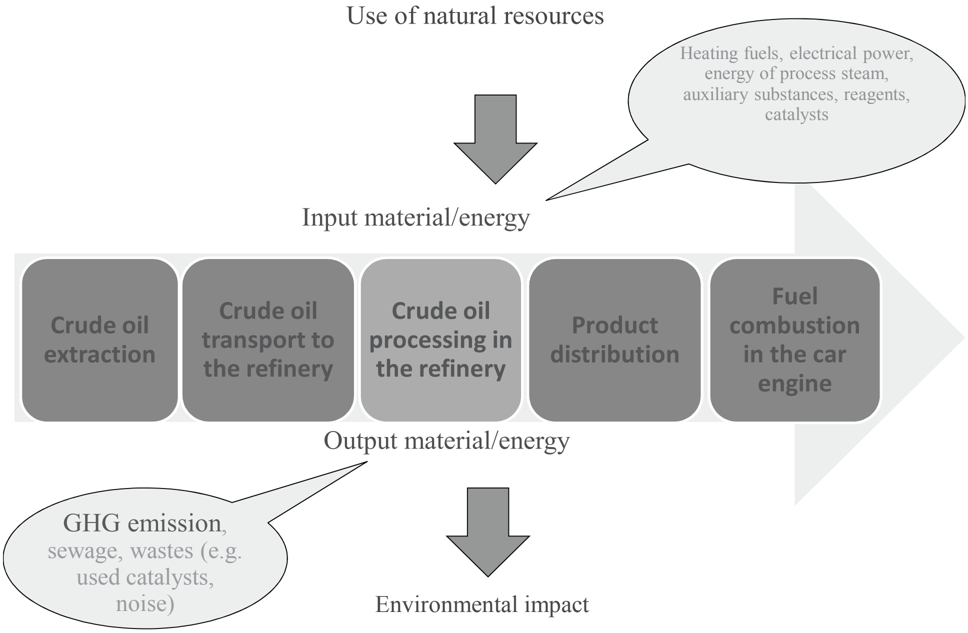

Figure 2 Life cycle of conventional motor fuel

Life cycle of hydrocarbon motor fuel begins when crude oil is explored and extracted. The next stage covers its transport to an oil refinery. Then crude oil is processed to motor fuel, which in figure 2 is showed in orange square. When motor fuel is already manufactured in the oil refinery, it is then distributed to filling station, where it is purchased by the end-user. Life cycle ends, when fuel is combusted in a car engine, thanks to which used product need not to be disposed of.

Accomplishment of each stage requires utilization of natural resources and generates emission of greenhouse gases, sewage, noise etc. to the natural environment. Fuel Quality Directive focuses on only one category of environmental impact i.e. global warming, and therefore by its provisions it has obliged motor fuel manufacturers to monitor and reduce greenhouse gases emission. It must be borne in mind, that the said obligation has been imposed on fuel suppliers (i.e. oil refineries) which means, that they must also allow for emission of greenhouse gases generated by independent external entities (e.g. crude oil suppliers).

Depending on production path, emission factors can be different at different stages, but it proves to be always the highest during combustion stage in the car engine. Figure 3 shows schematically share of GHG emission during life cycle of low-sulphur diesel [3].

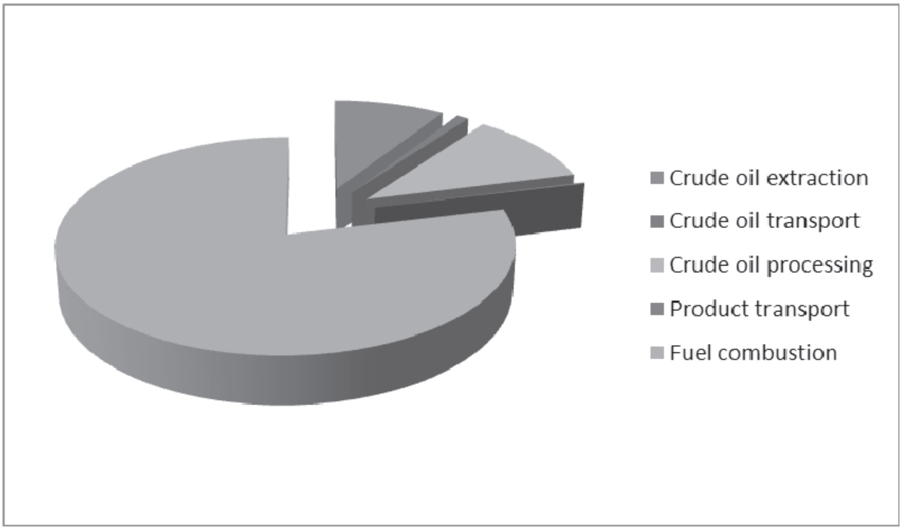

Figure 3 Share of GHG emission during life cycle of low-sulphur diesel

Major sources of greenhouse gases emission during particular stages of motor fuel life cycle are discussed in more detail below.

Crude oil extraction and its transport to oil refinery

Exploration and extraction of crude oil is the moment, when natural resource is exploited for motor fuel production. Factors of greenhouse gases emission during this stage depends mostly on [4]:

- duration of oil field exploitation;
- proportion between volume of dissolved deposit gas and amount of extracted crude oil;
- depth of oil well;
- extraction pressure;
- crude oil viscosity;
- crude oil specific gravity according to American Petroleum Institute (API), which allows fast determining, whether crude oil is "light" or "heavy";
- type of extracted resource (conventional crude oils, oil sand, other resources);
- crude oil extraction method (inland, off-shore, exploratory method, etc.)

According to [5], taking as an example the Norwegian and the Nigerian crude oil, calculation of GHG emission allows for the following factors:

- deposit gas released to the atmosphere;
- deposit gas combusted in gas flares;
- desulphurised deposit gas combusted in gas turbines;
- drilling works, well maintenance;
- use of diesel.

Apart from sources of GHG emission specified above, volatile emission should be also considered. Volatile emission is unintentional and uncontrolled release of greenhouse gases to the atmosphere, which occurs on valves and gaskets in equipment and apparatus, which is difficult to be assessed. Factors for assessing this type of emission were developed by the Canadian Association of Petroleum Producers (CAPP), the Environmental Protection Agency (EPA) and the International Association of Oil and Gas Producers (OGP) [4, 6].

According to calculations made in [5], combustion of deposit gas in turbines have the biggest share in GHG emission, while in case of the Nigerian crude oil this is release of deposit gas to the atmosphere. Gas combustion during extraction of crude oil emits to the atmosphere approximately 400 millions of tons of CO_2 a year, which makes approximately 1.5% of the world's CO_2 emission. While in Nigeria, extraction of 1 kilo of crude oil releases 0,2961 gCO2eq to the atmosphere [5]. Therefore European communities strongly demand that this emission is reduced. This goal can be achieved i.a. by actions such as injecting the gas back to the well, gas liquefaction and exportation, using the gas in chemical synthesis, etc. [4]. It is of particular advantage to inject CO_2 to the well, as this gas is used in EOR – Enhanced Oil Recovery processes. Amount of used carbon dioxide depends on pore volume and deposit depth. In most cases of multi-contact crude oil displacement processes, CO_2 density is about 500–700 kg/m^3. As this type of process proves to be significantly efficient, researches have been carried out in order to optimise the process [7].

The next stage of motor fuel life cycle, when greenhouse gases are emitted, is transport of crude oil to the oil refinery. During this stage the following factors are important [5]:

– distance between oil fields and oil refinery;
– crude oil density;
– type of transport (marine, pipeline).

According to calculations presented in [5], oil-tanker transport of 1 ton of crude oil on the distance of 1 km emits 0,0254 gCO_2eq.

Crude oil processing at the refinery

When crude oil is delivered to the oil refinery, it is first directed to crude distillation unit, where crude oil is separated to its particular fractions, which are further processed in order to obtain fuel components and other products. Then, components are mixed with each other and with other purchased components and additives. Apart from motor fuels, other products such as lubricants, asphalts, etc. are also manufactured in the oil refineries. Therefore it is of great significance to determine suitable procedure to allocate GHG emission with regard to petroleum products.

The major source of GHG emission during this stage is mostly connected with utilization of energy carriers necessary to carry out the processes. These are mainly electrical power, process steam, heating fuels, as well as cooling water. Use of particular carriers is allocated with regard to refinery products [3]. Heating fuels can be purchased from outsources (e.g. natural gas), or these can be refinery products (refinery gas, furnace oil, petroleum coke). Type of heating fuel exerts direct impact on GHG emission factor during this stage. The reason behind this is that particular heating fuels have different GHG emission index in relation to their energy. In order to prove differences in these values, emission indexes for a number of heating fuels are presented in table 1 below. Index values have been sourced from the study prepared by the National Centre for Emission Balancing and Management *[Polish name: Krajowy Ośrodek Bilansowania i Zarządzania Emisjami KOBIZE]* [8].

Table 1.
Emission indexes for heating fuels according to KOBIZE

No	Fuel	Emission index $kgCO_{2eq}·GJ^{-1}$
1.	Natural gas	55.82
2.	Biogas	**54.33**
3.	Petroleum coke	**99.83**
4.	Liquefied petroleum gas	62.64
5.	Light heating oil	73.33
6.	Heating oils	76.59
7.	Refinery gas	66.07
8.	Non-biological industrial/commune wastes	**140.14**

Data presented in table 1 shows, that depending on the type of used fuel, emission factor generated during combustion of 1 GJ of fuel can be three times higher. If it is only the type of heating fuel, which is changed, it is possible to considerably decrease GHG emission factor during fuel production in the oil refinery (also with regard to fuels). It must be emphasized here, that application of different heating fuels usually changes boiler efficiency, which can further contribute to decrease of GHG emission.

Electrical power is important energy carrier used in the oil refinery. It can be both produced in the refinery, or it can be sourced from the national grid and purchased from external supplier. In the first case GHG emission will mostly depend on the type of heating fuel and efficiency of boilers used in a power plant of the fuel manufacturer. What matters in the second case is GHG emission factors for supplied electrical power, which is determined by its producer. These factors will vary depending on natural resources, geographical conditions, technological advancement of the country, as well as type of used renewable energy sources. Average emission factors for particular countries were calculated by a number of research institutes, and it was decided to choose the ones which were used in draft directive specifying method for calculating greenhouse gases emission during life cycle of conventional motor fuel [9], which as in [10], is presented in table 2 below.

Different values presented in table 2 result from structure of electrical power production present in a given country. In Poland hard coal and brown coal are the most important fuels, which make approximately 90% of power production; however it is worth mentioning, that production level from renewable energy sources continues to increase. In 2011 production from biomass resources increased by 33% in industrial plants, whereas power production using co-combustion technology increased by 18%.

Technological progress, which is stimulated i.a. by the European Union policy promoting renewable energy sources, results in systematic decrease of the aforementioned rates, which - based on analyses carried out by the European Environment Agency [10] is presented in figure 4 below.

Values presented in both table 2 and figure 3 are average values. In fact, depending on implemented solutions, these values will be different for different suppliers, even within a single country. In Poland for instance, each power supplier reports different CO_2 emission rates in relation to MWh. PGE reports 0,774 $MgCO_2 \cdot MWh^{-1}$ [12], while Enea announces 0,4244 $MgCO_2 \cdot MWh^{-1}$ [13].

Modernisation and improved energy efficiency of refinery processes is another way to reduce GHG emission. Advantageous actions include i.a. application of low-emission burners (replacement during major repairs), recirculation of part of flue gases to combustion section, or application of after-combustion techniques [14].

Table 2.
Average GHG emission factors for electrical power in EU Member States

No.	Member State	GHG emission factor ($gCO2eq \cdot MJ^{-1}$)
1.	Austria	86.1
2.	Belgium	111.7
3.	Bulgaria	251.7
4.	Cyprus	283.1
5.	Czech Republic	222.8
6.	Denmark	211.1
7.	Estonia	442.5
8.	Finland	116.1
9.	France	40.6
10.	Germany	196.1
11.	Greece	324.2
12.	Hungary	188.3
13.	Ireland	241.7
14.	Italy	196.7
15.	Latvia	156.4
16.	Lithuania	48.3
17.	Holland	198.9
18.	Poland	329.2
19.	Portugal	208.3
20.	Romania	301.1
21.	Slovakia	98.1
22.	Slovenia	167.2
23.	Spain	177.5
24.	Sweden	21.9
25.	Great Britain	182.8

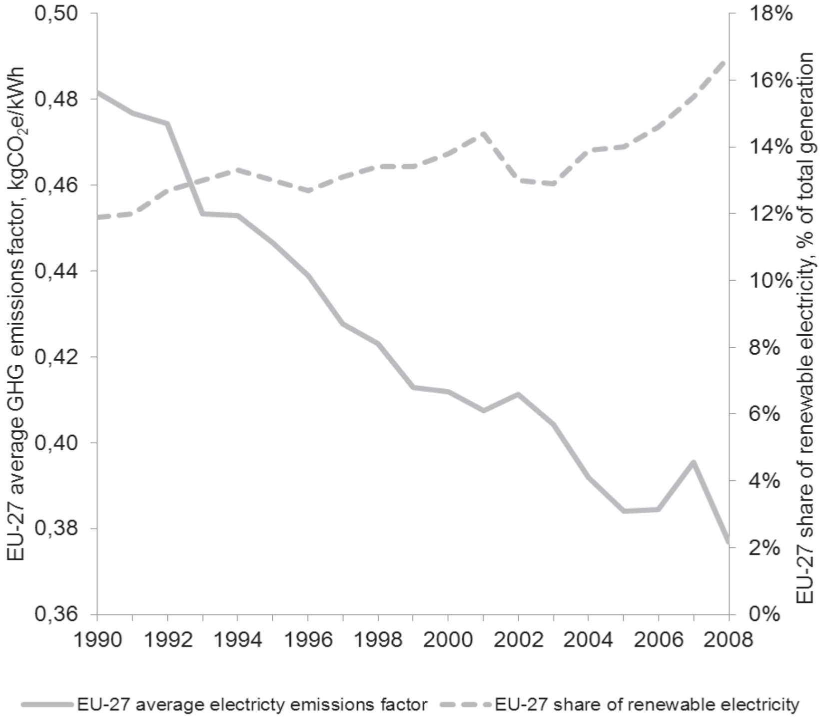

Figure 4 Changing tendency in GHG emission factors in relation to share of renewable energy sources in power production - average value for EU-27 [10]

Table 3.
Efficiency of actions taken during fuel production stage in refinery on the example of Tarragona refinery, based on [15]

	Action	Share in final reduction of GHG emission (%)
1.	Changed fuel	42
2.	Design modification of refinery units	31
3.	Review of actions criteria	8
4.	Improved operation of equipment	7
5.	Optimum use of units	7
6.	Exchanged equipment	5

However, the most efficient way to reduce greenhouse gases emission during this stage is changing of heating fuels. International petroleum concern Repsol implemented programme aimed at improvement of energy efficiency and reduction of greenhouse gases emission, and as a result it was possible to reduce greenhouse gases emission in Tarragona refinery by 282 kt·year^{-1}. This effect was achieved thanks to multiple actions and €44M expenditure. Scope of actions taken in this programme and their share in final result is presented in table 3 below [15].

4. Distribution of ready-made products

Storage and distribution of motor fuel to the end-user i.e. to the filling stations, is last but one stage of motor fuel life cycle. In Poland there are two major companies, which process crude oil and manufacture motor fuel: PKN ORLEN S.A. and Grupa LOTOS S.A. Fuels manufactured by these companies are distributed by fuel bases through product pipelines, as well as rail and road transport. Pipelines and rail transport are used for product distribution on long distances, whereas road transport provides product supply within maximum distance of 150 km [16].

During this stage motor fuel suppliers invest mainly in even more fuel base management systems. As a result it is possible to achieve management systems which allow decreasing of hydrocarbon emission to the atmosphere (even by 75%), thanks to which level of product loss can be reduced, whereas with suitable structure of oil tank it is possible to achieve greater fuel base capacity than at standard solutions, thanks to which greater amounts of product can be stored on a given area (park of 11 oil tanks with modernised structure has similar storing capacity to park of 12 standard oil tanks).

5. Combustion in car engine

Combustion of motor fuel in the car engine is the last stage of life cycle. GHG emission factor during this stage depends on a number of factors, such as road infrastructure, technological progress of vehicle fleet, climate and others. Change of these factors in order to decrease emission factor lies beyond actual capabilities of the motor fuel supplier. However, in order to meet targets imposed by FQD (i.e. emission reduction by at least 6% in the motor fuel life cycle by 2020) it has been assumed, that biofuel combustion in the car engine generates zero level GHG emission. The reason behind this is that it was stipulated, that amounts of carbon dioxide assimilated by plants in photosynthesis are similar to amounts released during combustion. Therefore for the purposes of FQD implementation, only GHG emission generated during biocomponents/biofuel production stage is taken into consideration. Following assumptions made by the Legislator it can be concluded, that motor fuel supplier can actually reduce GHG emission factor during fuel combustion in the engine by using biofuels [1]. Efficiency of this method depends on the type of biofuel and its production path. According to [18] in case of fuels designed for spark-ignition engines, it is most efficient to use sugar cane ethanol (typical emission factor reaches 24 $gCO_{2eq}\cdot MJ^{-1}$), whereas wheat ethanol proves to be least efficient (57 $gCO_{2eq}\cdot MJ^{-1}$), FAME from used oil (10g $CO_{2eq}\cdot MJ^{-1}$) and palm oil according to non-specified technology (54$gCO_{2eq}\cdot MJ^{-1}$).

Summary

Analysis of environmental impact of the product during its life cycle allows making complex assessment of threats, which occur during production, utilization and disposal of a given product. In case of motor fuel an obligation to reduce emission during life cycle was specified in FQD and imposed on fuel suppliers. The highest GHG emission factor occurs during combustion stage in the car engine, whereas lower factors are observed during processing stage and crude oil extraction, respectively. It is possible to implement actions aimed at lessening adverse environmental impact suitable for each stage, which mainly include technological improvements, change of heating fuels and sources of electrical power. Combustion in the car engines is the only stage, when adding biocompotents to fuels is the only instrument, which can contribute to reduction of GHG emission.

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BIOENERGY: A GLOBAL PERSPECTIVE ON THE OPPORTUNITIES AND THREATS OF ALTERNATIVE ENERGY SOURCES

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Abstract. Global production of bioenergy is growing globally. Both the European Union (EU) and USA have established goals/targets for bioenergy. There are two major components of bioenergy; respectively biofuels (principally ethanol and biodiesel) and biopower (use of biomass for electricity and heat production). There are both opportunities and threats to bioenergy from technological, societal and economic viewpoints.

Key words: Bioenergy, biofuels, starch-based ethanol, cellulosic ethanol, biodiesel, biopower

Introduction and Overview:

There is considerable investment in bioenergy globally. In 2009, the European Union (EU) established a target for renewable energy of 20% of energy usage with the bioenergy/biomass representing largest component [1]. For instance, the 2020 goal of the EU obtaining power from the following [1]:

- biomass - 1,210 terawatt hours (TWh) of energy *and in comparison*
- wind - 494TWh

At present, biomass meets over 50% of renewable energy within the EU and more than 80% in some countries such as Poland [2].

Bioenergy can be divided into three facets:

- Biofuels (principally ethanol and biodiesel)
- Biopower (use of biomass for electricity and heat production)
- Bioproducts (e.g. polylactate plastics)

There is considerable support for bioenergy. The Union of Concerned Scientists [3] considers that "Without sustainable, low-carbon biopower, it will likely be more expensive and take longer to transform to a clean energy economy." Moreover, they state that "like all our energy sources, biopower has environmental risks that need to be mitigated". Major potential sources of bioenergy include the following:

- Human waste
- Animal waste
- Food industry
- Crop residues
- Forestry residues
- Perennial plants grown for biomass
- Wood
- Corn/maize
- Soybeans and other oil plants – rape, palm

The projected increases in biofuels and biopower are in competition with natural gas. While widely endorsed by environmentalist, bioenergy and biofuels is opposed by some environmentalists [e.g. 4]. Moreover, Jose Graziano da Silva, FAO director general, stated "*FAO has been raising its voice against using food to produce bio energy"* [5].

