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AGGLOMERATION OF POPLAR BIOMASS - PRELIMINARY RESEARCH

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There are many indications that plantations of energy crops will be, next to forests, side crops (eg. straw) and green areas in cities, the main source of biomass for solid biofuels production such as wood chips, pellets and briquettes. This production system will guarantee required amount of biomass with quality required for further processing. One of the popular species on this purposes is poplar (*Populus ssp.*) A characteristic feature of this type of biomass is its low density (0,33 – 0,45g/cm³). In order for the efficiently use of energy contained in this kind of biomass, it is necessary to process it into compacted solid biofuels. A very good way to improve the physical properties of this raw material is its agglomeration it to form of pellets.

The paper presents studies focused on agglomeration of biomass of ten poplar cultivars used in Europe commercially in short-rotation forestry systems. Studies were conducted in diversity of parameters concerning properties of material like fragmentation level (10 and 6mm) and material moisture (10, 13 and 16%). On the process part parameters like densification pressure (50, 100, 150 and 200 MPa), and the die holes diameter (16 and 20mm) were analysed. The study was conducted on a testing machine equipped with a special agglomeration node. The resulting pellets were analysed to determine specific density and tensile strength. Particle size distribution, absolute density, envelope density and porosity of biomass were determined. As a result of the research, it was found that the moisture and pressure are major parameter of the agglomeration process for the quality of produced pellets.

Keywords: *agglomeration, poplar, fuel quality, specific density, tensile strenght*



AGING OF SOLAR PANELS

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Photovoltaics is one of the fastest growing technologies. One of the most important advantages of photovoltaics is simple design and ease montage. These features make the investment process of photovoltaic systems is easier and much shorter than in the case of many other renewable energy technologies. At present most of photovoltaics installations based on thin-film and polycrystalline silicon technique because production technologies of those panels are easier, and therefore cheaper, than in case of single crystal material. However, the material quality of thin-layer and multicrystalline material is lower than that of single crystalline material due to the presence of grain boundaries.

The rate of aging of the panels depends on the technology they have been made and on the operating conditions such as temperature, humidity, intensity and spectral distribution of solar radiation. The average lifetime of photovoltaic panels is about 25 years. At this time, the appearance of the panel changes and the radiation conversion efficiency decreases.

In a typical photovoltaic panel, the upper side of semiconductor is coated with a layer of ethylene vinyl acetate (copolymer EVA), anti-reflective glass which has high radiation transmittance coefficient. The bottom side of semiconductor layer is covered with copolymer EVA layer and Tedlar® layer. Each layer has different properties which are changing due to the influence of time and external factors. Modify absorption and transmission properties of the top panel layers result in a changing the spectral characteristics of the radiation reaching the semiconductor material.

In the paper has been discussed main effects of ageing monocrystalline and polycrystalline silicon solar panels based on parameters of an existing photovoltaic installation located in North-East Poland and parameters declared by the manufacturer of solar panels. In the elaboration discussed the effects of aging materials building photovoltaic panels on the processes of heat and radiation transfer. In article has been presented made in simulation programs models of heat and radiation transfer in the photovoltaic cell. The article concludes with regard to the properties and aging of materials building photovoltaic panels for solar radiation conversion efficiency.

Keywords: *aging, solar radiation conversion, silicon*



AGLOMERATION OF ORGANIC-MINERAL FERTILIZERS BASED ON WASTE PRODUCT FROM BIOMASS COMBUSTION AND BIOGAS PRODUCTION

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The production of fertilizers based on high quality waste materials is a highly important problem in environmental protection, mainly due to the protection of natural mineral resources. In addition, the combination of organic and mineral raw materials makes these fertilizers innovative in the fertilizer economy. Studies on the process of agglomeration of fertilizers based on ash from biomass combustion, digested and valorising additives were initiated from the laboratory tests of the agglomeration process performed in the EDZ 20 testing machine. Such production of the pellets enables to control the agglomeration pressure of the obtained granules, based on force acting on material and matrix hole diameter. Presented studies, due to the possibility of making a large number of sample granules with different parameters (diameter, agglomeration pressure, composition of raw material compositions), allows to determine their influence of the basic parameters on density and durability parameters. As the research material unique mixtures of mineral and organic substances mixture were used. The main components were ash from biomass combustion power plant in the Połaniec and the digestate from a biogas plant located in Piekoszów. Sulfur and phosphorite were used as components to enhance the fertilizer value of the tested prototype blends (variant A). There were also blends supplemented with urea (variant B) to add nitrogen to composition.