Biofuels

Global production of biofuels (2011) is summarized below:

Global	58.9 million tonnes oil equivalents
USA	28.3 million tonnes oil equivalents (>85% ethanol fuel)
Brazil	13.2 million tonnes oil equivalents (>85% ethanol)
European Union	9.7 million tonnes oil equivalents (>75% biodiesel)

Source: BP 2012[6]

2A. Corn based Ethanol

Ethanol represented over 95% of biofuels in the USA [7]. Since then production has increased markedly with biodiesel now representing more than 10% of production [6].

Global fuel bioethanol production (2012) can be summarized as follows:

Global	85.1 billion liters
North America	54.6 billion liters
South America	21.3 billion liters
Europe	5.0 billion liters
Asia	4.0 billion liters

(Source: Renewable Energy Association [8]

It has been concluded that "*current corn technologies are much less petroleum-intensive than gasoline but have greenhouse gas emissions similar to gasoline*" [7]. Production of ethanol in the USA in 2013 was 50 billion liters [8]. The vast majority of this is derived from starch from corn/maize [8]. In contrast, Brazil's ethanol production from sugarcane is about 5 billion liters year^{-1} [9]. It is questioned whether there is significant scope for expansion due to problems with corn based ethanol

– Need for substantial subsidy
– High water usage in production
– Competition between human or livestock for corn starch.

2B. Cellulose ethanol

Sticklen stated that "*cellulosic biomass, which is both abundant and renewable, is a promising alternative*" [10]. Perennial herbaceous plants such as switchgrass (*Panicum virgatum* L.) offer considerable potential for cellulosic ethanol production as a biofuel. It has been estimated that cellulosic ethanol produced from switchgrass could result in a 94% lower greenhouse gas emissions than gasoline [11]. Switch grass can be produced on marginal land unsuitable for production of agricultural crops. Switchgrass has a high yield. For instance in field trials, yields of switchgrass of between 5.2-11.1 metric tonnes per hectare have been obtained [11]. This is equivalent to 60 GJ ha^{-1} y^{-1} (16.7 megawatt hours ha^{-1} y^{-1}) [11].

Harvested dried switchgrass contains the following constituents convertable to ethanol:

– Total hexose (cell wall polysaccharides and soluble sugars) 342 - 398 g kg−1
– Pentoses (arabinose and xylose) 216 to 245 g kg^{-1} [11].

There have been estimates of the theoretical maximal yield of ethanol from 400 L Mg^{-1} (metric tonnes^{-1}) from biomass or 1750-3690 L ha^{-1} [11].

Progress is being made in technologies to produce cellulosic ethanol. These include:

– Pretreatments to enhance the digestibility/increase access by fermenting organisms such as steam, lime, hot water and ammonia [12].
– Ammonia fiber extension [e.g. 13, 14]
– Plants bioengineered to produce cellulases and hemicellulases [7]

In the USA in 2007, under the renewable fuels standard (RFS), a large increase in renewable fuel was mandated including the following:

– 2010 – 380 million liters of cellulosic biofuels (cellulosic ethanol) [lowered to 25 million liters in December 2009]
– 2011 – 950 million liters [lowered to 25 million liters in December 2010]
– 2012 – 1900 million liters
– 2013 – 3800 million liters
– 2022 – 61 billion liters

(Bracmort et al., 2011; US Energy Information Administration, 2013a) [15, 16].

Production of cellulosic ethanol in 2012 was 76 million liters [16]. Obviously there are "*significant hurdles must be overcome before commercial-scale production can occur*" [15]. The Food, Conservation, and Energy Act of 2008 (the US 2008 farm bill) included a subsidy ($0.26 liter^{-1}) for cellulosic ethanol [15].

2C. Biodiesel

Biodiesel is produced from vegetable oil seeds or waste fats and oils. Europe is the major producer of biodiesel with over 8 million tonnes oil equivalents in 2011 [6]. The major source of oil is from rapeseed. The major producers of biodiesel are the following:
– Germany 2.8 million tonnes oil equivalents
– France 1.7 million tonnes oil equivalents

Source: BP, 2012 [6]

There are 113 biodiesel plants in the USA with an annual capacity of 8.1 billion liters per year [17]. According to the US Energy Information [17], the feedstocks used for biodiesel production in the USA were the following in March 2013:
– Soybean oil 192 thousand metric tonnes
– Yellow grease 32.7 metric thousand tonnes
– (used cooking oil from the restaurant industry)
– Maize/Corn oil 32.2 metric thousand tonnes
– Tallow (rendered beef or sheep fat) 24.1 metric thousand tonnes

2D. Biodiesel from microalgae

Microalgae in the process of photosynthesis, plants fix carbon dioxide using solar energy thereby fixing carbon dioxide. Either ponds (seawater, freshwater or brackish water) or closed system bioreactors [18] may be employed for the microalgae in temperate or tropical environments. According to the Biomass program of US Department of Energy [18], there are numerous potential advantages of algal biofuels including the following:
– "Potentially produce 100 times more oil per hectare than soybeans—or any other terrestrial oil-producing crop."
– Reduced atmospheric carbon dioxide.
– Use of biomass residue after separation of oils for biopower production.

Biopower

Biomass burning has long been a major form of energy generation. Through early human development, plant oils and animals fats has been used almost exclusively for lighting by burning in lamps. In pre-industrial countries, biomass (wood, peat etc.) was the primary source of energy for heating and cooking and it continues to the widely employed. In addition, biomass was employed in some industrial processes. In developing countries, biomass is still widely employed for cooking. Incomplete combustion is a problem for household biomass use with the production of the greenhouse gas, methane. There is scope for the development of systems with the following characteristics:
– Improved efficiency (and consequently less fuel needs)
– Considerably reduced generation of the greenhouse gas, methane, through incomplete combustion
– Production of biochar as a mechanism for carbon sequestration. Potentially, biochar may prove useful improving soil fertility [19].

In the European Union, there have substantial efforts to increase electricity generation from biomass to reduce the carbon footprint ideally to zero (carbon neutrality) and thereby decrease net greenhouse gas emission to zero [1, 2]. For instance, the United Kingdom government is seeking to increase generation of electricity generated from biomass. The Tilbury B power station was converted to burning wood chips and three of the Drax coal fired power stations are slated for using biomass by 2016 generating 12.5 terawatt hours per year [2]. According to the Natural Resources Defense Council [20], biomass power already accounts for over 50% renewable energy in the USA. The Canadian government has estimated that the country produces 54 million metric tonnes of dry biomass and, if used for power generation, would produce 2 gigawatts of electricity [21].

According to the National Renewable Energy Laboratory [22], the principal feed-stocks for biomass to power in the USA are paper mill residue, lumber mill scrap and municipal waste. However, there is increasing both production and export of wood pellets as part of the wood to energy sector, particularly in Europe. North American exports of wood pellets to Europe have been rising rapidly to a 28.8 million metric tonnes in 2012 with a 70% increase of the third quarter of 2012 compared to 2011 [23].

Burning biomass releases carbon dioxide. This can theoretically be completely offset by carbon dioxide fixed by photosynthesis in plant growth. However, this offset depends on how the plant biomass is produced (considering inputs and alternatives for the land use) together with transportation and other costs in processing the biomass. According to the National Renewable Energy Laboratory [22], "*use of biomass energy has the potential to greatly reduce greenhouse gas emissions. Burning biomass releases about the same amount of carbon dioxide as burning fossil fuels." However, fossil fuels release carbon dioxide captured by photosynthesis millions of years ago—an essentially "new" greenhouse gas*. Alternatively, it is reasonable to reiterate an alternative, but nonetheless thoughtful, viewpoint. According to the Natural Resources Defense Council [20] "*the misconception that trees are 'carbon neutral' sources of biomass is embedded in many renewable energy policies that promote biomass uniformly, and can often distort the marketplace towards unsustainable sources of biomass like whole trees*". In contrast, the sources of woody biomass can be harvested dedicated species of trees with rapid growth rate (e.g. poplars) or sustainably produced timber can be in a manner or timber residues (the parts of trees left after logging). These are viewed as "*a more sustainable source of biomass than whole trees*" [20].

It appears that there are distinct problems with the present technology with the use of biomass. There have been fires in power stations including in California [24]), Denmark [25], England [2] and the Netherlands [26] and at re-cycling plants [27]. Furthermore, according to NASA [28], "*Burning vegetation releases large amounts of particulates (solid combustion particles) and gases including greenhouse gases*". The latter obviously include carbon dioxide together with significant quantities of methane. Particulates have the potential of negatively impacting human health. There are reports of power plants burning biomass subject to fines from regulatory agencies due to release of pollutants [29]. Burning of biomass opposed by some groups of environmentalists due to concerns about forest depletion, pollutants etc. [4, 30, 31].

Overall Conclusions

Clearly there is a need for improved technology with higher efficiency (including co-generation of heat and electricity) and more complete combustion; thus reducing release of pollutants. It is possible to envision a policy environment encouraging sustainable practices

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STUDIES ON LOCATION AND CALORIFIC VALUE OF INVASIVE GOLDENROD SPECIES IN THE WIŚNICKIE FOOTHILL

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Abstract. Aim of our study was to (1) evaluate the intensity of invasive *Solidago* sp. occurence along the Wiśnickie Foothills, (2) assess the calorific value of *Solidago* plants collected from different habitats. *Solidago gigantea* dominates in the studied area, especially in the eastern part of the Foothills. *Solidago canadensis* occurres in a lower frequency, mostly along rivers' banks in the eastern part of the Foothills. The level of land management influences the severity of invasive *Solidago* occurrence, which are more frequent in the poorer managed eastern parts of Wiśnickie Foothills. The calorific value of goldenrods collected in the flowering stage is very low, 14.74 J kg^{-1} and 14.98 J kg^{-1} for *Solidago gigantea* and *Solidago canadensis*, respectively. Calorific value of *Solidago gigantea* collected from the dry fallow is higher, as compared to plants collected from the wet fallow.

Key words: Solidago canadensis, Solidago gigantea, occurrence, biomass

Introduction

Among the invasive plant species of Poland two goldenrod species, *Solidago canadensis* and *Solidago gigantea* deserve special attention. Over a relatively brief period of time they have occupied almost the entire country [7] and are also a major problem in several other European countries and around the world. [10] underline, that invasive goldenrods are responsible for substantial decrease of biodiversity in the habitat, which could be a result of their allelopathic properties [10]. Weber [2001] reports that the range of goldenrods in the coming years will increase even more. Invasive goldenrods in Poland are not evenly distributed, i.e. in the Małopolska region both goldenrods are noted in equal intensity, while in the North-East of Poland *Solidago canadensis* dominates.

Among the factors which increase the invasiveness of both species, one can point to a very high number of small, volatile seeds, the ability to reproduce through vegetative propagation, strong competitive abilities and a wide ecological tolerance [6]. Still, there are few positive aspects of the presence of goldenrod in flora. First, they contain essential oils of interesting chemical composition [4], are melliferous and recently their energetic utilization is emphasized [9].

The aim of the present study was to characterize the occurrence of invasive goldenrods in the Wiśnickie Foothill and to evaluate the calorific value of the goldenrods' biomass, harvested from the different types of habitats.

Material and Methods

In 2012-2013, field research along the roads of the Wiśnickie Foothill was carried out. *Solidago* species occurrence, the location and severity of its occurrence [single plants, loose clumps, canopy] and plants height were assessed. Species were identified according to [5] botanical key.

In order to determine the calorific value of goldenrod biomass the samples of *Solidago canadensis* and *Solidago gigantea* were collected from the contrasting habitats [ruderal or fallow, dry or wet]. The collected plants in the flowering stage were air-dried in the barn. Then the samples were weighed and assayed for the content of ash and the dry mass. The heat of combustion in the calorimeter bomb KL 12, according to the PN-81/G-04513 and ISO 1928 standards, was measured. Based on the heat of combustion measurement the calorific value was calculated.

Characteristic of the studied area

Wiśnickie Foothills, located between the valleys of Raba and Dunajec rivers, belongs to the macro-region West-Carpathian Plateau and sub-province Outer Western Carpathians. It is a hilly area of a maximum altitude not exceeding 500 m a.s.l. The area of the Foothills is of 722 km^2 and this is a typical agricultural land. From the south it borders with the Beskid Wyspowy mountains, from the east – the Rożnowskie Foothills, and to the west with Silesia. In the western part of the Wiśnickie Foothills there are mostly apple-orchards located, whereas in the eastern and central parts – the arable fields, but also many fallows and ruderal lands.

Results and discussion

There were 50 research points in total localized along the Wiśnickie Foothill. Based on the field trips the intensity of *Solidago canadensis* and *Solidago gigantea* occurence was assessed and displayed as a map (Fig. 1). Both species of invasive goldenrods were found on the Wiśnickie Foothill, but the severity of their invasiveness is different. *Solidago gigantea* visibly dominates in the studied area. It occurred in the high numbers mostly in the Eastern parts of the Foothill and along the main rivers in this area: Raba, Dunajec and Stradomka (Fig. 1), forming dense canopies or numerous clumps along their banks. *Solidago* *canadensis* is much less frequent, it was observed along the rivers or as the clumps on fallows or ruderal sites (Fig. 1). Canopies of this species were rare in the studied area. The western area of the Wiśnickie Foothill (between localities: Szczyrzyc-Sawa-Łapanów) is much better managed, there are many apple orchards but also the arable fields, and in such a landscape both goldenrod species were not noted (Fig 1). [3] points out to the level of agricultural land management as a key-factor for a spread of the invasive species – the better land management, the lower invasive species frequency. The percentage share of both goldenrods was as follow – 60% for *Solidago gigantea*, 20% for *Solidago canadensis*, and 20% for localities, where the both species co-occurred.

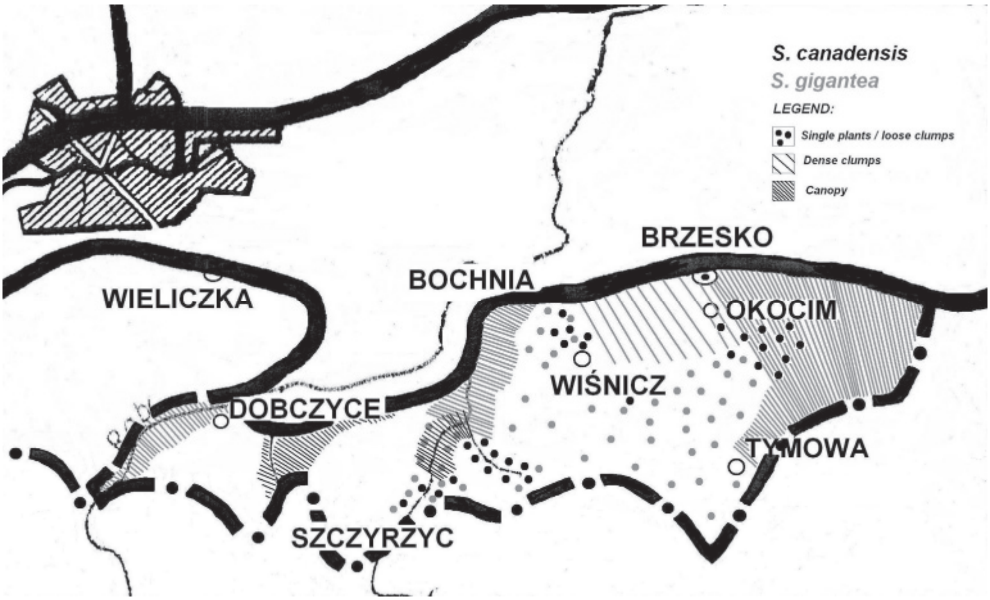

Figure 1. The distribution of Solidago canadensis and Solidago gigantea along the Wiśnickie Foothills

Invasive goldenrods were more frequent in wastelands – ruderal sites, fallows, river banks (Tab. 1-3). Moderately often they were noted in the bounds, between the crop-fields, pastures or meadows. In such localities either single plants or loose clumps were observed (Tab. 1-3). Occurence of *Solidago* species was latitude-independent. The most important factor for their occurrence was the state of land management practices.

Table 1
Detailed description of Solidago gigantea *localities in the studied area*

No	Localization	Elevation (m asl)	Habitat	Intensity of occurence	Plant height (m)
1	Borzęta	382.3	Bound by the meadow, wet	Clumps	1.5-1.6
2	Muchówka	379.7	Fallow, wet	Single plants	1.4
3	Zegartowice	358.2	Slope by the forest, dry	Clumps	1.9
4	Królówka	343.0	fallow	Clumps and single plants	1.4
5	Okocim Brzesko	342.8	Ruderal, wet, near the river	Clump	1.8
6	Pogwizdów	321.2	Along the forest, on the slope	Single plant	0.9
7	Lipnica Murowana	301.6	By the road, on the meadow, close to the forest	Single plants	1.2
8	Brzezowa	300.7	At the top of hill, fallow	Canopy	0.9
9	Iwkowa	288.1	Fallow n. forest, dry	Canopy	1.5
10	Lipnica Murowana	279.7	By the road, ruderal	Loose clump	0.5
11	Tymowa	270.6	Slope between the meadows, wet	Clump	1.7
12	Stary Wiśnicz/ Podzamcze	265.4	Ruderal, dry	Clump	1.0
13	Wytrzyszczka	256.9	Along the road, ruderal	Clumps	0.8-0.9
14	Zawada	254.6	On the hill, ruderal, wet	Canopy	1.2
15	Kępanów	244.8	By the river, wet	Clump	---
16	Tworkowa	244.6	By the watercourse	Clumps	1.8-2
17	Uszew	234.0	Ruderal, dry	Clumps-canopy	1.5
18	Winiary	232.7	Fallow, wet	Canopy	1.8
19	Jurków	229.9	Ruderal, wet	Canopy	1.4-2.0
20	Jurków	229.9	Ruderal, dry	Clump	1.4-1.6
21	Gwoździe	227.5	Along catenary, in the forest; fallow on the other side	Canopy	1.6-2.0
22	Nieprześnia	227.0	Ruderal, close to the watercourse	Clumps	1.7
23	Gdów	223.3	Fallow, wet	Canopy	1.5-1.6
24	Zagórze	222.7	Ruderal, dry.	Single clump	1.4-1.5
25	Wieruszyce	220.0	Along the road and Stradomka river	Clumps	1.4
26	Faliszewice	218.8	By the watercourse	Loose clumps	1.5
27	Faliszewice	218.8	By the river Dunajec	Canopy	1.4-1.6
28	Kamyk	212.2	Along Stradomka river, close to the road	Clumps and single plants	1.0
29	Wielka Wieś	211.2	Along the road and on the banks of a pond. Ruderal, wet	Clumps and canopy	1.4-15.0
30	Olszyny	207.2	Ruderal, dry	Clumps	1.4

Table 2

Detailed description of Solidago canadensis *localities in the studied area*

No	Localization	Elevation (m asl)	Habitat	Intensity of occurence	Plant height (m)
1	Królówka	339.0	Along the road, wet	Single clump	0.8
2	Nowy Wisnicz	292.3	Along the road, nearby the meadow	Single, loose clump	1.0
3	Pogwizdów	291.6	On the slope, near forest, dry	Loose clump	0.5
4	Nowy Wiśnicz/ Podzamcze	266.4	By the castle	Canopy	1.1
5	Olchawa	266.0	On the slope, ruderal	Clumps	0.8
6	Kobyle	251.3	Ruderal, wet	Canopy	1.3
7	Łapanów	232.9	Along the road, 60 m from the watercourse	Clumps	1.1
8	Winiary	232.7	Ruderal, dry	Single clump	1.5
9	Kamyk	218.0	Along the river	Single plants	0.6
10	Boczów	203.0	Ruderal, dry	Clump	---

Table 3

Detailed description of both Solidago *sp. localities in the studied area*

No	Localization	Elevation (m asl)	Habitat	Intensity of occurence	Plant height (m)
1	Okocim	342.8	Fallow dry, on the slope	* S. canadensis: canopy; S. gigantea: single clumps	S. canadensis: 1.8 S. gigantea: 1.6-1.8
2	Lipnica Górna/Muchówka	334.0	Along the watercourse	clumps	S. canadensis: 1.3 S. gigantea: 1.2
3	Brzączowice	292.3	fallow, wet	Loose clumps	S. canadensis: 1.8 S. gigantea: 1.5-1.6
4	Suburbs of Myślenice	277.8	fallow, dry	S. canadensis: clumps S. gigantea: canopy	S. canadensis: 1.8-2.0 S. gigantea: 1.6-1.8
5	Sawa	265.6	fallow, dry	clumps	S. canadensis: 2.0 S. gigantea: 1.5-1.6
6	Zawada Uszewska	248.5	Ruderal, wet	S. canadensis: canopy; S. gigantea: single clumps	S. canadensis: 1.8 S. gigantea: 1.4
7	Kępanów	244.8	Ruderal, in the middle of the meadow, semi-wet	clumps	S. canadensis: 1.2-1.8 S. gigantea: 1.2
8	Raciechowice	228.2	Meadow, wet	Clumps and single plants	S. canadensis: 1.5 S. gigantea: 0.6-0.8
9	Dębno.	225.7	fallow, dry.	S. canadensis: single clumps; S. gigantea: canopy	S. canadensis: 1.7 S. gigantea: 0.8-1.0
10	Grodkowice	223.1	Fallow, dry	S. canadensis: canopy; S. gigantea: single clumps	S. canadensis: 1.7-1.8 S. gigantea: 1.2-1.4

* Solidago

The calorific values of both goldenrod species were low, due to the phase of their collection – flowering (Tab. 4). On average, calorific value of *Solidago gigantea* was similar to this of *Solidago canadensis*, 14.7 J kg^{-1} and 15.0 J kg^{-1}, respectively, which shows that both species can be collected together for the energetic purposes. Our results are contrary to the results of [1], who obtained high calorific values for goldenrods collected in the time from mid-September till the late-winter. The time of energetic material strongly influences its calorific value due to the level of moisture in it, the later, the lower [2]. That could be a reason for the differences of results obtained in our work and by [1]. The calorific value of *Solidago canadensis* was similar irrespective of the type of habitat and its humidity. In case of *Solidago gigantea*, significantly higher calorific value was noted for plants collected from the dry fallow, and the lowest - from the wet fallow (Tab. 4).