After laboratory semi-technical scale formation test, six most promising mixtures were than verified on MGL200 pelletizer. All measurements were made with repeatable process parameters and the moisture content of the raw material was approx. 18%. During the tests the energy consumption of the granulation process was determined and the quality of the obtained granules was determined by specifying envelope density, bulk density and mechanical durability.

Keywords: *Digestate, Biomass Ash, Fertilizers*

Research was funded by the National Centre for Research and Development and the National Fund for Environment Protection as a part of GEKON program - "Proecology production of organic and mineral fertilizers based on waste: by-products of combustion and biogasification of biomass".



AN INNOVATIVE AIR – WATER HEAT PUMP WITH ECOLOGICAL REFRIGERANT

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The heat pump market is growing year on year and more than 20,000 units were sold in 2015 alone. The majority were air to water heat pumps for heating or for only warming up domestic hot water utilizing inside air.

The project ordered by Kołton S.C. company, co-funded by Regional Operating Programme 2014-2020 of the Lesser Poland Region, was conducted in the AGH-UST Educational and Research Laboratory of Renewable Energy Sources and Energy Saving in Miękinia and had the following goals: defining the type of air-water heat pumps, determining the refrigerant, design, developed and testing the prototype.

According to EU F-gas regulations, the use of refrigerant with high GWP (Global Warming Potential) will be limited. It was one of the reasons to develop a heat pump using an environmentally friendly and natural refrigerant – R290. The type of construction the heat pump is monobloc, which simplifies the installation. It uses components dedicated for R290, such as a scroll compressor, evaporator and condenser 4-way valve, electronic expansion valve, etc.

The first tests of the device gave the following results: for an air temperature of 2°C and a water temperature of 35°C the heating power was 13,2 kW and COP was 3,69.

Further tests will be conducted to optimize the parameters of the heat pump and the controlling algorithm.

Keywords: *air-water heat pump, ecological refrigerant, COP*

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ANALYSIS OF MUNICIPAL WASTE MANAGEMENT IN CHOSEN URBAN MUNICIPALITY ON THE BASIS OF SELECTIVE COLLECTION

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The qualitative and quantitative analysis of waste from groups 15, 17 and 20 covering 11 types of waste collected in the years 2014 - 2015 in the city with a population of over 50 thousand showed a significant increase of their mass of 415.55 Mg, despite a slight increase in the number of inhabitants, as well as reducing the number of declarations for inclusion in the waste management system. Seasonal variation in the amount of waste collected, with particular regard to the spring season, occurred during the period considered. The highest (50%) share of the collected waste was classified in the group of 20, and the dominant group (33.6%) represented glass packaging waste. Likewise, the highest achieved daily collection rate of 0.039 kg · hab.-1 day-1 and yearly 13.9 kg·hab.-1·year-1 were related to glass packaging waste and showed a general increase. The low 6% share of large-scale waste was characterized by the broadest range of results achieved. The statistical analysis of the study results confirmed a high positive correlation showing the increase of waste most often with the participation of waste classified to group 17. The increase of the quantity of selectively collected waste in the area of the analyzed city confirms the gradual effectiveness of the implemented system solutions.

Keywords: *waste management, municipal waste, segregation, urban municipality*



ANALYSIS OF SHEAR PROCESS ALONG SHOOT FIBERS OF SELECTED SPECIES OF FAST-GROWING TREES

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The paper presents results of analysis of shear process along shoot fibers of two species of fast-growing plants, from which 180 samples were obtained. The aim of the analysis of the shear process is primarily to demonstrate the effect of diameter and shoot moisture on critical stress values. The study included an analysis of the influence of sample layouts (tangentially or radially), the effect of humidity and the impact of shoot diameter on critical stresses. The work involved acquisition of material, classification of shoots, material seasoning, sample preparation, moisture measurement, endurance tests and results analysis with conclusions. The material was poplar and acacia. The material was divided into three groups with diameters: 15, 25, 35 mm.

Samples were made in the shape of fries with a square cross section with sides 1 cm long. Studies have shown no effect of sample placement on critical stress values and that the smallest stress strain in the samples was 2 MPa for poplar shoots and 4.83 MPa for shoots of acacia.

Keywords: *shearing along the fibers, poplar, acacia, critical stresses*



ANALYSIS OF THE AGGLOMERATION OF CHALK MINERALS BY THE PRESSURELESS METHOD FOR THE PURPOSE OF FERTILIZATION

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The paper presents the analysis results of agglomeration process of the chalk minerals by the pressureless method. The aim of the analysis of the non-pressurized agglomeration process was first of all to find the relationship between the variable agglomeration parameters and the properties of the obtained granulate. The tests carried out as well as careful analysis of the properties of the obtained granules were aimed at indicating the process parameters allowing to obtain granules with the highest strength parameters, among other things, for compressing during the process with the highest granulation capacity with the smallest dispersion of granulometric distribution of granules.. Variable parameters of the process were rotational speed, inclination angle of working disc and amount of water activating the granulation process. For this study was evaluate the granulometric composition, bulk density, strength of individual granules in the static compression test, and the geometric distribution of the main fraction particles (3.15-8 mm) obtained during the photoptic analysis.

Keywords: *slow-release fertilizers, non-pressurized agglomeration, compressive strength, disc fertilizer granulator*



MUNICIPAL WASTE-TO-ENERGY PLANT IN POLAND

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In Poland, one of the largest investments in the Waste-to-Energy sector in Europe, has finished. Projects under the Infrastructure and Environment Program for 2007-2013, has brought Poland six new Waste-to-Energy plants that have been built in administrative areas of Krakow, Konin, Bydgoszcz, Szczecin, Bialystok and Poznan. Up to now, only one plant in Warsaw with a maximum capacity of 50,000 Mg/year has been operating in Poland. This value has increased to about 1 000 000 Mg/year. The presentation aims at initial investment plans, their current status as well as the technologies and parameters of individual plant. Polish WtE sector is described on a global as well as local scale.

Keywords: *energy recovery, incinerators, MSW, waste management.*



ANALYSIS OF THE POSSIBILITY OF THE USE OF OLIVE POMACES FOR ENERGY OBJECTIVES

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The purpose of the study was to determine the use of stored olive pomace as a solid biomass for energy purposes

Olive pomace kept for 3 years in the form of prisms at the Faculty of Production Engineering and Energetics of the University of Agriculture in Cracow. Samples were taken from three heights and then standardized for each of them.

Work has been done to compare energy properties such as calorific value, depending on the sampling depth of the material from the prism..

Then the research material was analyzed for the agglomeration process. Within this stage of the study, pellets of assumed diameter and with different agglomerate pressure values were made.. The next step was to measure their density and compare the mechanical strength using the Brazilian test.

Keywords: *olive pomaces, energy properties, biomass*



ANALYSIS OF THE POTENTIAL OF METHANE EMISSION AND ENERGY POWER FROM FAECES OF FARM ANIMALS IN POLAND

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The emission of methane is 12% of the total emission of greenhouse gases in Poland. The key industries emitting methane in Poland are transport, agriculture and waste management. The agriculture emits 31% of methane in Poland. In the animal production the key sources of gas emissions are the enteric fermentation and the decomposition of animal faeces. Depending on a type of the farm animal management system their faeces are manure and slurry (bedding system) or liquid manure (non bedding system). Those faeces may be agriculturally managed as natural fertilizers according to the Act on Fertilizers and Fertilization. This Act provides for periods in which faeces may be used to fertilize soils and the way they are stored until there are directly used. Natural fertilizers must constantly be stored on sealed plates, whereas liquid fertilizers need to be kept in sealed tanks. One of the solutions reducing the emission of methane into the environment is biogas systems that manage animal faeces in a safe and energy efficient way. Therefore, the objective of the study is to analyse the potential of farm animal faeces and of biogas energy power in Poland. For this purpose, the estimated quantity of electric power and thermal energy that may be produced by biogas plants were calculated with respect to the potential of animal faeces. The research was conducted on the basis of the data of the Agency for Restructuring and Modernisation of Agriculture. The calculations based on the number of farm animals (cattle, pigs and hens). The 2013-2016 data were used to show the volume and direction of methane emission changes and biogas energy power for Polish provinces.

Keywords: *animal faeces, methane emission, energy potential*

The study was conducted as part of the 2016-2020 Multiannual Programme under the Resolution of the Council of Ministers No 154/2016 dated 12 December 2016.