Table 4
Energetic characteristics of Solidago *sp. in the flowering stage*

Habitat		Ash (%)	Total water content (%)	Heat of combustion (J kg^{-1})	Calorific value (J kg^{-1})
Solidago gigantea					
fallow	dry	5.7	11.8	17.5	16.2 b
	wet	5.2	10.8	15.3	13.7 a
ruderal	dry	6.6	9.8	15.4	14.1 ab
	wet	5.2	11.2	16.3	15.0 ab
Solidago canadensis					
fallow	dry	5.2	10.4	17.1	15.8 a
	wet	5.6	10.9	16.3	14.8 a
ruderal	dry	6.5	10.8	16.4	15.0 a
	wet	5.5	10.9	15.7	14.4 a

Conclusions

In Wiśnickie Foothills there are both invasive goldenrods noted – *Solidago gigantea* and *Solidago canadensis*, but the first one is much more abundant. *Solidago gigantea* occurres in a massive amounts in the eastern part of the Foothills, near Okocim. *Solidago canadensis* is more frequent along the river banks, especially Stradomka and Raba. The East part of the Wiśnickie Foothills is agriculturally well managed (apple-orchards and arable fields) and for that reason the number of goldenrods in this area is low. The calorific value of goldenrods collected in the flowering stage is low, but *Solidago gigantea* collected from the dry fallow is characterized by higher calorific value, as compared to the wet fallow.

Acknowledgements

The study was supported by the University of Agriculture in Cracow, statutory research programme No. DS 3124

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THE ANALYSIS OF THE PARAMETERS OF THE COMBUSTION BRIQUETTES FORMED BY THE METHOD OF THE CURLING WITH UNCUT CEREALS STRAW IN VARIOUS TYPES OF CENTRAL HEATING BOILERS

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Abstract. In research of Industrial Institute of Agricultural Engineering in Poznan briquetting by the method of the curling to the compaction cereal straw was used. Briquettes produced by this method are allocated as biomass combustion for so called small energy. A single briquette is a cylinder of diameter of 85 mm, length of 250-300 mm which is characterized by a high density around 500 kg·m^{-3}. Attempts were made to burn them in three different traditional central heating boilers: Eko Duo 25 with power of 25 kW, STK 22 with power of 22 kW and 23 UWT with power of 23 kW produced by PROTECH Sp. z o. o. of Gierałtowice. In research briquettes made from wheat straw were used. The study was carried out by observing the combustion process certain portions of briquettes while making measurements of water temperature at the entrance and exit of the boiler, temperature and gas composition. The study showed that the total fuel briquettes excess of air is required and there is a need for frequent, periodic movement of briquettes burning on the boiler grate. Quality results of collected gas showed that the levels of pollutants do not exceed the legally authorized levels. Obtained from the combustion of briquettes boiler power remained was also at a satisfactory level. Moisture content combustion during the test briquettes was located between 10 and 15%.

Keywords: biomass, combustion, central heating boilers, briquettes.

Introduction

Cereal straw is a valuable fuel which fits in a range of energy sources that are renewable sources of energy [1; 2; 4; 10]. The problem of the production and use of renewable energy sources is one of the most important issues of global and European energy policy. The use of straw as a renewable source of energy in Poland is not very significant. This is due to the fact that, compared with other conventional energy carriers, straw as the raw material is rather cumbersome energy material. This is due to the fact that the material is not uniform, the lower, with respect to unit volume, energy, compared to conventional energy sources. To standardize and improve the usefulness of straw for energy purposes there is a need to increase its bulk density, which may be obtained by the concentration of masses of loose straw [1; 2; 4;]. In research of Industrial Institute of Agricultural Engineering in Poznan briquetting by the method of the curling using to cereal straw was used [1; 2]. Briquettes produced by this method shall be allocated as biomass burning for so-called low energy. A single briquette is a cylinder of diameter of 85 mm, length of 250-300 mm, and it is characterized by a high density about 500 $kg \cdot m^{-3}$ [1].

The use of straw as a fuel eg. in boiler farmer households should also be noted that the amount of energy obtained per unit of mass is greater than the amount of energy put into the preparation of fuel for combustion. The calorific value of 1 kg of straw white with a moisture content of 10-15% is 14-15 MJ, which is equivalent to about 4 kWh of energy from the combustion [2; 4; 5;]. This paper contains results of burning these briquettes in three different typical central heating boilers.

Materials and methods

The aim of the study was to identify and analyze the combustion process of briquettes obtained by folding straw cereals conducted in a typical central heating boilers. It has allowed the evaluation of the usefulness of these types of boilers for combustion of straw briquettes without making modifications to their construction. During the research the water temperature at the outlet of the boiler, the flue gas temperature and the concentration of some elements and compounds in the produced flue gas were determined. The study was conducted on briquettes made from wheat straw. The humidity content in the briquettes during the combustion test is between 10 and 15%.

The temperature was measured by the respective thermometers. Gas analysis was performed by MRU Portable Flue Gas Analyzer - Nova H8. Straw humidity percentage by weight was determined by drying-weighing. The humidity briquettes were selected at random basis from a partion of intended for incineration, weighed on a laboratory scale WS-21, and then dried for 3 hours at 130 °C in the oven. After that time they were removed from the oven and reweighed. Humidity was determined from the known relationship (1):

$$w = \frac{(E - m) \cdot 100}{E} \quad [\%] \tag{1}$$

where:
E – initial weight of the sample in g,
m – mass of the sample after drying in g.

The study used three typical central heating boilers: Eko Plus DUO 25, STK / UWT MS 22 and 23, which simplified diagrams are shown in Figure 1.

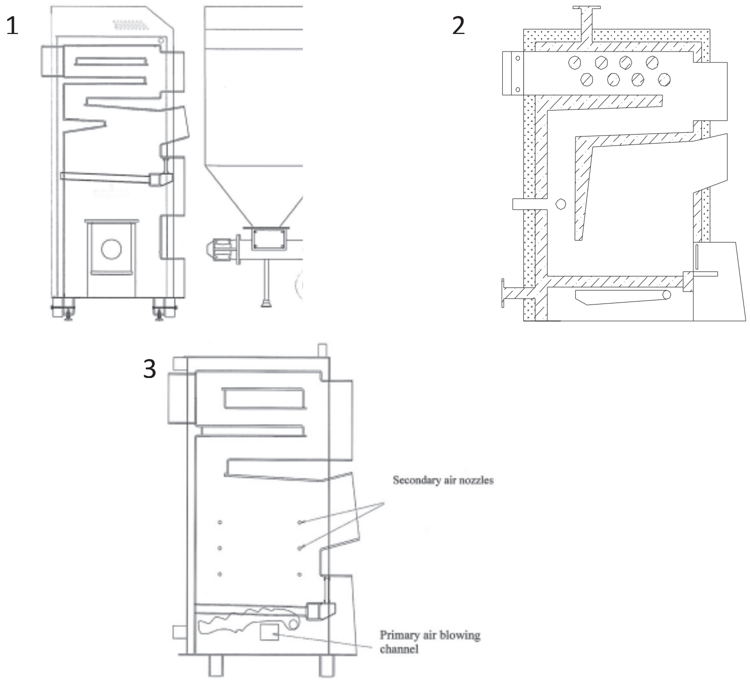

Fig. 1. Schemes C.O researches boilers: 1 – Eko Plus DUO 25, 2 – STK / MS 22, 3 – 23 UWT

Boiler EKO PLUS DUO 25 is a water, steel boiler designed to burn coal and fines from the fuel tank and screw conveyor. Boiler EKO PLUS model DUO 25 has a second furnace to allow combustion in the traditional way. It is situated above the retort burner. The large feed hopper allows proper boiler power, even in the absence of electrical power.

The second study involved a boiler with lower combustion chamber type STK/MS 22. Combustion takes place on the grid water where the briquettes are lit from below. Air blast was brought under the grate.

The last test was a boiler unit UWT. It was equipped with a water grate and control kit consisting of a controller with PID control and blower. The air was supplied under the grate and several air nozzles located across the combustion chamber.

Results and discussion

The combustion of briquettes in all boilers performed under similar conditions both in terms of mass flow, and the excess air coefficient. Research parameters of boilers and exhaust gas composition were carried out under steady heat. Operating pressure boilers tested were as follows: for Eko Plus DUO 25 - 111.5 kPa for STK / MS 22 - 50.6 kPa and for

UWT - 101.3 kPa. The average size of the mass flow of fuel to all the tested types of boilers was 5 $kg \cdot h^{-1}$, and the produced thermal power was in the range of 18-20 kW.

At the bottom of Eko Plus DUO 25 combustion took place on the traditional grid. Air blast was directed under the grate. Working with ventilator proceeded very steadily followed a very dynamic changes in the parameters emissions. Briquettes fired from the outside, in a densely laid out batch appeared craters, which freely flows through the air forced by the fan. It was necessary to get the briquettes burning periodically on the grate boiler, every 10-15 minutes, in order to maintain smooth operation of the combustion process. Work proceeded on the natural stable, but the results differ significantly from those expected, also followed the blow and significant fluctuations in the parameters emissions.

In the case of STK/MS 22, the combustion process has been very similar to the boiler EKO PLUS DUO. There was very quick burning of the fuel layer at the back of the grid and the free flow of air without fuel remaining. It resulted also in this case the need for periodic, every 10 minutes, getting the briquettes burning on the grate boiler in order to maintain smooth operation of the combustion process.

In turn, during the tests the boiler UWT assumed its full part briquettes and lighted from above, blowing from the nozzles in the combustion chamber of a well-maintained fire for about one hour. When the fuel level decreased (briquettes burned up) there began to appear in significant redundancy of exposed air nozzles, but it did not cause a major disruption in the process of burning briquettes. In contrast to this process, it was observed that in both models previously tested boiler (in which the fire service expire without interference) that briquettes burned properly. Boiler despite significant losses due to excess air in the exhaust held several kW power (the power rating of 23 kW). Movement of the grill briquettes boiler was needed after about an hour, which improved the results obtained. Without moving the briquettes it would be burned but in a much longer period of time.

Average values of the basic parameters of the boilers during combustion of straw briquettes are shown in Table 1.

Table 1
Average values of selected parameters of the tested boilers

The boiler type	Average water temperature at the outlet of the boiler	Average flue gas temperature	The average size of the chimney draught
	(ºC)	(ºC)	(hPa)
Eko Plus DUO 25	71.0	182.4	0.33
STK/MS 22	43.5	-	0.25
UWT	56.9	161.8	0.20

The flue gas temperature measured at the outlet of the boiler combustion throughout the briquetts contained in: a boiler EKO PLUS DUO in the range of 140 to 240 °C and the boiler UWT - from 135 to 230 °C. For boiler STK / MS measurements of this parameter not were performed.

Obtained as a result of burning briquettes outlet temperature of the boiler feed water heating system is between 40 and 80 °C. Its volatility, after the 50 – 60 °C was negligible.

The resulting supply water temperature levels allows to maintain the desired temperature in heated rooms.

During the tests of combustion of briquettes made from straw uncut roll method also performed analysis of the composition of the gas produced. Combustion of straw, and hence the pellets formed therefrom is complete and should be complete with high redundancy O_2 [3; 5; 8; 9]. During combustion tests carried out with the briquetts redundancy air, wherein the oxygen concentration in the exhaust gas varied between 10 – 20% of the volume Table 2.

As already mentioned for proper combustion process created by folding uncut straw briquettes was necessary to cyclic (different for each test boiler) to move a burning bed. This process affected the level of CO in the exhaust tab. 2. and was compared the mean values for concentrations of this compound contained in the harmonized standard PN-EN 12809 values relating to coal combustion [7]. It was noted that in the case of briquettes from straw combustion in boilers tested concentrations of CO obtained allow to classify respondents boilers of the 1st class [9]. The differences in the values obtained combustion parameters, which in some cases are even significant, due to the construction of individual test boilers, and hence the course of the combustion process in them. The measured NOx concentrations were variable, depending on the boiler, with the highest values at their burning briquettes in a boiler SKU 22, and the lowest – UWT, Table 2. It should also be noted that burning briquettes characterized by considerable redundancy values of air, which resulted in getting the low efficiency of the process.

Table 2
Average levels of certain chemical elements and compounds in the exhaust

The boiler type	Average levels				λ
	(O_2)	(CO)	(CO_2)	(NO_x)	
	%	$mg \cdot m^{-3}$	%	$mg \cdot m^{-3}$	-
Eko Plus DUO 25	15.8	2684	5.0	109	5.91
STK/MS 22	14.7	818	6.1	157	4.27
UWT	16.5	3544	4.3	38.2	6.24

Conclusion

Tests of burning briquettes formed by folding the uncut straw cereals enabled to determine the future direction of research and eliminate models boilers with not appropriate parameters.

Despite the problems with the combustion process and to maintain constant gas parameters during the first and second tests without a problem it was heat up the heating system of the building to the set temperature. Obtained as a result of burning briquettes outlet temperature of the boiler feed water heating system is between 40 and 80°C. Its volatility, after the 50 – 60°C was negligible.

Attempts to combustion in the boiler UWT were the most successful. Combustion carried out from the top, using airflow above and below the furnace was more stable and does not cause a problem with expiration of the layer.

Combustion chamber in conventional boilers will not be effective. In the subsequent stages of the design it should be adapted to the combustion boiler straw briquettes. It can be assumed that the boiler can also burn properly as wood.

In the case of briquettes from straw combustion in boilers examined the values of concentrations of CO allows the classification of subjects boilers of the 1st class.

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UTILISATION OF BIOMASS FOR ENERGY

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Abstract. Hungary has joined the European Union's binding target of 20% renewable energy from final energy consumption by 2020, and aims at increasing the share of renewable energy sources from gross final energy consumption to 14.65% .In this reason the gross quantity of renewable energy sources would add up to 165-170 PJ by 2020, which is to be used for electric power supply, traffic, heating and cooling purposes. The increase in the generation of renewable electric power has increased primarily due to biomass utilization up to now. By 2010, the amount of renewable electric power reached 2,9 TWh/year, being equal to 7.1% of the net domestic electric power generation. Biomass was started to be utilized in greater quantities in 2004, the largest part of which was used to generate electric power. The reason for this was that user infrastructure did not require substantial investments, only traditional coal burning power stations had to be converted to multi-fuel power stations.

Key words: biomass, energy, Hungary

Introduction

The overall energy consumption in Hungary is about 1160-1200 PJ. This means the amount of primer energy sources, and real consumption is approximately 30-35% lower. The difference comes from conversion losses and the own consumption of energy converters. The major consumers include the inhabitants, traffic, industry and service industries.

Hungary has also joined the European Union's binding target of 20% renewable energy from final energy consumption by 2020, and aims at increasing the share of renewable energy sources from gross final energy consumption to 14.65% (Government Decision No 1002/2011 (I.14.)). By this, the gross quantity of renewable energy sources would add up to 165-170 PJ by 2020, which is to be used for electric power supply, traffic, heating and cooling purposes.

The increase in the generation of renewable electric power has increased primarily due to biomass utilization up to now. By 2010, the amount of renewable electric power reached 2600-2900 GWh·year^{-1}, being equal to 7.1% of the net domestic electric power generation. The volume of biomass utilization became stable by 2009-2010, within which the amount of biogas consumption slightly increased, on the other hand, wind energy consumption raised to a significant extent, adding up to 620 GWh·year^{-1} in 2010 [2].

Biomass was started to be utilized in greater quantities in 2004, the largest part of which was used to generate electric power. The reason for this was that user infrastructure did not require substantial investments, only traditional coal burning power stations had to be converted to multi-fuel power stations. The disadvantage of the technology is that the so-called waste heat produced during the generation of electric power in power stations can only be utilized to an insignificant extent, which causes a very low energy transformation efficiency of 20-30% (Figure 1).

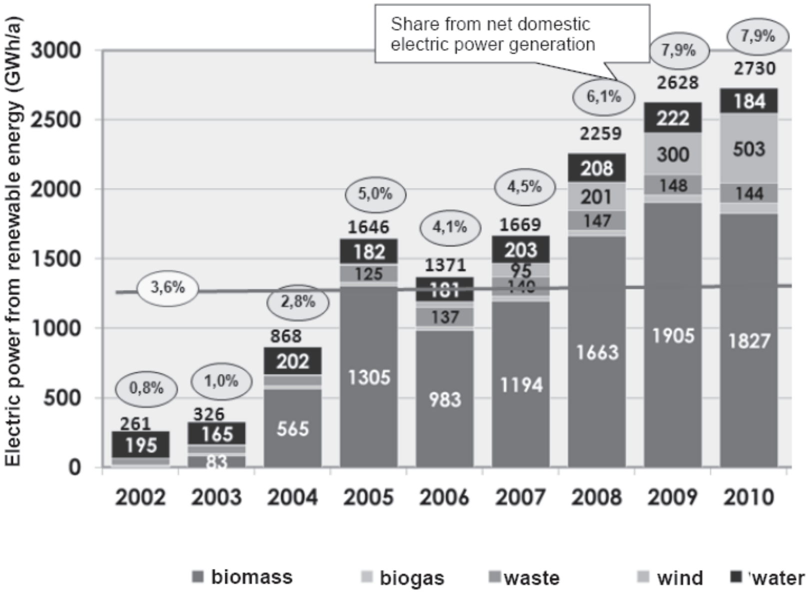
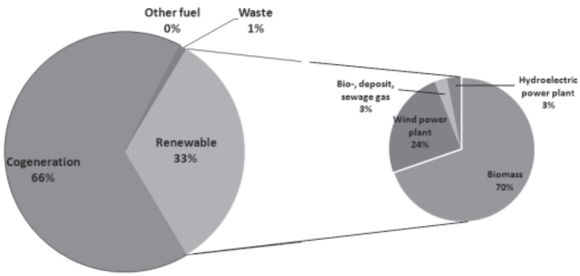


Figure 1. Generation of electric power from alternative energy sources

This quick rise was promoted by the support of the government given to the generation of electric power from biomass, irrespectively of the efficiency of production and utilization. Significant subsidies were provided to cogeneration (CHP) gas-fired power stations as well. Thus, 80-90 thousand million Hungarian forints were flown annually to cogeneration small power plants and renewable electric power suppliers as subsidy by 2010. From which 19-20 thousand million Hungarian forints were subsidy on electric power produced from biomass and 8-9 thousand million Hungarian forints were subsidy on other renewable sources like water, wind, geothermic, solar and other energy sources. The largest part of the subsidy was used to develop cogeneration power plants (Figure 2):

Even forestry experts agreed on that it was time to cut down and use the surplus, aged and sometimes ill trees although it occasionally led to misuse. The price of wood and consequently the income of forest managers considerably increased. [6].