ANALYSIS OF THE PRESSURE AGGLOMERATION PROCESS OF COMMINUTED HERBS INTENDED FOR CONSUMPTION

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The total production of herbs in 2015 in Poland was estimated at 21,000 tonnes. The most often, such quantities of material are stored in the form of comminuted dried fodder. Due to its low dumping value, this material creates problems in terms of transport and storage (the need of large warehouse). This scientific research was focused on the trial of pressure agglomeration of two herbal plants intended for consumption, i.e. chives and parsley. The aim of the study was to present the interdependence between process variable parameters and compressive strength of compacted pelleted material. The variables parameters in the process were: pressure (25, 50, 75, 100 Mpa) and the sleeve diameter (25, 50, 75, 100 Mpa). The strength test was based on the Brazilian test, and then the analysis was made depended on results obtained with regard to the combination of diameters and pressures, as well as the physical properties of the input material (bulk density, humidity, fractional composition). During the study, expansion measurements were performed for each of the tested combinations. In addition, the photographs included in the thesis show the re-hydration trial of the condensed material.

Keywords: *herbs, compaction, pressure agglomeration, Brazilian test, relieve, re-hydration.*



DETERMINATION OF MYRISTIC ACID AMOUNT IN BIOFUELS USING NEAR INFRARED SPECTROSCOPY

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European Union guidelines for renewable energy sources indicate the need to increase the share of biofuels in the energy sector, while limiting the use of bio-components derived from feedstock. The solution to this problem is the use of waste materials (animal fats and waste cooking oil) in biofuel production processes. This is a secondary market product, which means that the amount of raw material for biofuel production is limited with various composition. It is necessary to verify steadily the quality of the raw material and product during its manufacturing process. Chemical composition and rheological properties strictly determine the quality of the biofuel produced. Currently, an analytical method is in place to detect and characterize impurities that, even in trace amounts, reduce the quality of the resulting biodiesel. Currently, common diagnostic methods are based on the use of high pressure liquid chromatography (HPLC) or gas chromatography (GC). These methods are sensitive and accurate, but unfortunately, they are both time consuming, expensive, require preliminary sample preparation, and generate significant amounts of chemical waste. An alternative to chromatographic methods is spectroscopic methods, which involve the interpretation of the near-infrared light spectrum, the waves absorbed by the molecules of the analyzed biofuel sample.

In this study, a quality control method is developed to evaluate myristic acid amount in waste fat methyl esters and is based on near infrared spectroscopy combined with multivariate analysis. More specifically, calibration models are constructed using partial least squares regression (PLS) for the prediction of myristic acid amount in II generation biofuel.

The results can be utilized in sensor calibration for biofuel quality and its conformity with EN14214 norm.

The study was conducted as part of the 2016-2020 Multiannual Programme under the Resolution of the Council of Ministers No 154/2016 dated 12 December 2016.



ANALYSIS OF WIND FARM - COMPRESSED AIR ENERGY STORAGE HYBRID POWER SYSTEM

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This paper presents a hybrid system which consists of wind turbines and compressed air energy storage (CAES) facility. The inclusion of CAES into an existing wind farm helps to control power output of the entire plant. Due to wind farm location the considered CAES system was assumed to be a small scale with above ground air vessels. Mathematical, dynamic simulation of CAES model was performed. Possibilities that result from technology characteristics and limitations are discussed. Conclusions on annual co-operation of CAES systems with wind turbines are presented.

Keywords: *electrical energy storage, CAES, hybrid system, mathematical modeling*



ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF THE MANUFACTURING PROCESS OF PHOTOVOLTAIC PANELS

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The main disadvantage of photovoltaics has been until recently that the ecology was more harmful than helpful - the construction of the cells required far more energy than they were able to deliver. Although in a local context it may have made sense and allowed to produce pure energy in a particular place, it was definitely negative in the global perspective.

The paper focuses on the environmental and human impacts of silicon and tellurium-cadmium production processes. The main hazardous substances used in cell production, as well as the byproducts of toxic manufacturing processes, have been characterized. The type of environmental and human toxicity and possible ways to reduce this impact has been demonstrated.

Keywords: *photovoltaic panels, environmental impact, manufacturing process*



CO-COMBUSTION OF BIOMASS AND TORREFIED BIOMASS WITH A TURKISH LIGNITE IN A 30 KWTH CIRCULATING FLUIDISED BED COMBUSTION SYSTEM

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This work covers the biocoal production from pine chips by screw type torrefaction system and co-firing with Turkish lignite in circulating fluidised bed combustion under air and oxygen-enriched atmosphere. The torrefaction system up to 5 kg/h is designed and manufactured based on the principle of rotating screws (auger) for passing biomass through the reactors. 100 kg of biocoal was produced under 300°C reactor temperatures and 30 min residence time conditions for combustion experiments. In the combustion experiments, 30 kWth fluidised bed combustion system was used. The laboratory scale CFBC system consists of one fuel feeder, a combustor, cyclone, down comer, bag filter, FD fan and ID fan. The combustor is a 3" AISI 310 stainless steel pipe of 108 mm inner diameter and 6 m height. Air is fed to the system by an air blower with a head pressure of 200 mbar. Fuel mixtures were fed by a screw feeder. Fuel feeding rate is controlled by a frequency controller. Air and oxygen flow rate is controlled by mass flow controller (MFC). All co-firing experiments with biomass and biocoal blends of lignite have been carried out with air and oxygen-enriched conditions.

In this study, the effect of oxygen-enriched conditions was investigated. Tests were carried out with one lignite, one biomass and one biocoal obtained from biomass and their blends. Biomass share is increased up to 30 %, biocoal share is increased up to 50%. It was found that the fuel mixtures up to 50 % of biocoal were combusted effectively in the system whereas burning difficulties were determined in burning experiments with 30% biomass mixture. The oxygen concentration in the oxidant was kept between 21 and 27% for the oxygen-enriched combustion experiments. It is concluded that, oxygen-enriched co-firing is an option for reducing SO₂ emissions and carbon capture and storage.

Keywords: biomass, coal, biocoal, combustion, torrefaction, oxygen-enriched, CO₂ capture



COMPARATIVE ANALYSIS OF SELECTED PELLETS

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The thesis contains analysis and its methodology, specifying the technical characteristics of forest biomass, based on laboratory tests and statistical analysis. An attempt was made to determine the value and quality of selected wood pellets.

The research took place without major technical problems, pointing to a repeatability of attempts. Values of the analyzed material were similar to those provided by the manufacturer.

Main aim of the study was to detailed analysis of the physical properties of selected wood pellets. Dendromas which came from different manufacturers had varied construction and composition. The analyzes were performed according to specific standards.

Studies cover issues such as specific and bulk density, heat combustion with calorific value, ash content, and volatile pellets. This research and analysis confirm that it is possible to determine which of the selected biomass products exhibits the best energy, ecological and economic conditions.

Keywords: *forest biomass, pellet, dendromass, waste stromal, calorific, wood waste*



DESIGN AND DEVELOPMENT OF A DIDACTIC AND RESEARCH STAND FOR EXPLOITATION TESTS UNDER DEFINED CONDITIONS

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To develop the laboratory of renewable energy sources in Miękinia, a new stand with a heat pump was created. The main aim of this stand is to increase the range of research in the Laboratory. This stand consists of:

- heat pump module,
- module to simulate parameters of heat source and heat sink
- module to display and register data and a remote control

This creates opportunities for research about the efficiency of heat pumps in reference to present standard PN EN 14511 and previous standard PN EN 255. The data allows us to define the impact of the methodology described in the standards on the coefficient of performance. This stand is able to calculate the coefficient of performance according to set parameters of work, like temperature of heat source, temperature of heat sink or difference between inlet temperature and outlet temperature on the heat sink side. There is also research about the effect of the superheating of refrigerant on the efficiency of heat pumps. All of the research with this stand is to examine the efficiency of heat pumps.

This stand was also made to do didactic work. It has the possibility to show the following, how the heat pump works, how the refrigerant circulates inside the heat pump, and what happened with the refrigerant in elements of a heat pump like compressor, evaporator, condenser, expansion valve. There is also the possibility to show the dependence between the coefficient of efficiency and the temperature of heat source or heat sink.

Keywords: *heat pumps, COP, didactic stand*

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DESIGN AND DEVELOPMENT OF A DIDACTIC MOBILE INSTALLATION WITH SOLID FUEL BOILERS AND A HEAT PUMP

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Low emission of dust and pollutants from coal-fired boilers is the main source of air pollution in the Malopolska Region. This is due to the low awareness of inhabitants, particularly in suburban and rural areas. Outdated heating systems and non-energy efficient houses need to use considerable amounts of energy. The authorities of the region undertake activities aimed at educating and raising the awareness of the inhabitants.