	Mill. HUF
Cogeneration	56680
Waste	827
Other fuel	0
Renewable	28007
Biomass	19520
Wind power plant	6812
Hydroelectric power plant	802
Bio-, deposit, sewage gas	873

Figure 2. The amount (in HUF) and rate of state subsidy in 2010

Seeing that deforestation was excessive in some places and the efficiency of transformation was low, the government withdrew the subsidy by 2011 from large non-cogeneration biomass-fired power plants and small amortised CHP gas-fired power plants. As a result, the amount of electric power output reduced to 1375 GWh in 2011, as against to the planned amount of 1870 GWh. Some ‘worn-out’ biomass-fired power plants were even closed down.

The government intends to implement a really ambitious plan on the utilization of renewable energy sources by 2020. The **National Action Plan** (NAP) specifies the production of electric power capacity of approximately 1530 MW by 2020 in the frame of a 14.65% renewable energy program (Figure 3).

The NAP continues to calculate with biomass as the major renewable energy source. Solid biomass primarily includes firewood produced by traditional sylviculture, agricultural by-products and plant-chips from energy plantations. Significant improvement is expected in the fields of biogas, agricultural wastes and residual materials from communal sewage purification plants. Wind energy utilization is of high volume, and is intended to be increased by 120%.

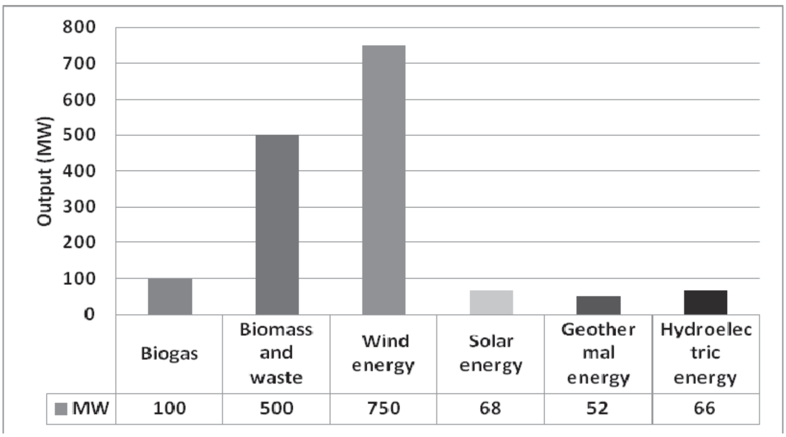


Figure 3. Expected electric power production capacity by 2020 [7].

To reach the planned renewable electric power production of 5500-5600 GWh·year^{-1} by 2020, **biomass** (including biogas) production and partially wind energy have to be increased significantly. Importance of heat pump can appreciate as well. Utilization of thermal energy based on electric power raises economy questions due to the multiple transformations. It can be found many examples for spread of heat pump application. [4, 5].

Biomass

From biomass we can produce heat energy, electric power and various gaseous, liquid or solid fuels (such as oil, alcohol, gas, biogas, chips, pellets, etc.).

Oil, alcohol and gas are used as fuels, while solid processed materials, for instance chips, pellets, briquettes are mainly utilized to produce heat. [9].

It has to be acknowledged and should not be disregarded that the production of various biomasses requires substantial amount of energy (e.g. for converting herbaceous plant biomass into hard fuel pellet). Efficiency is demonstrated by the OUTPUT/INPUT (O/I) rate comparing the chemically bonded energy content of the end-product before use to the total energy content of all the energy sources used for production. In professional literature sometimes very beneficial rates are stated, for instance the O/I rate for hard stem energy plantation collected to the edge of fields is 15-20. It has to be noted that this rate is reduced by transportation, shopping and preparation, depending on the energy requirement of technologies, to O/I = 3-6 or even lower. [8].

From the aspect of energetics, the amount of so-called **net energy gain** is to be examined, taking into consideration, in addition to the above, conversion losses as well. When only electric power is produced from biomass, the I/O rate does not exceed 3.0. When only therm1al energy is generated (for heating) the O/I rate can be as many as 6, which is, of course, reduced by transportation.

These figures also indicate that biomass is not practical to be used only for generating electric energy. Combined production is much more advantageous when all the heat is utilized in addition to the generation of electric power. In this case, the efficiency rate is almost equivalent to heating (Figure 4).

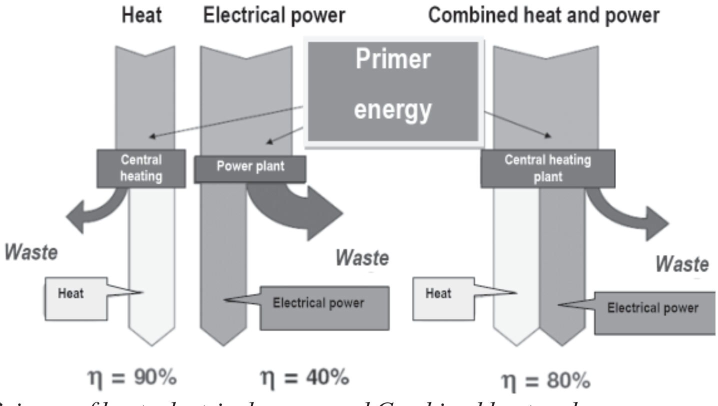


Figure 4. Efficiency of heat, electrical power and Combined heat and power generation [10]

There are a lot of estimations known on the total energetic biomass potential of Hungary. Some of which calculates with 200-300 PJ·year^{-1} as the possible upper limits. It is estimated that the average biomass production from agriculture is approximately 100 PJ, while the maximum production is 170 PJ. The most important factor of uncertainty is the possible utilization of various biological by-products as the amount of cereal straw, corn-stalk, grape-shoot, etc. depends highly on weather.

Biofuels

The amount of cereals and oil seed crops used for biofuels adds up to 4% of the annual raw material production of the world.

Biodiesel

In 2010, 21 million m^3 biodiesel was produced in the world, 56% of which was produced in Europe. Biodiesel is mixed into diesel oil in the rate of 5%. This rate has to be doubled by 2020. The required production capacity (23 million m^3) is practically available, which is now operated with a utilization rate of 56%. In several countries where biodiesel was offered as a separate fuel, it was withdrawn from the supply of filling stations as price differences dropped to the minimum in comparison to traditional diesel oil, significantly reducing its market advantage.

In Hungary, biodiesel is marketed as a component of traditional diesel oil mixed in at a rate of 4.7%, which is to be increased to 8% by 2020. The biodiesel production capacity established so far in the country (180 thousand tons) is capable of meeting the demand of fuel producers and distributors.

To achieve the mixing quota planned and undertaken by 2020, 240 thousand m^3 biodiesel will be required. This can be obtained from the processing of oil-seed rape (95%) and a minimum amount of sunflower produced in Hungary at the present level of production. It is also possible to increase the production capacity. Biodiesel production and utilization in Europe may be influenced by the market prices of oil-seed crops which has shown continuous increase lately.

Bioethanol

Bioethanol is used as a component of petrol-driven motor vehicles mixed in the fuel E85 and partially as a separate fuel. Last year, 4.4 million m^3 bioethanol was produced in the European Union, and 6.1 million m^3 was mixed in petrol, 27.9% of which came from import. European bioethanol producing capacity adds up to 7 million m^3, but it only operates with a utilization rate of 62.8 due to the high raw material (cereal) prices. In order to reach the targets by 2020, the EU has to increase bioethanol production to at least the double of the present amount, i.e. to 12-14 million m^3. Within the EU, only France, Spain and Hungary are capable of exporting bioethanol.

In Hungary, significant bioethanol production capacity has been established. In the near future, production capacity in the country will reach 810 thousand m^3·year^{-1}. The majority of the product is exported as the amount used at present in Hungary is 75 thousand m^3/year, which will be increased to not more than 140 thousand m^3·year^{-1} by 2020.

Biogas

Biogas production based on agricultural primary and secondary by-products and other biological wastes has increased substantially in the world. Europe is in the vanguard as more then 8500 biogas plants are operated here.

In Hungary, 46 biogas-producing plants are run at this time with an overall electric power generation capacity of 37 MW, from which 31 plants uses agricultural raw materials and the rest produces biogas from food and communal wastes or sewage sludge. The majority of the plants built in the vicinity of livestock farms and mainly using animal slurry and plant-based raw materials (silage, hay, residuals of cereal cleaning, etc) or food industry wastes have an output of 600-700 kW. Increase the amount of biogas production can be see examples in the research area. The results of the common research between Szent István University and the University of Szeged show that the beneficial effect thermal pre-treatments for aerobical biodegradability and biogas yield. [1, 3].

Using the biogas-producing capacity installed in the recent past, the country is able to produce 150-170 GWh/year electric power. This amount can be tripled or quadruplicated by 2020. It is important to ensure that waste heat is also utilized (for heating, drying, heating green-houses, warm-water fish-breeding) as this is required for the economic operation of plants. A solution could be the purification and concentrating of biogas (biomethane), enabling it to be fed into the natural gas network or used as fuel in motor vehicles.

Ecological sustainability

Experts involved in agriculture and soil management are right in criticising the utilization of cereal straw and corn-stalk for energy purposes and state that these materials are needed to maintain soil fertility and provide nutrition for the soil as a living organism. Accordingly, a substantial part of these materials has to be returned in the soil to maintain the original structure, water storage capacity of soil and to provide materials (carbon, minerals, microelements, etc.) required for plant growth. These experts claim that by continuously removing the yield from the field we degrade the soil, reducing its productivity as well as the nutritive value of the plants produced there.

The removing of some by-products such as grape-shoots, fruit trimmings does not mean significant ecological harm, however, they are not really important from energetic aspects either as their energy density is so insignificant in an unprocessed form that their transportation is not economic for distances above 20-25 km. Many people have reservations, with good reasons, about the utilization of wood produced in our forests in electric power plants, and the state subsidy provided for this.

Between 2004 and 2010, an annual amount of 6.4 PJ (400 thousand tons) wood was fired in Hungarian power plants, which requires over 500 thousand hectares of forests in addition to the usual timber felling. This was enough for 5% of the domestic electric power demand.

In the case of energy forests, much smaller areas are needed as much larger amounts of wood can be produced with 2- or 3-year turns. Professional literature contains very different data for this as well ranging from 2.0 to 14.0 tons of annual yield per hectare. Misinterpretations in evaluations are caused by that the moisture content of wood is not defined when yield is given. Fire-wood was traditionally used after a 3-year delay period in air-dry condition, which is not possible these days. Even if the wood is cut in winter with low moisture content and is used after a delay period in the next heating season, the moisture content will not be lower than 40-50% and the maximum net calorific value will only be 11-13 $MJ \cdot kg^{-1}$.

Calculating with the averages of values defined in literature for agricultural by-products, about 6500000 tons could be collected annually. Energy content is calculated in the next table:

By-product	Energy content	Energy content	Operational energy rate	Fossil requirement
Tons/year	GJ/tons	PJ/year	O/I	PJ/year
6 500 000	13	85	5/1	17

Thus, calculating with 50% transformation efficiency, the amount of utilized energy is 42.25 $PJ \cdot year^{-1}$, which does not reach 5% of total domestic energy need, and it requires a fossil usage of 17 $PJ \cdot year^{-1}$. [11].

Biomass utilization for the purposes of electric power generation diminished considerable even in 2011 because the state subsidization of electric power was ceased. In accordance with the NAP, the restoration of the subsidy cannot be expected. Biomass utilization for heating can only be performed in larger village or city central heating plants (industrial, public utility, private sector). The majority of these will apply cogeneration systems favourable from the aspect of energy efficiency as only these types will obtain state subsidy in the future. Such facilities can be utilized for longer times and with higher effectiveness. The same applies to labour utilization, and the return of invested capital is of higher chance.

Alternative electric power programme

Figure 5 demonstrates the planned increases in electric power by 2020.

The plan shows that the present biomass production is intended to be increased by about 70%. Accordingly, the increase in biomass has to be doubled in comparison to the level of the year 2012 to achieve the target by 2020. However, the development requires substantial costs: 580-650 million euros (160-180 thousand million Hungarian forints) only for the power plants, which will give an overall amount of about 300-350 thousand million Hungarian forints together with infrastructural facilities.

Ecological sustainability also sets a limit to the plan as the expected increases in food production also have to be taken into consideration.

The concept of decentralized biomass-firing small power plants is reasonable especially when raw materials can be provided from the vicinity of the settlement. It also facilitates local employment, but their construction does not seem feasible in many cases under the present economic trends as they require significant resources.

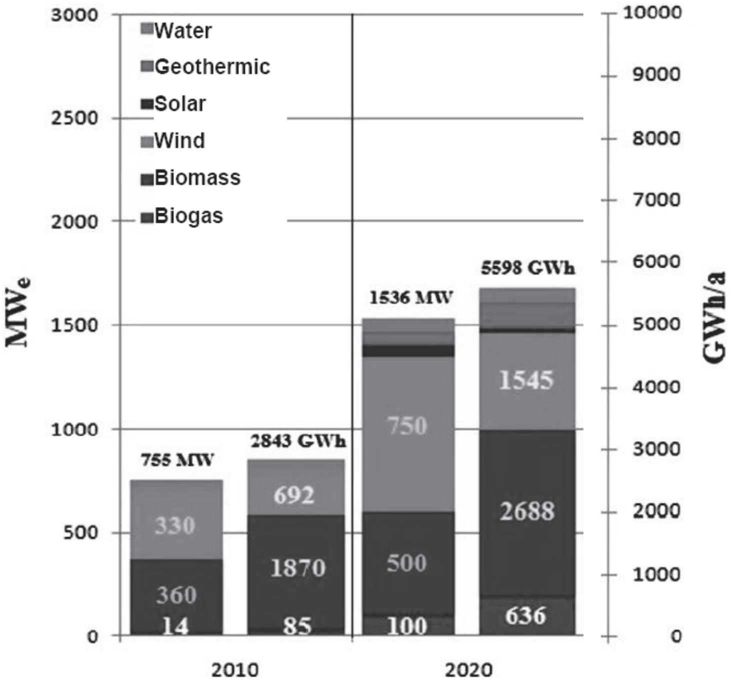


Figure 5. Planned quantity (MW) of various renewable energy sources and expected production (GW) [7].

Acknowledgments

This work was financially by the TAMOP 4.2.1.B-11/2/KMR-2011-0003

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RENEWABLE ENERGY ASSISTED CAMPUS BUILDING AIR CONDITIONING SYSTEM INSTRUMENTATION FOR EDUCATIONAL PURPOSES

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Abstract. Last years a big, approx. 10.000 m^2 campus building was rebuilt and enlarged at our university. The old heating system was changed totally, and a new cooling system was built in. This new system got bivalent as the conventional system was completed with 10 pcs separate 100 m deep U-type-tube bore-hole ground heat exchanger altogether with 60 kW heat peak power heat pump, 280 kW electric power air-source air – water heat pump, and heat exchanger in the air handling system of a 350 seating capacity lecture-hall. Additionally, with educational purposes, a small wind generator on the roof belongs to the system, and in the future low power solar photovoltaic cells will be built. We are making a complex measuring system first of all for educational purposes, but the wide spread data collecting gives the possibility of improving and optimizing the control system and estimating an optimal energy storage unit. The paper describes the main parts and functions of the measuring system.

Key words: renewable energy, bivalent system, measuring system, heat pump

Introduction

The single-floor Museum of Agricultural Machinery is situated in the Campus of St. István University and belongs to the Faculty of Mechanical Engineering. It was built in 1968. In the beginning of the first decade of 2000's the need of renovation of the building arose. By a lucky chance the Faculty of Mechanical Engineering had the possibility not only for the renovation, but for extending the building with an additional floor, too. The renewed building's name is Integrated Engineering Information Technology Training Center (IEITTC). The project was finished in 2012. Now the IEITTC with 10.000 m^2 superficial area kept the original farm machinery museum function, and gave new locations for the education of mechanical engineering. The general plan of location can be seen on the fig. 1.

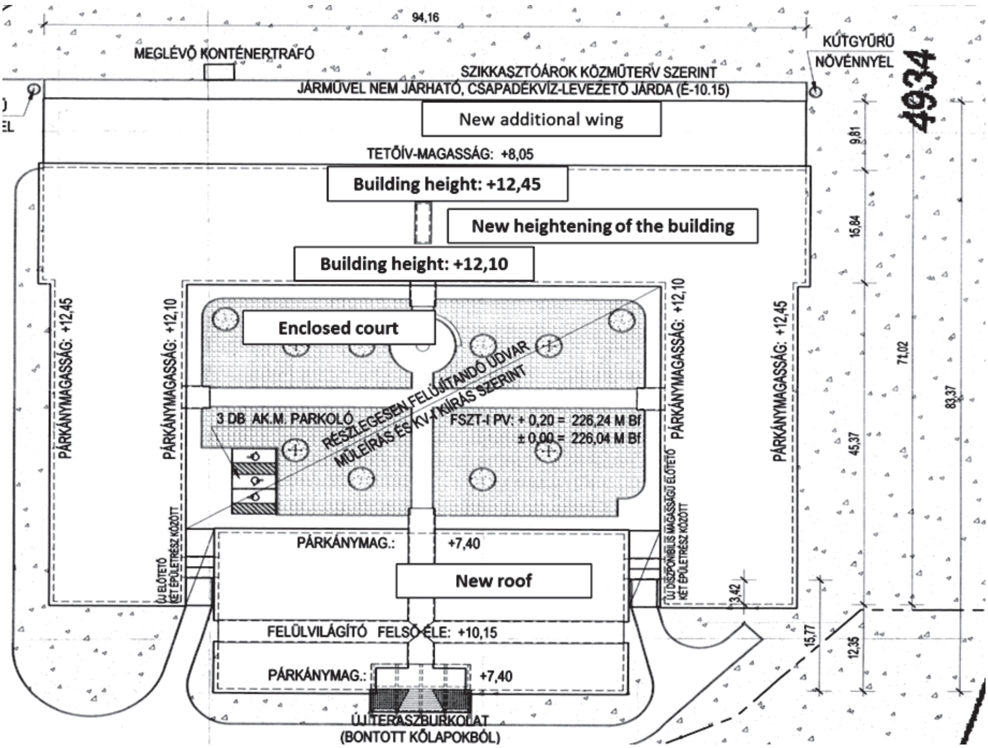

Fig.1. General plan of location

Heating-cooling system

The old heating system was changed totally, and a new cooling system was built in. This new system got bivalent as the conventional gas heating system was completed with 10 pcs separate 100 m deep U-type-tube bore-hole ground heat exchanger altogether with 60 kW heat peak power, 80 kW electric power air-source air – water heat pump, and heat exchanger in the air handling system of a 350 seating capacity lecture-hall.

In the building there are three kinds of heating and two kinds of cooling system. Radiator heating is in corridors and in serving rooms. Fan-coil heating-cooling systems are in small laboratories and big lecture-halls. Radiators are not involved in cooling. Air handling system provides for proper and economical air handling in big lecture-halls and in small laboratories.

2 pcs 100 kW and 1 pc 80 kW condensation gas boilers, actuating valves, safety apparatus, air-bleed valves, expansion tanks, manual controlled valves, closing valves, circulation pumps, heat pump and control system are located in boiler house. Gas boilers supplied by the normal public gas service. 10 pcs and 100 m deep each borehole ground sounds locate under the east wing of the building. They provide heating or cooling of the heat pump. The sounds together with heat pump system are filled with glycol to avoid freezing. The secondary side of the heat pump and the other parts of the heating/cooling system are

filled with water. Heat production units provide 42°C water and consuming circuits take out the desired water income with inverter driven circulation pumps.

Cooling is provided by heat pump and in case of cooling peak load an air-water heat pump can help, which is located on the roof. Both of them can provide 7/12°C cooling water and they work together with puffer tank located in boiler house. The consuming circuits take out the required cooling liquid with inverter driven circulation pumps for fan-coils and air handling system. Fan-coils in rooms can be controlled by thermostats.

The whole system is controlled by Elcon DIGINET programmable building equipment controller. Main operating modes are heating and cooling. The controller set the proper actuator valves automatically according to operating mode. The reference signal of the controller is function of outer air in a given temperature range.

Measuring system

Unfortunately because of the shortage of the project budget, only the operating sensors were built in the whole system. Just after finishing the project, the St. István University won a research project TÁMOP-4.2.1.B-11/2/KMR-2011-0003 with title: "Increase of the level of the education and research" together with subproject in the Faculty of Mechanical Engineering: "Energy production based on renewable energy sources". As the rebuilt IE-ITTC in its heating-cooling system has renewable energy sources, and the new project can sponsor the instrumentation we decided to install a new, independent measuring system. Unfortunately this task is very difficult, because a subsequent instrumentation in case of operating building equipment is sometimes almost impossible. Based on our experiments [1] and our existing instruments and sensors we decided to instrument the building and complete it with training solar panel, training low power wind turbine and training photo-voltaic cell, too. This instrumentation gives us a good possibility to demonstrate for our students a complex, conventional and renewable energy flow system in use. We can re-search the improve the dynamical behavior of the controlled system, optimal control of the system according to settling times, summarized CO_2 emission, costs, etc…

The simplified block diagram of the measuring system can be seen on the Fig. 2. We want to measure the main parameters: gas flow, electric powers of heat pumps, heat flow in main units (fan-coil units, radiator units, heat puffer, …) the ambient air temperature and humidity, the wind speed, small (training) solar panel power, small (training) wind turbine power and small (training) photovoltaic cell power, on-off states of circulation pumps, etc…

We measure the temperature mainly with Pt100 RTDs, in some cases with thermocou-ples. Unfortunately we can clamp the sensors only onto the surface of the pipe below the heat isolation. The most difficult task is the measuring of the flow of water or glycol. There is no possibility to plumb into the pipes, because the whole system is ready. There are in-verter driven circulating pumps in water circuits, and we can suppose, that the flow is ap-proximately constant during operation. We can measure the flow with snap-on ultrasonic flow sensor, these measurements can be repeated regularly for checking purposes, and after that, we can record only the on-off state of the circulating pump, instead of application of built in flow sensor.

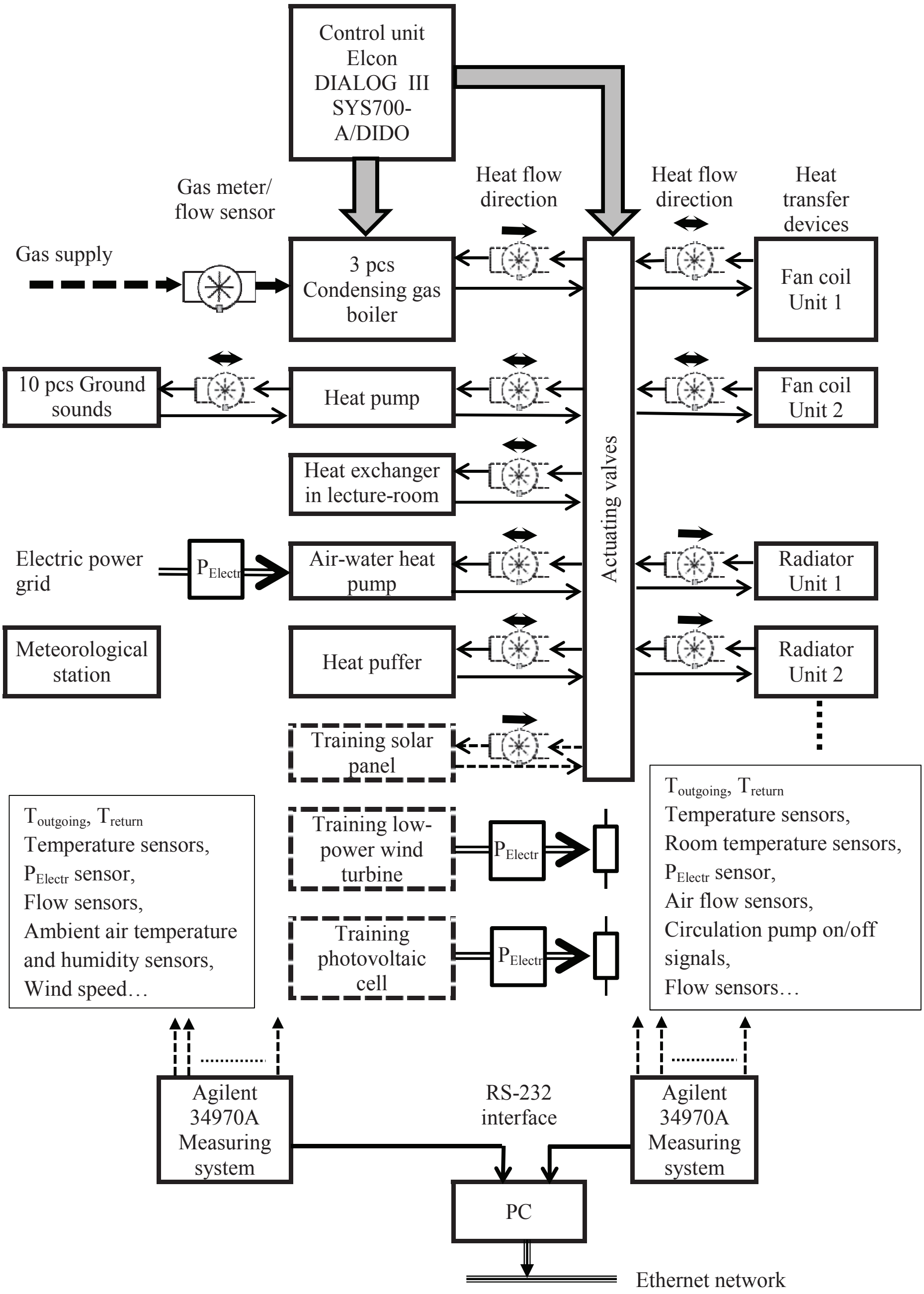

Figure 2. Simplified block diagram of the system

We use two pieces Agilent 34970A measuring system together with a PC. The whole measuring process can be followed through Ethernet network.

Results

We could install only the measuring cables for 40 channels from the boiler house to the measuring room. This post-install process was very difficult because of architectural reasons and building-up the fire barriers. Approximately 10 temperature sensors work now, the small wind turbine is on the roof, but it is not connected to the data logger.

Acknowledgements

Our paper is supported by the project TÁMOP-4.2.1.B-11/2/KMR-2011-0003.

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BIO-OIL DERIVED FROM MICROALGAE AS A POTENTIAL SOURCE OF ENERGY

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Abstract. In the article, the use of microalgae as a renewable source of energy have been discussed. Pyrolysis is one of the most important thermal conversion processes from biomass to bio-fuel. The pyrolysis of biomass can be implemented on the industrial scale as a separate, independent process providing useful solid, liquid and gas products, as well as the initial step of other utilization processes. In this work, the microalgae *Chlorella* was converted into liquid, solid and gaseous products by pyrolysis in a fixed-bed reactor at the different temperatures ranging from 350 to 550°C.

Key words: microalgae, pyrolysis, bio-oil, energy

Introduction

Over more than a hundred years of agriculture and road transport, hydrocarbon fractions obtained through the conservative and decomposition processes of crude oil processing were the main engine fuel, and the only widely recognised one. Oil is still the most important strategic energy resource, with great influence on the political and economic situation of different countries, continents and the whole world. The ongoing process of depletion of oil resources and often unpredictable swings in oil prices, as well as the reduction of the greenhouse effect caused by CO_2 have made looking for alternative renewable energy sources necessary. The use of renewable energy sources is one of the most important elements of sustainable economic development, bringing both environmental and energy benefits. Therefore, an essential element of the EU energy policy is to gradually increase the share of energy from these sources in the global energy production. This policy requires the member states, including Poland, to make significant organisational and technical efforts relating to the production of renewable energy. EU Member States should provide 10% share of renewable energy (biofuels) in the transport sector and a 20% increase of energy efficiency by 2020 [1]. Under the EU Directive, Poland is committed to the development of the National Action Plan, which will show the possibility of achieving the share of energy from renewable sources at a set minimum or exceeding it by ensuring appropriate actions and measures, as illustrated in Figure 1 [2]. Poland sees an increasing interest in using biomass, which can be converted into various energy sources [3-5].

Microalgae is a widely distributed low-grade water plant which have great potential for fossil fuel substitution in energy generation and conversion [6]. Algae in particular are considered as a potential source for biofuels and chemicals nowadays. Compared with lignocellulosic biomass, microalgae as energy resource have the following advantages: (1) higher photosynthetic efficiency, higher biomass production and faster growth [7, 8]; (2) possible growth of algae on non-arable land and thus no competition with agricultural lands for food and feed production [9, 10]; (3) utilization of salt and organic matter derived from waste water [8]; (4) effective reduction of greenhouse gas concentration [11]. On an industrial scale only few algae species are produced, and the one of the most widely cultivated is chlorella [12].

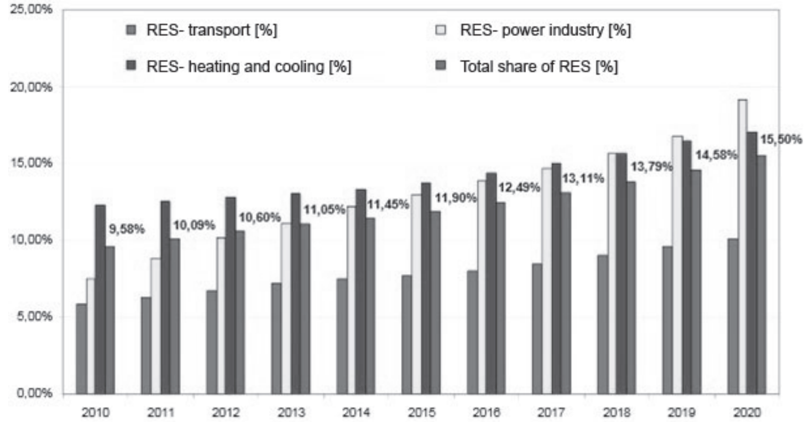

Figure. 1 The national goal and expected percentage share of renewable energy in heating, cooling, power industry and transport

Currently, cultivation of microalgae can be done in open-raceway ponds and in closed-culture systems called photo-bioreactors. Raceway ponds are typically made of a closed loop, oval shaped recirculation channels, generally between 0,2-0,5m deep, with mixing and circulation required to stabilize algae growth and productivity [13]. The microalgae's CO_2 requirement is usually satisfied from the surface air, but submerged aerators may be installed to enhance CO_2 absorption [14]. Compared to closed photobioreactors, open pond is the cheaper method of large-scale algal biomass production. High algae biomass production rates are achievable with open pond systems but as it can be seen in Table 1 there are still inconsistencies in the production rates reported in literature [13].

Raceway ponds may be the most commonly used for commercial production of microalgae. However they have some disadvantages like: little control of culture conditions, difficulty in growing algal cultures for long periods, cultures are easily contaminated and are limited to few strains of algae [19].

Table 1.
Microalgae productivity figures for open pond production systems

Algae species	X_{max} $(g \cdot l^{-1})$	P_{aerial} $(g \cdot m^{-2} \cdot day^{-1})$	P_{volume} $(g \cdot l^{-1} \cdot day^{-1})$	Reference
Chlorella sp.	10	25	-	[15]
Chlorella sp.	40	23,5	-	[16]
Chlorella sp.	40	11,1	-	[16]
Spirulina platensis	0,47	14	0,05	[17]
Spirulina platensis	0,9	12,2	0,15	[18]
Spirulina platensis	1,6	19,4	0,32	[18]

In order to remove large quantities of water and process large algal biomass volumes, a suitable harvesting method may involve one or more steps and be achieved in several physical, chemical, or biological ways, in order to perform the desired solid–liquid separation. Most common harvesting methods include sedimentation, centrifugation, filtration, ultra-filtration, sometimes with an additional flocculation step or with a combination of flocculation– flotation [20].

Algal biomass can play an important role in the process of obtaining energy sources to power agricultural machinery and vehicles. There are several different biomass conversion processes that can yield high calorific value products. Main routes for processing algae are presented in Fig. 2 [13].

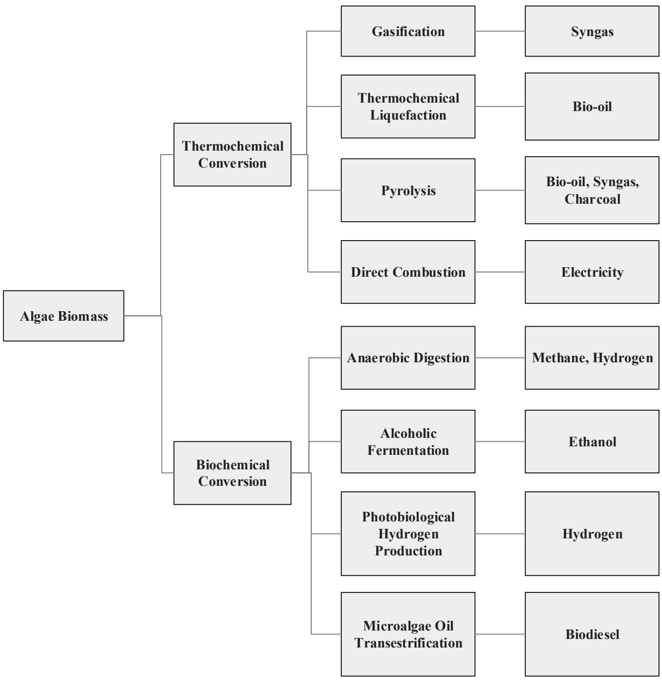

Figure 2. Potential algal biomass conversion processes for energy and fuel purposes

Biochemical conversion is based on the processing of energy contained in the biomass into biofuels by anaerobic fermentation, alcoholic fermentation, photobiological hydrogen production or transesterification of oil from microalgae. Biochemical conversion of algae material is considered mainly for the production of light molecules such as methane, ethanol and hydrogen. Thermochemical conversion of biomass uses the complete organic part of biomass feedstock, not only lipids like in many other conversion routes. The use of algae biomass for the production of modern sustainable biofuels through e.g. pyrolysis [21-23], hydrothermal liquefaction [24-26] or gasification [27-29] is currently the subject of many studies.

Among the various methods of thermochemical conversion of algal biomass, pyrolysis seems to attract the most attention. Pyrolysis is a simple process and produces bio-oil under relatively mild conditions (atmospheric pressure, 400-550ºC, inert atmosphere) [30,31]. It is based on the thermal decomposition of biomass in an oxygen-free atmosphere. Pyrolysis is the process of converting algal biomass into bio-oil called pyrolysis oil, aqueous phase, gas and char. The desired fraction is the organic fraction, which is referred to as pyrolysis oil or bio-oil [32]. Bio-oil can be readily stored or transported [23]. Pyrolysis of biomass can be executed on an industrial scale as a separate and independent process that provides useful products. Based on the heating rate of the biomass remains in the reactor, three types of pyrolysis can be distinguished:

1. slow pyrolysis (conventional), which involves long-term retention of material in the reactor with heating rate around 0,1-1$^{\circ}C \cdot s^{-1}$. The resulting product is equally gaseous, liquid and solid.
2. fast pyrolysis, with heating rate around 10-200ºC/s. The product is about 50% liquid
3. flash pyrolysis with heating rate around 1000ºC/s. The product is mostly liquid [33].

Due to the possible conversion rate of biomass into bio-oil flash pyrolysis is the most effective way of obtaining pyrolysis oil. Pyrolysis of biomass or, in particular, algae results in different amounts of organic, aqueous, gaseous and solid fractions, depending on the biochemical composition of the algae feedstock and the process conditions, as it was shown in Fig. 3.

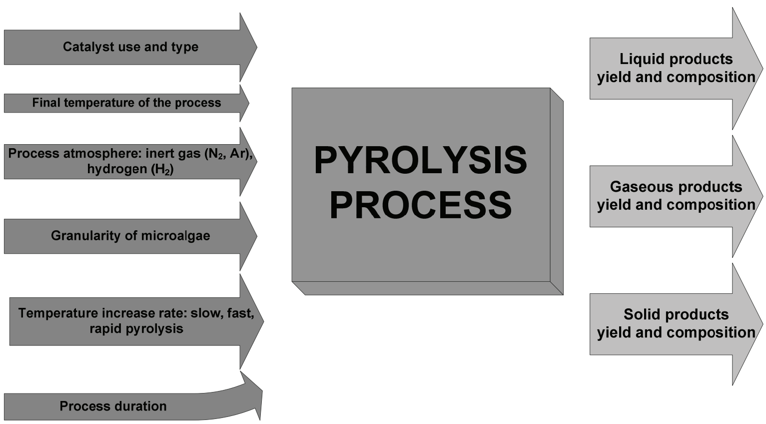

Figure 3. Selection of the pyrolysis process conditions

Experimental

The microalgae sample *Chlorella* was obtained from Ingrepro B.V. (The Netherlands). These algae were grown autotrophically in an open raceway pond. After purchasing, microalgae in dry powder form were stored in airtight packages. Characteristics of microalgae sample used in this study are presented in Table 2.

Table 2.
Characteristics of microalgae sample

Feedstock properties (wt%)		Ultimate analysis (wt%)[a]	
Moisture	6,4	C	54,3
Ash	13,1	H	8,2
Volatile matter	69,1	N	7,6
Fixed carbon	11,4	S	0,5
		O[b]	29,4

[a] Calculated on dry and ash free basis.
[b] Calculated by difference

The pyrolysis experiments were performed using a fixed-bed reactor. The schematic diagram of the experimental setup was shown in Fig. 4. About 3 g chlorella was placed in a quartz reactor (18 mm inside diameter, and 200 mm length).

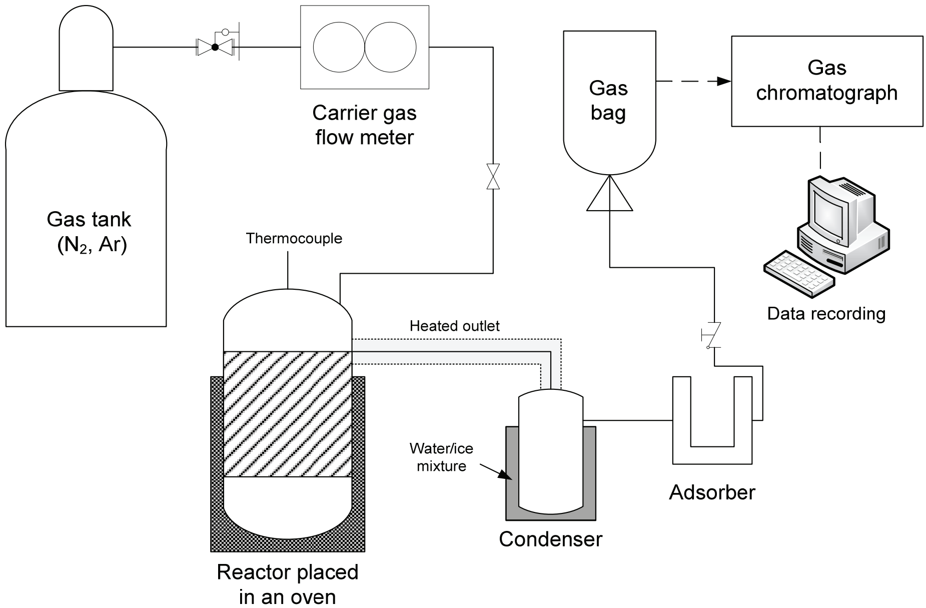

Figure 4. Test stand diagram

The feedstock was heated by an electrical furnace, and the emerging vapors were transported by carrier gas to the condenser vessel. The temperature in the reactor was measured with a thermocouple placed inside the bed. Argon as a carrier gas, purged the reactor from the inlet located in the top of the reactor and its flow rate was controlled by a flow meter (40 ml min^{-1}). A condenser (kept at 0°C) connected at the heated exit of the reactor was used to collect the liquid products. The tube connecting the reactor and the condenser system was heated to 200ºC to avoid pre-condensation of vapor produced.

The incondensable components in volatiles formed gaseous products were collected in a gas bag. Liquid products obtained in experiments were separated, divided into oily phase (top phase) and an aqueous phase (bottom phase) and weighted respectively. After each experiment, the solid char was removed and weighed, and then the gas yield was determined by the difference.

The experiments were carried out at temperature range between 350-550°C with holding time of 30 min. The total liquid products were comprised of an aqueous and organic phase. Bio-oils were separated into *n*-pentane soluble and *n*-pentane insoluble compounds (e.g. asphaltenes, resins). The *n*-pentane soluble fraction samples were subjected to gas chromatograph analysis. The gas chromatograph analysis with flame ionization detection (FID) was performed using a HP 5890 gas chromatography with hydrogen carrier gas and an capillary column. Gaseous products collected in the gas bag were analyzed by gas chromatography analyzer (PE Clarus 580 GC) with FID and TCD detector.

Results

The experiments were performed to investigate the effect of temperature on product yields in the pyrolysis process. The final pyrolysis temperature was maintained at 350, 400, 450, 500 and 550ºC, respectively with holding time 30 min. Results of studies are shown in Table 3 and in Figure 5.

The yield of bio-oil was the lowest at 350ºC, and then increased with increasing temperature. The highest yield of 32,75 wt.% was obtained at 450ºC. Above 450 ºC, the yield of bio-oil decreased. With conversion temperature rose from 350 to 550ºC the yield of char decreased from 45,86 to 30,22 wt.%. Simultaneously gaseous and aqueous phase yield slowly increased from 15,72 to 22,86 wt.% and from 11,74 to 18,35 wt.%, respectively. Organic fraction (bio-oil) and aqueous phase was shown in Fig.6. As it can be seen obtained bio-oil was dark and viscous liquid.

Table 3

The influence of the final temperature of the pyrolysis of Chlorella on the yields of individual products

Temp. [°C]	Solids [% wt.]	Liquids [% wt.]	Bio-oil [% wt.]	Water products [% wt.]	Gas. Products [% wt.]
350	45.86%	38.41%	26,67%	11,74%	15,72%
400	36,23%	47,21%	30,59%	16,63%	16,56%
450	32,87%	50,44%	32,75%	17,68%	16,70%
500	31,51%	49,61%	31,58%	18,03%	18,88%
550	30,22%	46,92%	28,57%	18,35%	22,86%

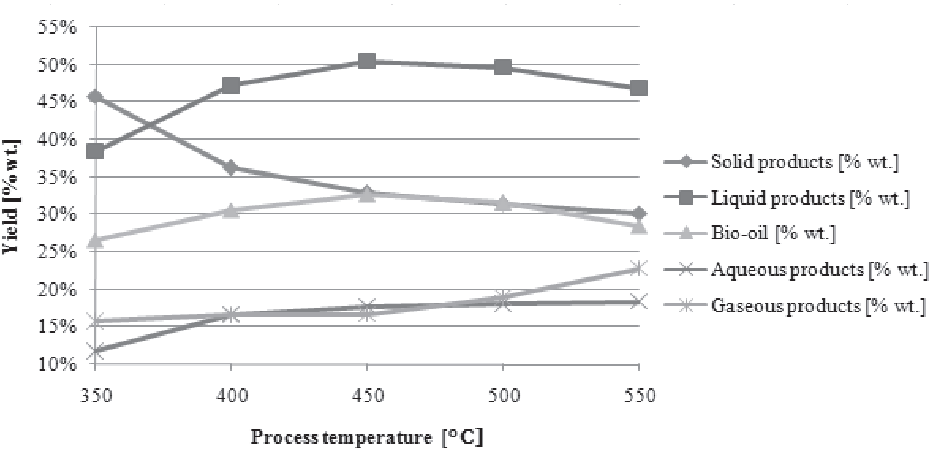

Figure 5. The influence of the final temperature of the pyrolysis process of algal biomass of Chlorella on the yields of individual products.

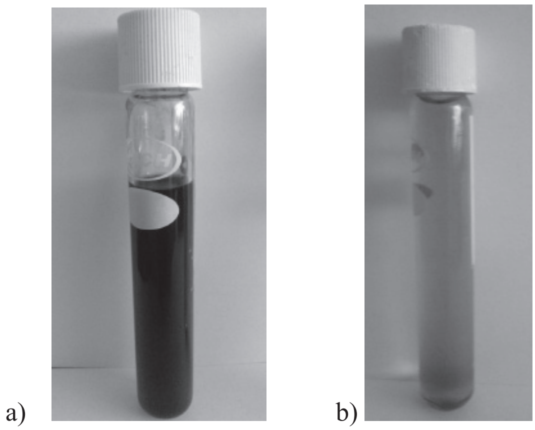

Figure6. a) Bio-oil (top phase) and b) aqueous phase (bottom phase)

Presented results are slow pyrolysis results, but the observed trend in product yields is similar to those found in a fast pyrolysis process [21]. Decrease in solid residue, optimal temperature for bio-oil production and increase gas have been reported earlier and explained as due to different extends of secondary reactions [19]. It is hard to compare results from literature because product yields during pyrolysis is determined by the reactor type, design of the condensation section, and experimental conditions.

The composition of gaseous products of the pyrolysis of *Chlorella* is shown in Table 4 and in Figure 7. The gas products consisted mainly CO_2. It can be also seen that yield of gaseous hydrocarbons increased with temperature. For example yields of CH_4 and H_2 increased from 3,36 to 12,17% and from 2,59 to 15,60%, respectively as the conversion temperature increased from 350 to 550ºC. It has been reported that formation of volatile hydrocarbons such as CH_4, C_2H_4, C_2H_6, etc. occurs at temperatures above 450°C when decarboxylation and the formation of CO_2 is complete [17].

Table 4.
The composition of gaseous products of the pyrolysis of algae Chlorella

Temp. [°C]	H_2 [% vol.]	CH_4 [% vol.]	C_2 [% vol.]	C_3 [% vol.]	C_4 [% vol.]	C_5 [% vol.]	C_{6+} [% vol.]	CO [% vol.]	CO_2 [% vol.]
350	2,59%	3,36%	2,37%	2,10%	1,44%	0,17%	0,82%	10,83%	76,32%
400	5,17%	7,64%	5,08%	3,68%	2,25%	0,27%	0,91%	9,74%	65,27%
450	15,87%	10,24%	5,12%	3,18%	2,04%	0,27%	0,93%	9,30%	53,05%
500	15,43%	11,20%	4,92%	2,94%	1,78%	0,18%	1,16%	10,18%	52,21%
550	15,60%	12,17%	4,88%	2,91%	1,69%	0,21%	1,50%	10,14%	50,90%

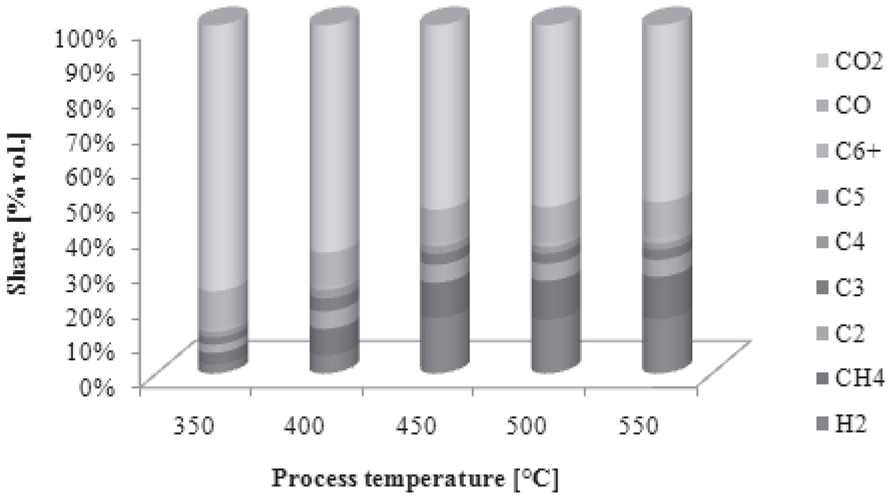

Figure 7. The composition of gaseous products of the pyrolysis of algae Chlorella

The chromatogram of bio-oil derived at 400°C- compounds soluble in pentane was shown in Figure 8, while the presence of oxygen compounds is presented in Figure 9. Significant majority of components had retention time for substances with boiling temperature below 350ºC, which is typical for diesel oil. Various molecular groups were detected, for example: hydrocarbons (heptene, decane), acids (acetic acid, propionic acid), nitrogenous compounds (pyroles) or oxygen compounds (acetone, methanol).

The chromatograph of aqueous phase derived in process temperature of 400°C is presented in Fig. 10. It can be seen that aqueous phase contained much smaller number of compounds than organic fraction (bio-oil). Mainly alcohols and acids were detected.

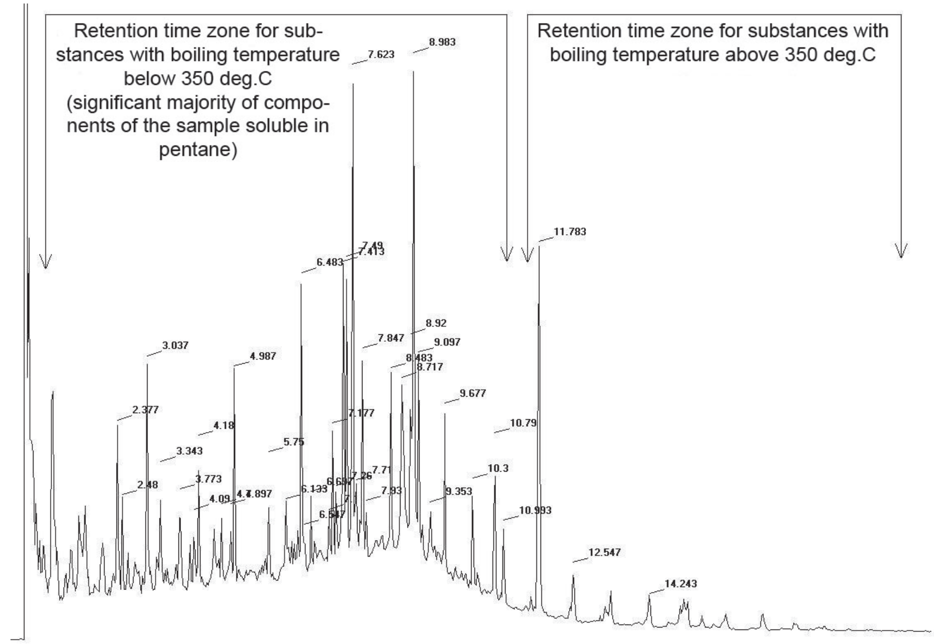

Figure 8. Chromatogram of a sample of bio-oil (upper phase - oil); process temperature 400°C; the compounds are soluble in pentane

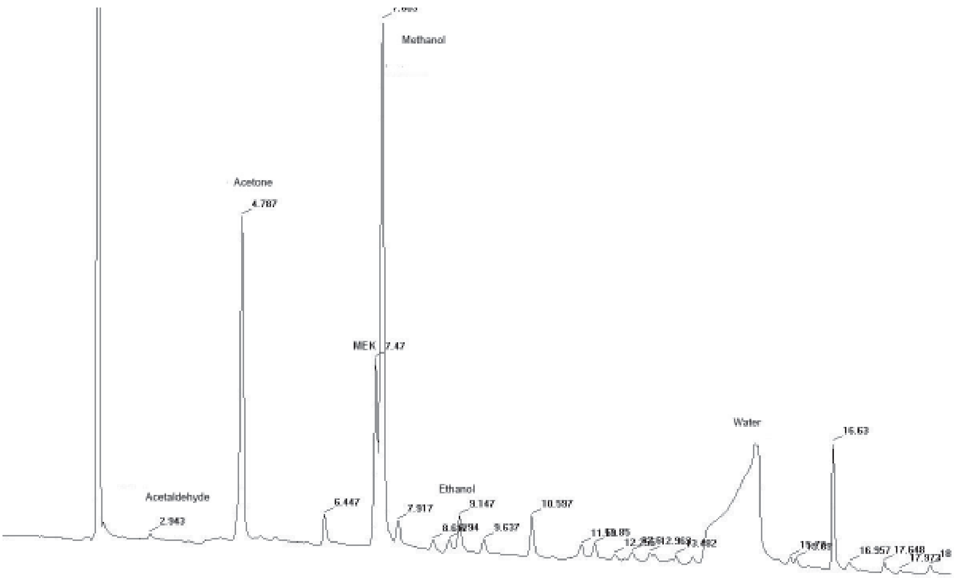

Figure 9. Chromatogram of a bio-oil (upper phase); process temperature 400°C; oxygen compounds

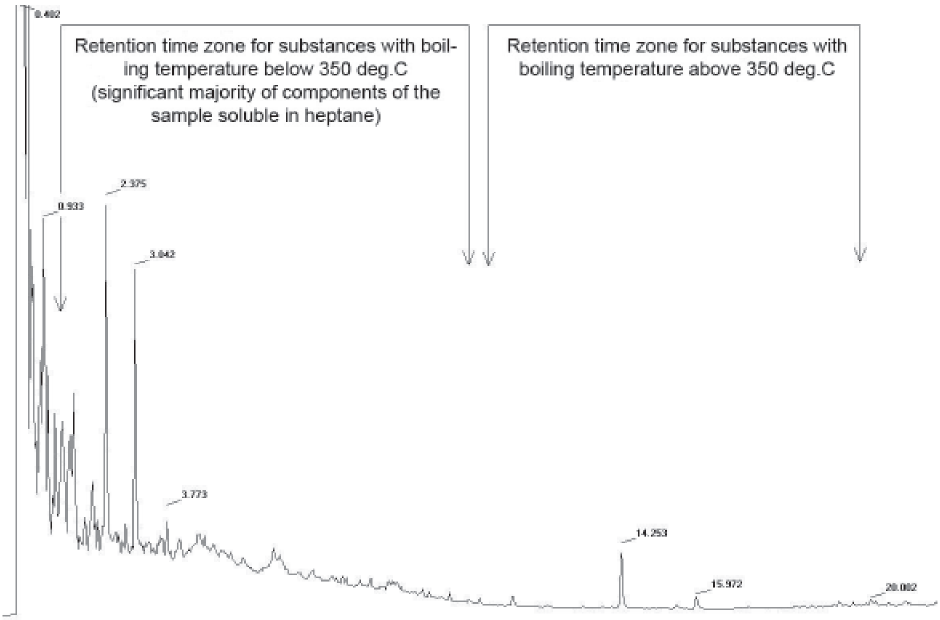

Figure 10. The chromatogram of a aqueous phase (bottom liquid phase); process temperature 400°C; water extract

Conclusion

The presented results of a study of *Chlorella* algal biomass in the process pyrolytic thermal decomposition allow us to formulate the following conclusions:

1. At 450°C maximum yield of liquid fraction of 32.75 (% wt.) was reached, which confirms the existence of an optimum temperature for obtaining liquid products; above this temperature cracking reactions to gas products may occur, as evidenced by the increasing yield of gaseous fraction with increasing process temperature.
2. Most of the components of bio-oil sample (apart from resins and asphaltenes) represent the boiling point of diesel oil (<350°C); the retention times in the chromatogram lower than 10 minutes; above are the visible components with boiling points typical for lubricating oil.
3. Oxygen compounds content in bio-oil are similar to bio-oils derived from wood biomass (the largest shares are: acetone, methanol, methyl ethyl ketone (MEK) and ethanol);
4. The higher the temperature, the higher the content of aldehydes and methanol, especially visible increase in acetone content.
5. For bio-oil's compound soluble in pentane: with increasing pyrolysis temperature (especially over 500°C), increase content of components boiling above 350°C.

The bio-oil from pyrolysis of microalgae can be used in many applications as direct combustion for energy generation, source of chemicals or as semi-finished product of substitute for conventional fuels. A bio-oil due to high viscosity and high content of asphaltenes and resins before direct use as engine fuel have to be further upgraded for example by hydrogenation or zeolite cracking. There still exist many problems to be solved in the process of producing fuels from microalgae but microalgae may play an important role in providing energy in the future.

Acknowledgements

The study was carried out as part of the statutory activities of the Department of Energy and Fuels AGH University of Science and Technology in Krakow, task number 11.11.210.213.

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THE IMPERATIVE OF BIOFUELS: AN OVERVIEW

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Abstract. There have been large increases in human energy usage through human development. With improving economic development, global energy usage is projected to increase markedly in the next 18 years. While there are projected increases in usage of all energy stocks, the largest increases are projected for biorenewable energy. The European Union is a leader in biorenewable energy with the USA and China projected as likely major players.

Key words: biopower, historical perspective, biofuels, bioethanol, biodiesel, global assessment and projections

Introduction

There has been tremendous growth of energy consumption during human development. This is clearly seen in seen from the data [1,2] below:

– Neolithic era– 15 MJ day^{-1} per person
– Feudal/medieval (pre-industrial) societies – 45 MJ day^{-1} per person
– Industrial society – 300 MJ day^{-1} per person
– Post-industrial society – 1 thousand MJ day^{-1} per person

Global consumption of energy continues to grow with economic growth and improving standards of living. It is projected that in 2030, global consumption of energy will reach 17.7 billion tonnes of oil equivalents (TOE) compared to 12.2 billion TOE in 2011 [3]. A forecasted structure of world's energy sector in 2030 is shown in figure 1 with the projected changes in the energy sources summarized in figures 2 and 3.

Renewable energy is projected to make up an increasing significant proportion of energy usage (figures 2 and 3). The potential of the various sources has been estimated quantitatively and these are summarized in table 1.

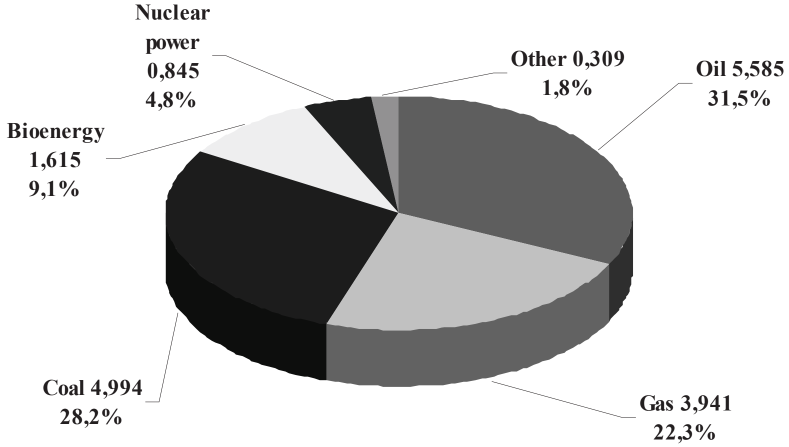
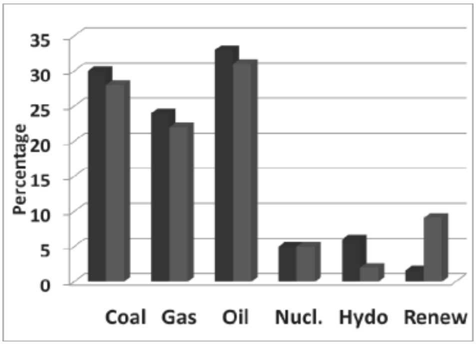


Figure 1. Projected structure of global production in 2030 (9 billion TOE [4,5]



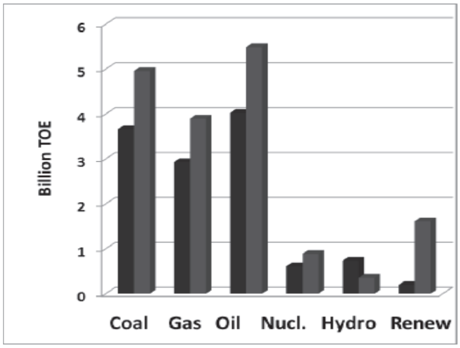


Figure 2. Changes in percentage of global energy usage from different sources between 2011 and those projected for 2030 [based on 3]

Figure 3. Changes in global energy usage from different sources between 2011 and projected for 2030 [based on 3]

The increase in renewable energy is attributable to policies and subsidies from governments (supra-national: European Union; national e.g. China, Germany, USA) together with technological advances. In British Petroleum report, it is stated that: "*Renewables growth is initially led by the EU, but from 2020 the US and China are the largest sources of growth*" (BP, 2012).

Table 1.
The potential of renewable energy sources for the planet [based on 6, 7].

Renewable energy sources	General potential, billion t of conv.fuel per year	Technical potential, billion t of conv.fuel per year	Economically justified potential, billion t of conv.fuel per year
Biomass energy, including:	40	2.55	2.0
forests	15	1.5	1.5
other plants	10	1.0	0.5
seaweed	15	0.05	0
Hydroenergy, including:	6.065	3	1.52
water currents	3	2.91	1.5
waves	3	0.05	0.01
tides	0.065	0.04	0.01
Radiant energy from the Sun	86000	5	1
Thermal energy of seas and oceans	7500	1	0÷1
Wind energy	860	5	1
Geothermal energy	16	0.4	0.2
Total	94422.065	16.95	5.72-6.72

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EFFECTS OF THE BIOMASS ASH ON GROWTH OF CEREAL PLANTS

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Abstract. We are currently, in Poland, observing increasing construction of huge combusting units for biomass. This might, in the next 2-3 years, lead to the accumulation of about 200,000 tons, or more of biomass ashes as a by- product resulting from this process. Biomass ashes have some positive properties i.e., high pH, high levels of K, and Ca, medium levels of Mg, P and some microelement. It could be treated as a source of useful material for improving soil reaction and plant fertilization as well as a component for mineral or organic-mineral fertilizers. In an earlier experiment, where the effect of ashes on plant germination and primary growth was estimated, no negative effect was observed, but it must be continuously monitored since its chemical content and reaction could vary extensively depending on the type of combusting unit and material burnt. The paper is a presentation of results from sprouting beds, pots and field experiments with different plants. Actual data obtained indicate that ashes have no negative influence on plant germination, initial growth of seedlings and physiological processes in the leaves.

Key words: biomass, fly ashes, mineral- organic fertilizer

Intriduction

The growing need for energy production from renewable sources means that biomass is currently more often used instead of coal or lignite to fire power plants.

Both, the fly ash composition and its properties will vary depending on such factors as: plant genetic features, agronomic treatments used in the plant cultivation, climatic factors, methods applied in processing biomass, and the type of installation and the temperature at which the combustion process takes place. Properties of biomass generated ash can vary quite significantly depending on the type of raw material, type of boiler or combustion process. Ashes are characterized by a high content of calcium (Ca) and potassium (K), the presence of phosphorus (P), magnesium (Mg) and micronutrients as well as high pH (9-13). The composition of different type of biomass is provided in Table 1. There is, however, lack of nitrogen (N) and organic substances.

Apart from the preferred components such as potassium (K), phosphorus (P), magnesium (Mg), ash may also contain heavy metals (Stankowski and Maciorowski 2011). Sometimes the presence of certain heavy metals can be in excessive concentration.

Potentially, ash as a fertilizing substance can be used for plants [25, 2].

Table 1.
Nutrients contained ash from the biomass combustion (based on data from Wrocław University of Environmental and Life Sciences)

Biomass	%P_2O_5	%K_2O	%CaO	%MgO
Hay pellets	4.3	10.4	18.8	2.7
Grain oats	11.8	14.8	3.5	4.5
willow	4.0	8.9	34.4	0.3
oakwood	2.2	9.4	40.3	3.5
Triticale straw	4.8	28.8	16.4	1.5
rye straw	3.6	6.5	7.4	3.4
sorghum	3.4	13.6	8.1	2.9
wood chips	1.3	3.6	15.4	6.3

Table 2.
The presence of heavy metals in ash from pure biomass combustion (based on data from Wroclaw University of Environmental and Life Sciences)

Biomass	Pb	Cd	Hg	As
Grain oat	1.53	0.42		
willow	0.017			
wood chips	85	8.26	0.172	3.72
oakwood	33.1- 39	7.8- 29	0.0041	21.9- 23
approved metal content in mineral fertilizers*	140	50	2	50

*Regulation of the Minister of Rural Development of 18 June 2008. on the implementation of certain provisions of the Act on fertilizers and fertilization, No. 119, Journal of Laws-2008 poz.765 of 2008-07-7

Ash is useful both as a soil improver and a plant fertilizer. It is, however, worth remembering that the acquired biomass should be from controlled sources. There is need to monitor its chemical composition, and to sort or classify ashes into those suitable for use as a valuable fertilizer in accordance with the standards defined by the Law on fertilizers and fertilization.

The quality of biomass ash exhibits considerable variation. In investigating the processing possibilities, attention will have to be paid to characteristic properties of ash.

Ash has an unfavorable physical form. Dustiness makes it difficult for both transportation and use in the field. Changing the form of powdery granules as well as retaining their chemical composition in the alignment through the skillful blending of ash from the pure biomass combustion with ash from coal, offers greater prospects of their use in agriculture. Despite the lack of nitrogen (N), ashes in their composition contain a lot of macro and micro elements sought after by farmers.

The use of ash as a fertilizer requires the granting of permission from the Minister of Agriculture and Rural Development. The law on fertilizers and fertilization of 10th July 2007, which has been in force since 15th November 2007, regulates the conditions and procedures for marketing fertilizers and plant conditioners. Chemical fertilizers from beyond the European Community are marketed under the authorization of the Minister responsible for agriculture. The Act, besides regulating types of mineral-, organic-, and organic-mineral fertilizers, also sets out categories of funds to improve the quality of soil and plants. The procedures for obtaining the necessary permits are not as demanding as in the case of other fertilizers. The authorization must include:

– the results of research and opinion showing compliance with quality requirements and the requirements in terms of pollutants;
– a review of suitability for use.

An obstacle to the attainment of relevant permits for ash, is the need for constant and repeatable chemical composition of the product, which is difficult in the case of fly ash from co-incineration

Effects of biomass ash on *Festuloliumbraunii* growth

The pot experiment was conducted in the laboratory of the Department of Agronomy at The West Pomeranian University of Technology in Szczecin in 2008. The effect of ash fertilization was confirmed by measuring the growth of shoots and roots, chemical composition and photosynthetic activity.

Table 3.
Content of trace elements in the ash (g· kg^{-1} S.M]

Biomass ash		P	K	Ca	Mg	Na
wheat grain (Austria)	*ZP*	3.39	49.0	134.8	43.8	0.43
Straw (Suchań)	*S*	2.59	32.7	58.2	8.0	1.29
wood briquettes (Recz)	*BD*	0.69	13.4	177.1	20.3	6.99

Source: http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

Table 4.
Variants of ash fertilization

Biomass ash	dose of ash (g·pot^{-1})		dose of ash (g of component·pot^{-1})			
			P		K	
	I	II	I	II	I	II
ZP+N	10.17	20.34	0.0346	0.0692	0.498	0.996
S+N	15.23	30.46	0.0396	0.0792		
BD+N	37.27	74.53	0.0149	0.298		

Source: http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

Table 5.
Variants of mineral fertilization

Mineral fertilizer	N		P		K	
	($g \cdot pot^{-1}$)	($kg \cdot ha^{-1}$)	($g \cdot pot^{-1}$)	($kg \cdot ha^{-1}$)	($g \cdot pot^{-1}$)	($kg \cdot ha^{-1}$)
Control	0	0	0	0	0	0
Control N	0.3	100				
NPK I			0.0297	9.9	0.249	83
NPK II			0.0594	19.8	0.498	166

Source: http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

Table 6.
Yield ($g \cdot pot^{-1}$)

Crop	Dose (D)	Variant of fertilization (W)				Average
		ZP+N	S+N	BD+N	NPK	
First	I	77.8	68.8	68.9	66.5	70.5
	II	75.5	74.5	73.3	76.5	75.0
	Average	76.7	71.6	71.3	71.4	72.8
	NIR 0,05	W- 5.05, D- 3.06, WxD- ns				
	Control N- 69.5, Control – 48.2					
Second	I	42.8	45.6	42.5	38.6	42.4
	II	46.2	48.0	42.8	42.9	45.0
	Average	44.5	46.8	42.6	40.08	43.7
	NIR 0,05	W- 4.02, D- 2.11, WxD- ns				
	Control N- 37.9, Control – 14.3					

Source: http://cbepolska.pl/images/ZUPS_111123/prezentacje/08ZUPS_Robert_Maciorowski.pdf (25.08.2013)

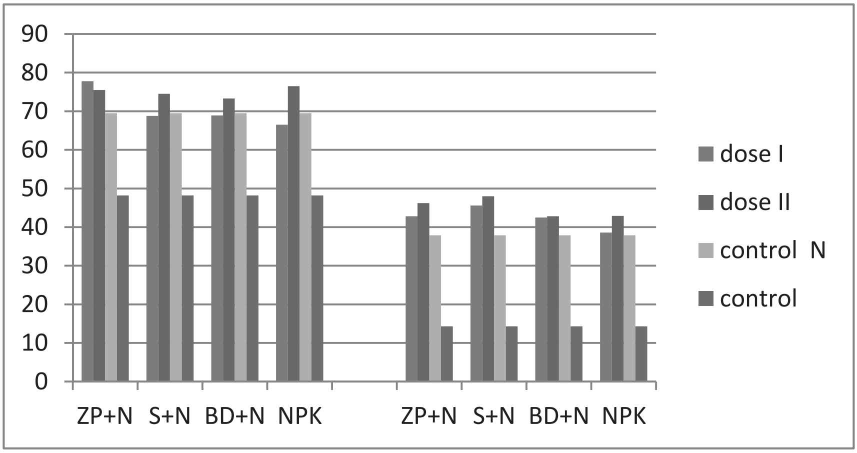

Figure 1. Plant yield [g/vase] depending on fertilizer variants from first and second swaths

The positive effect of ash (version ZP + N) on the chlorophyll content and photosynthetic activity of plant processes was assessed by laser-induced chlorophyll fluorescence.

Effects of biomass ash on primary plant growth on some spring cereal species. Materials and methods.

The experiment was conducted in the laboratory of the Department of Agronomy at The West Pomeranian University of Technology in Szczecin during the 2012 spring period. Three species of spring cereals (Tybalt – a variety of wheat, Natasha - a variety barley, Slavko- a variety of oats), and four variants of the aqueous slurry of biomass ash (0 - control, 2%, 4%, 6%) were compared. The ash came from burning wood chips with 25 percent of sorghum in the fluidized bed boiler. Germination of seeds was carried out in the plates-germinator of the "Szmal" type. The germination process took place in trays with a slurry of ash for the period of experiment. There were 4 replications. After the emergence of the spring cereal species, the chlorophyll content in the 2-leaf stage was measured with chlorophyll meter Minolta SPAD 502 using a photo-optical method(SPAD). The height and weight of the seedlings was determined by measuring 25 pieces. The dry weight of seedling was determined by drying the product at a temperature of 130 ° C until the achievement of a constant weight. Statistical analysis was performed by analysis of variance of two factors in a completely randomized system. Confidence intervals were calculated using the Tukey's test at a significance level of 0.05.

Results and discussion

Cereal seedlings growing in a suspension of biomass ash, were characterized by a higher rate of SPAD value when compared with the control test. Increasing the share of ash from 0 to 2% and 4% contributed to increases in value of 1.3 and 1.8 respectively. Further increase in the share of ash in suspension remained without effects on the trait. The reaction of the tested species was varied. The most responsive of the plants was barley but only to the level of 2%.Wheat and oats reactions were weaker but the optimal option was at 4% of ash.

Table 7.
Effect of biomass ash (P) on chlorophyll content (SPAD) in the leaves of three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	23.2	25.3	29.9	26.2
2	27.1	25.8	29.7	27.5
4	27.0	26.4	30.7	28.0
6	27.7	26.2	30.4	28.1
Average	26.3	25.9	30.2	27.5
NIR0.05 for:	G- 0.770; P- 0.980; P(G) -1.697			

By increasing the amount of biomass ash a more rapid growth of tested cereal seedlings was observed (table 8, fig 1). Increasing the share of ash in the slurry from 0 to 2% and 4% resulted in increase in height by 23% and 31% respectively. The optimal variant was with the addition of 4% ash but the strongest response of 44% was found in the case of wheat.

Table 8.
Effect of biomass ash (P) on seedling's height (cm) of the three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	16.0	16.3	11.9	14.7
2	17.8	22.4	14.0	18.1
4	19.6	23.5	14.5	19.2
6	19.4	23.4	15.6	19.5
Average	18.2	21.4	14.1	17.9
NIR0.05for:	G- 0.88; P- 1.12, P(G) -1.94			

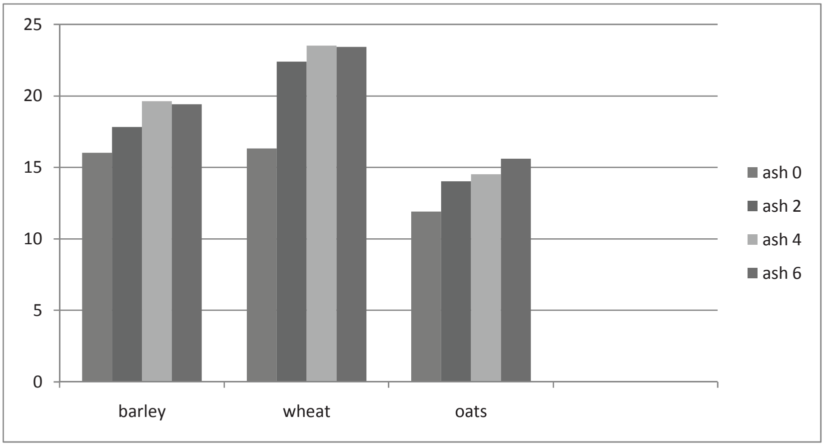

Figure 2. Effects of biomass ash fertilization variants on seedlings height [cm] of three spring cereal species

The fresh weight of seedlings (25 pieces) from the 2% variant was characterized by a higher value than the control (Table 5). Further increases in the share of ash in the water suspension did not result in a significant increase in the plant weight, but also without any negative effects by lowering the plants' weights.

Table 9.
Effect of biomass ash (P) on seedling's fresh weight (g) of the three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	2.64	1.54	1.16	1.78
2	3.31	2.29	1.41	2.34
4	3.44	2.54	1.44	2.47
6	3.58	2.32	1.72	2.54
Average	3.24	2.17	1.43	2.28
NIR0.05 for:	G-0.237; P-0.301, P(G) – r.n.			

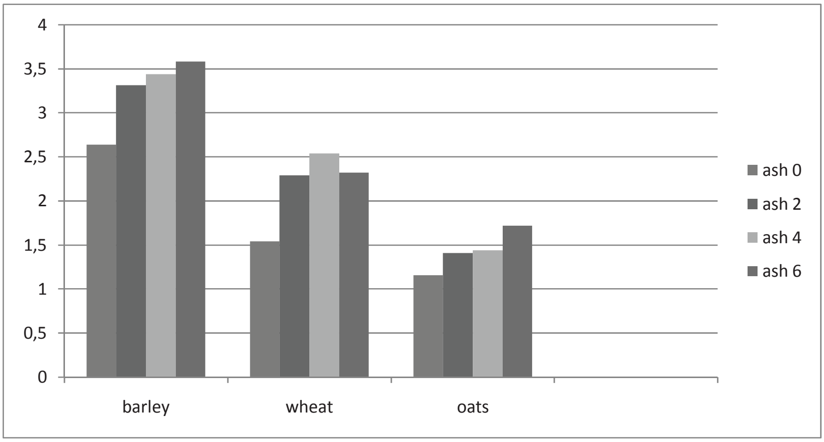

Figure 3. Effects of biomass Ash fertilization variant on seedlings fresh weight [g] of three spring cereal species

Changes in the dry weight of the seedlings (table 10) under the influence of a different variants of ash in the slurry was similar to values of seedlings fresh weight. The dry matter content of seedlings did not differ significantly, thus indicating the lack of impact of the different variants of the ash products on plants' hydration. The highest dry matter content was characteristic of wheat seedlings while the lowest was of barley seedlings.

Table 10.
Effects of biomass ash (P) on seedling's dry weight (g) of the three species of spring cereals (G)

Ash content (%)	Species			Average
	Barley	Wheat	Oat	
0	0.244	0.186	0.099	0.176
2	0.308	0.290	0.124	0.240
4	0.334	0.274	0.124	0.244
6	0.319	0.258	0.144	0.240
Average	0.01	0.252	0.123	0.225
NIR0.05 for:	G- 0.026; P-0.033, P(G) – r.n.			

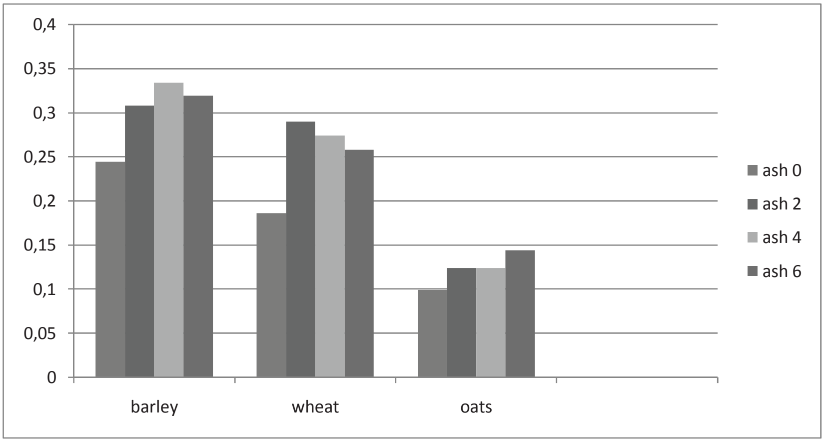

Figure 4. Effects of biomass ash fertilization variants on seedlings' dry weight [g] of three spring cereal species

Research findings [23] confirm the positive impact of biomass ash on the yield of Festulolium grass, when compared with the control. They were similar to observations from mineral fertilization. Stankowski and Meller (1995) and [9] also showed that mineral coal had a beneficial effect on plant growth and photosynthetic parameters of triticale, rye and barley.

Conclusions

1. The use of ash from biomass as a fertilizer component resulted in more rapid growth of wheat, barley and oats seedlings
2. The optimum dose was 2% - 4% of the ash in water suspension.
3. There were no adverse effects of the additive ash used in the tests.
4. The fertilizer can be used for the cultivation of industrial and technical agricultural lands for the purpose of biogas, bio-ethanol, biodiesel, biomass burning, and fertilization of ornamental plants, forests, green spaces, including reclaimed areas.

Assessment of agricultural use of ash from the combustion of various types of biomass in pot and field experiments

The two-year experiment was conducted in the laboratory of the Institute of Environmental Protection and Development, Wroclaw University of Environmental and Life Sciences between 2010 and 2011.

The experiment involved two research factors: type of ash and different levels of fertilization. Ash sourced from burning oats, willow, straw of winter cereals, sorghum, oak, hay pellets and wood chips was used in the experiment. Different levels of ash fertilizer, i.e., 5g·10 kg^{-1} soil- 10g·10 kg^{-1} soil- 20g·10 kg^{-1} soil were applied. A control version without ash fertilization was also included.

Materials and methods

The study involved the use of Wagner's pot, each with soil of low potassium and phosphorus content.

There were 5 replications with a control object, using the independent series method. Parabola, a variety of spring wheat, was sown with 30 seeds per pot (primed seeds).After the emergence of plants stabilized, the density was adjusted to 18 plants·pot^{-1}. Moisture content was maintained at 60% maximum capillary capacity throughout the growing season.

Number of pots: 8 types of ash x 3 doses of ash x 5 replication + 8 control objects = 128 pots

Results and discussion

Table 11.
Plant parameters (the first year of study), grain weight (g)

Dose of Ash·pot^{-1} [g]	Ash from combustion of biomass							
	Oats grains	Willow	Triticale straw	Spring wheat straw	Sorghum	Oak	Hay pellets	Wood chips
5	28.8	26.1	28.0	26.5	27.9	28.0	27.8	27.1
10	27.6	26.5	27.7	25.7	28.0	29.3	27.5	27.8
20	29.0	27.3	28.3	26.1	28.8	29.6	28.6	28.3
Average	28.4	26.6	28.0	26.1	28.2	28.9	28.0	27.8
Control	24.8							
NIR0.05	1.6							

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/09ZUPS_ROMAN_WACLAWOWICZ.pdf (25.08.2013)

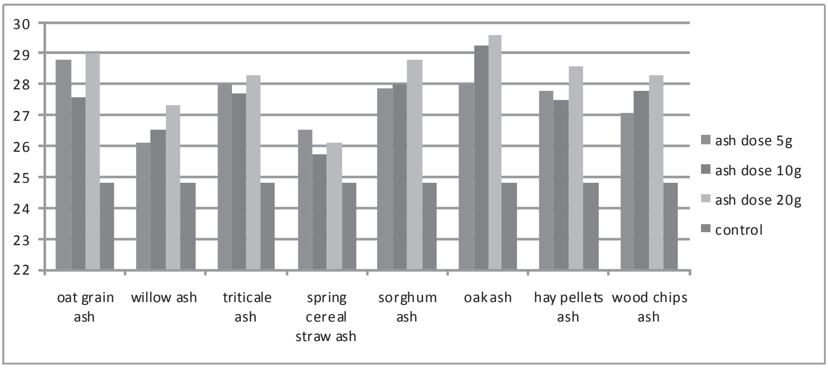

Figure 5. Grain weight [g] from varied levels of fertilization with fly ash from the combustion of biomass in the first year of experiment

Table 12.
Plant parameters (the second year of study), grain weight (g)

Dose of Ash·pot^{-1} [g]	Ash from combustion of biomass							
	Oat grains	Willow	Triticale straw	Spring cereal starw	Sorghum	Oak	Hay pellets	Wood chips
5	27.2	29.6	28.9	29.4	25.8	27.9	26.6	24.4
10	29.2	32.2	30.6	29.2	26.3	32.8	29.5	26.1
20	31.8	35.0	34.8	31.9	30.4	36.2	30.5	30.3
Average	29.4	32.3	31.4	30.2	27.5	32.3	28.9	26.9
Control	24.0							
NIR0.05	1.7							

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/09ZUPS_ROMAN_WACLAWOWICZ.pdf (25.08.2013)

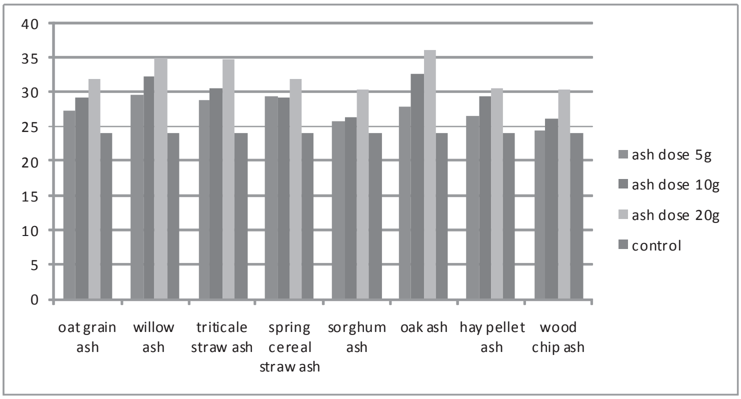

Figure 6. Grain weight [g] from varied levels of fertilization with fly ash from combustion of biomass in second year of experiment

Effects of industrial ash from the "Czechnica" power plant and local ash on the yield of triticale and on soil properties.

The next experiment was conducted on a field cultivated with triticale at the research centre of the Wroclaw University of Environmental and Life Sciences in 2011. The study focused on the effects of ash fertilization applied on triticale fields. The experiment involved two research factors: type of ash and different levels of fertilization. Two types of ash i.e., industrial (industrial - from Czechnica power plant: wood chips, wood chips + corn+ straw and wood chips + willow) and local (grain oat, straw from winter cereals, and oak wood) were used in the experiment. Three variants of fertilization: 3000 kg·ha^{-1}, 6000 kg·ha^{-1} and control without ash were applied.

Results and discussion

Table 13.
Estimation of yields (t·ha^{-1})

Ash dose (g·ha^{-1})	Ash from combustion of biomass					
	industrial			local		
	Wood chips (1)	Wood chip + maize + straw (2)	Wood chip + willow (3)	Oat grain (4)	Winter cereal straw (5)	Oak
3000	4.65	4.76	4.35	4.70	5.16	4.73
6000	4.88	5.08	4.1	5.22	5.21	4.76
Average	4.77	4.67	4.48	4.96	5.19	4.75
control	4.35					

Source:http://cbepolska.pl/images/ZUPS_111123/prezentacje/09ZUPS_ROMAN_WACLAWOWICZ.pdf (25.08.2013)

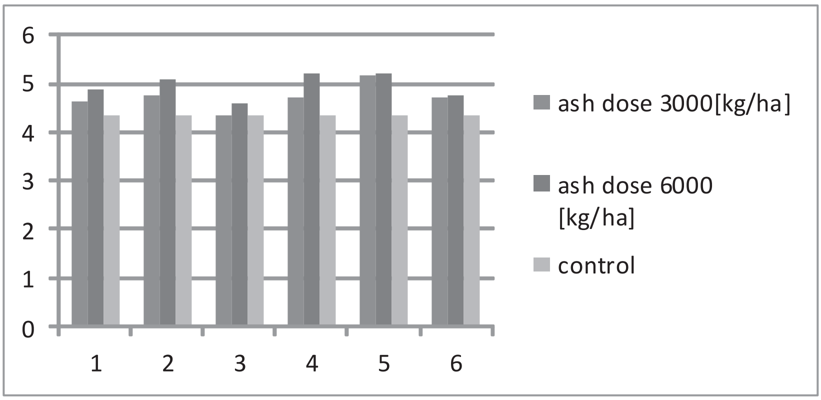

Figure 7. Grain yield [t/ha] from varied levels of fertilization with ash from combustion of biomass

The study showed that ash application in agriculture improves growth and yield of triticale.

Conclusions:

1. Recycling ash for soil use is totally environmentally friendly and compatible with sustainable development as it can benefit crop productivity and improve soil physical properties. Much of the macro and micro elements taken up by plants is returned to the soil, thus completing the mineral/ nutrient cycle in a habitat.
2. Byproducts of the combustion of biomass sourced from agricultural lands, generally do not contain toxic substances (especially heavy metals) in excess of the Polish standards and do not pose a threat to the environment.
3. By mixing the soil with ash from biomass combustion the yields of spring wheat and triticale are improved.
4. Increasing the dose of tested ashes led to overall improvements in crop yields.
5. Fly ash application in agriculture holds good promises, however, the impact of its application on soils' conditions needs to be studied further.

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INTERNATIONAL SCIENTIFIC CONFERENCE, SEPTEMBER 16-18, 2013, KRAKOW, POLAND

Bioenergy and Other Renewable Energy Technologies and Systems 203-208

POSSIBILITIES OF SUPPLEMENTING THE BASE OF SOLID FUELS FOR THE DISTRIBUTED ENERGY SECTOR

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Abstract. The aim of the undertaken research was to determine the suitability of selected plant species, acquired from areas excluded from agricultural use in Krakow region for energy purposes. Using the Braun-Blanquet phytosociological method, the dominant species were determined in that area. Those were canada goldenrod (Solidago canadensis L.), common wormwood (Artemisia vulgaris L.) and annual fleabane (Erigeron annuus (L.) Pers.). Next, their density, yields, planning and selected morphological features (the length of the stem and its diameter measured 5 cm above the soil surface). In accordance with the applicable standard, the heat of combustion of the above-ground mass of these plants with the following moisture content: 21.5 and 4.5% was measured. Solidago canadensis was characterised by the highest yield with the tallest and thickest stems, on average 1.63 $kg \cdot m^{-2}$, next Artemisia vulgaris (1.27 $kg \cdot m^{-2}$) and Erigeron annuus 0.43 $kg \cdot m^{-2}$. The highest values of the heat of combustion were recorded for the Artemisia vulgaris and Solidago canadensis biomass with the moisture content of 4.5%, they amounted to 19.80 and 19.77 $MJ \cdot kg^{-1}$.

Key words: vegetation of wastelands, solid fuels, heat of combustion

Introduction

Dynamic development of investment projects belonging to the so-called distributed energy, i.e. sources of energy with power ranging from 50-100 MW, in European power technologies is noticeable in recent years. This phenomenon results from, amongst other things, the limitation of environmental pollution and the improvement of energy effectiveness. These are usually entities using renewable energy sources, including also those in which plant biomass is used as a material intended for direct combustion. It can come from targeted cultivations or can be a by-product of agricultural and forest production. Forest biomass dominates in the USA [11]. In Poland, the use of forest biomass in professional boiler houses is to be reduced completely in 2015 within the meaning of regulations in force. However, the growing demand for biomass makes it necessary to look for its other sources, including its purposeful production on a larger surface area of lands [2, 9]. Even their availability does not quite solve the problem as using good, fertile soils for energy forestry seems to be disputable, due to the competition for food and feed production. In Poland, however, 40% of soils are characterised by poor quality and low agricultural suitability. Areas with such soils are first to be excluded from agricultural use. The surface area of fallow lands and wastelands was approx. 0.5 million ha in Poland in the years 2008–2009 [13]. Therefore, it seems reasonable to consider the possibilities of supplementing the aforementioned sources of biomass, with plants from areas lying fallow, the majority of which is not used in any way. They become the sources of weeds growing over cultivations, not to mention the fire hazard after the vegetation period. Some of the plants occurring in these areas are listed as invasive species [6, 12], which limit the natural biodiversity and which, pursuant to legal regulations in force, should be limited. S. Canadensis is a considerable threat for natural ecosystems in Poland, and its competitive power, as compared with native species, may be enhanced by allelopathic mechanisms found by numerous researchers [1, 23, 19, 16]. Also other species, occurring in large numbers in post-agricultural areas, are characterized by considerable vitality and fecundity. They could be used as a good source of biomass for heating purposes at local combined heat and power plants, thus improving the economics of transport.

The aim of the undertaken research was to determine the usefulness of selected plant species, growing on areas excluded from agricultural use for energy purposes.

Materials and methods

The research was conducted in the years 2012-2013, on land excluded from arable on the north-western outskirts of Krakow. The vegetation of the area was assessed using the Braun-Banquet phytosocilogical method [4]. The estimating of amount and sociability of examined species was performed in the patches of flora with area 50 m^2 in 10 repeating.

The degree of cover and sociability was determined for selected dominant species in the individual habitats, next the stems density per surface area unit was established and the measurements of the above-ground stems were performed to determine their total length and diameter 5 cm above the ground. Measurements were performed in a set of phase.

For comparative purposes, the examined species were collected at the same time during the seed formation period, which resulted from the applicable legal regulations concerning invasive species, to which S.canadensis is included. The collected stems were air-dried up to the moisture content of 13.5%, and next they were weighed to determine the yield. Samples for calorimetric analysis were prepared by air-drying stems up to the moisture content of 21.5% (first combination) and by drying the material obtained in this way in a laboratory dryer up to the moisture contend of 4.5% (second combination). The moisture content was controlled using the dryer and weight method. The material obtained was fragmented using a laboratory mill.

The heat of combustion was determined on calorimeter in accordance with the applicable standard [18]. The obtained results were drawn up in the program Statistica 9 with assigning homogeneous groups.

Results and discussion

Field research was conducted using the Braun-Blanquet phytosociological method and it allowed for distinguishing three basic plant species from fallow areas in Krakow region. Those were: Artemisia vulgaris, Solidago canadensis and Erigeron annuus. It results from other research [17] that the aforementioned species are also encountered in moist meadows in Krakow region. The structure of the vegetative mass yield of the analysed species is presented in Table 1.

Table 1.
Selected elements of phytosociological assessment of the analysed species and characteristics of their above-ground biomass.

Species	Degrees according to the Braun-Blanquet method		Density [pcs.·m^{-2}]	Moisture [%]	Yield [kg·m^{-2}]	Length of stems [m]	Stem diameter 5 cm from the base [mm]
	Surface cover in 5 gradual scale	Sociability in 5 gradual scale					
Common wormwood (*Artemisia vulgaris* L.)	3	3	65.67±2.52	13.5	1.27±0.55	1.19±0.33	5.75±2.43
Canada goldenrod (*Solidago canadensis* L.)	5	4	138.00±14.00	13.5	1.63±0.77	1.68±0.35	6.11±2.02
Annual fleabane (*Erigeron annuus* (L.) Pers.).	2	1	43.34±10.07	13.5	0.43±0.11	1.32±0.19	4.64±1.39

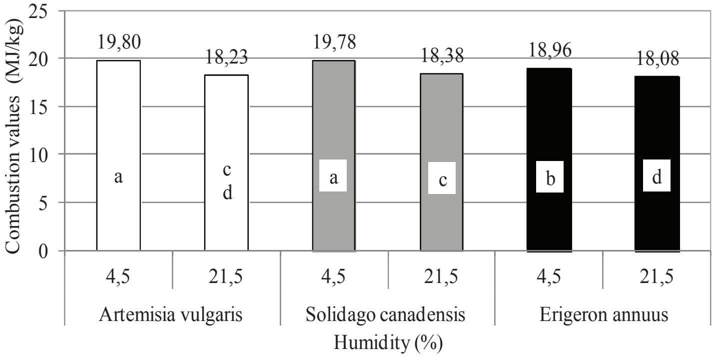
The highest yield of above-ground biomass was found in case of Solidago canadensis. It was on average 1.63 kg from 1m^2, with the average stem height of 1.68 m. Plants from this species occurring in south-western regions of Poland were of similar size [20]. On the other hand, earlier reports [22], concerning this species in Europe, describe slightly shorter stems with lengths of 1.54 ±0.215 m. In the present authors' research, the average stem diameter of Solidago canadensis was 6.11 mm.

Artemisia vulgaris had the second highest yield, amounting to 1.27 kg·m^{-2}. The average length of its stems was 1.19 m. The high yield variability of this species, depending on the year of research, is influenced by variable levels of liming and nitrogen fertilization, as indicated by research conducted in Lithuania [21]. In plot research [8] conducted in Egypt, Artemisia vulgaris reached the maximum height of 1.058 - 1.218 m depending on the year of examinations.

Erigeron annuus was characterised by the lowest yield amounting on average to 0.43 kg·m^{-2}, it reached the average height of 1.32 m and the stem diameter of 4.64 mm.

From energy crops, Miscanthus giganteus and Sida hermaphrodita biomass is used most frequently for energy purposes. However, yields of these species quoted in the literature are higher. For example, at targeted energy plantations of various Miscanthus giganteus genotype, Clifton-Brown and Lewandowski [5] obtained from 1900 kg·ha^{-1} biomass in the first year after starting the experiment up to 25.5 in the next years, while Borkowska and all [3] obtained 11000 kg·ha^{-1} in the third and fourth year of production for Sida hermaphrodita. However, such cultivations require high energy expenditures as compared to vegetation growing on fallow arable lands.

The analysis of the heat of combustion for biomass is necessary to determine its quantitative concentration of energy. Differentiation in the heat of combustion for stems of the analysed plants, depending on the species and the moisture content of the material was stated. The highest values of the heat of combustion were recorded for the Artemisia vulgaris and Solidago canadensis biomass with the moisture content of 4.5%, they amounted to 19.80 and 19.77 MJ·kg^{-1} (Fig. 1). For all examined species, an increase in the moisture content from 4.5% to 21.5% resulted in a decrease in the heat of combustion value, which is consistent with data contained in the literature [10]. The differences in the heating value of overground shoots between Artemisia vulgaris and Solidago canadensis both at the humidity 4.5 as well as 21.5% are statistically unimportant. The similar heating value was also stated for shoots from Artemisia vulgaris and Erigeron annuus but only at the humidity 21.5%.



a, b, c, d - homogeneous groups

Figure 1 Average heat of combustion values for stems of the examined plant species with the specific moisture content

Economic calculations are very important for the analysis of the use of plant biomass. For the group of plants under analysis, there are no costs connected with establishing the plantation, its fertilization and chemical protection. The relatively early harvest of S. canadensis prevents it from spreading, thus restoring natural biodiversity and facilitates its natural drying at the same time. Moreover, the appropriately high caloric value of the biomass, as compared to conventional fuels, can be obtained only with its specific, appropriately low moisture content [10], what was also confirmed in own examinations.

Heat of combustion values, obtained for the species under analysis, range from 18.08 to 19.80 $MJ \cdot kg^{-1}$. They are similar to the average values of this parameter quoted in the literature [14] for other types of biomass, which are currently used in the power industry, such as Miscanthus giganteus 18.5 $MJ \cdot kg^{-1}$ (moisture content 11.5%), fir wood 21 $MJ \cdot kg^{-1}$ (moisture content 6.5%), Danish pine 21.2 $MJ \cdot kg^{-1}$ (moisture content 8%), cereal straw 17.3 $MJ \cdot kg^{-1}$ (moisture content 6%).

The results of the authors' own research, as well as literature data, show that the heat of combustion for biomass assumes lower values as compared to basic energy, carriers in the form of solid fossil fuels such as coal, natural gas or oil, for which these values amount to: 28 $MJ \cdot kg^{-1}$, 56 $MJ \cdot kg^{-1}$, 42 $MJ \cdot kg^{-1}$ respectively [15]. Demirbas [7] provides heat of combustion values for vegetation biomass ranging from 14 to 21 $MJ \cdot kg^{-1}$, while such values for coal range from 23 to 28 $MJ \cdot kg^{-1}$. The heat combustion values obtained for the species under analysis fall within the range specified above.

Summary

On the basis of the research conducted in fallow areas, it can be concluded that Solidago canadensis biomass is the most suitable for supplementing solid fuels, due to its high yields and high heat of combustion values, while Erigeron annuus is the least useful due to these features. Solidago canadensis dominates fallow areas in Krakow region, according to the Braun-Blanquet method, it can be assigned 5 in terms of quantity with over 75% cover of the area under analysis and the 4th degree of sociability, i.e. the formation of larger patches. Such character of appearing is facilitating the harvest, which can limit a proliferation of this invading kind.

Artemisia vulgaris, characterized by lower yields but similar heat of combustion values, was spread in the areas under analysis to a lesser extent. The third species included in the study, annual fleabane, was the rarest and it was characterised by significantly lower yields and a lower caloric value as compared to the other species.Therefore, there does not constitute a stable source of biomass for combustion

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