The AGH-University of Science and Technology is a natural partner in these activities, especially in the field of education and popularization of energy efficient solutions.

One of them is a mobile educational installation designed by AGH in cooperation with the boiler and heat pump producer Galmet. The construction of the installation was supported by a grant from the National Fund for Environmental Protection and Water Management. The leader of the project is the Foundation for the Support of Ecological Initiatives.

The main aim of the designed installation is for didactic/educational purposes in the field of air quality and pollution reduction connected with the utilization of coal fired boilers with various efficiency classes, according the PN-EN 303-5:2012 standard. The whole installation is in a 4-wheel trailer adapted to conduct the measurements and present the results.

The installation consists of two solid fuel boilers (a boiler with automatic fuel feeder and a boiler with manual fuel loading), heat pump, heat buffer, radiator and connection fittings (valves, pipes, circulation pumps, etc.). This allows you the comparison of working conditions and pollutant emissions from each boiler. The system measures the level of pollution, exhaust gas analyzers and the results visualization system allows mobile research.

This paper presents the methods of our research and focuses on the issue of low emissions and their impact on our environment and the inhabitants of Malopolska.

Keywords: coal-fired boilers, mobile didactic rig, low emission, heat pumps

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DOES WETLAND BIOMASS PROVIDE AN ALTERNATIVE TO MAIZE IN BIOGAS GENERATION?

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Poland in recent years has experienced a “biogas-boom” with dynamically increasing number of plants of different size. The substantial amount of the agricultural biogas plants is now facing economical problems due to rising operational costs, which force them to quest for the cheaper alternative to silage maize. The aim of the study was to examine the biogas and methane yield of two wetland species: common reed and reed canary grass, and compare it to the biogas productivity of commonly used mixture of maize, poultry manure, and swine manure.

The biomethane potential assay of separate substrates (common reed, reed canary grass, maize, poultry manure, and swine manure) and mixtures (co-digestion of maize silage with poultry manure and swine manure with increasing share of the latter from 10 to 30%) was performed in OxiTop Control System OC 110® and in eudiometers. In OxiTop® experiment biogas production was continuously measured on the basis of a pressure changes in the reactor by the OxiTop® measuring head. In eudiometers the biogas composition was measured once a day.

In batch assay the methane yield of poultry manure was the highest and reached about 530 Nl CH₄ kg⁻¹ VS. The methane yield of maize silage was lower and equaled to 435 Nl CH₄ kg⁻¹ VS. Much lower values were received from reed canary grass and swine manure (204 and 171 Nl CH₄ kg⁻¹ VS, respectively) and the lowest from common reed (148 Nl CH₄ kg⁻¹ VS). In co-digestion experiment the highest methane production was obtained from digestion of 90% of maize with 5% of poultry manure and 5% of swine manure. The increasing of manures proportion to 30% in mixtures resulted in the decline of methane yields.

Due to significantly smaller biogas and specific methane yields grasses from landscaping are unlikely to wholly replace maize silage. However they can be considered as interesting co-substrate, with methane productivity that is comparable to swine manure. Collecting grasses is relatively cheap, as it does not require fertilization and crop protection expenditure, while mowing of biomass can contribute to protection of biodiversity of wetlands and abandoned meadows.

Keywords: *biogas, biomethane potential test, wetland biomass, reed canary grass, common reed, maize silage*



EFFECT OF STORAGE AT PHYSICAL-MECHANICAL AND ENERGY PROPERTIES OF MISCANTHUS GIANT

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The purpose of the study was to analyze the effect of storage of Miscanthus Giant on its physico-mechanical and energy properties.

The research material came from an experimental plantation of the Faculty of Production Engineering and Energetics of the University of Agriculture in Cracow. It was compared to plant material stored under cover where it was protected from atmospheric agents such as rain, snow and wind.

The studies compared energy properties such as energy content, moisture content and ash content. The second part of the research was used to determine selected physico-mechanical properties. Biometric measurements were made and selected mechanical tests were performed.

Keywords: *miscanthus giant, mechanical strength, energy properties, biomass*



EFFECT OF STORING ON FUEL AND FERTILIZING PROPERTIES OF SEWAGE SLUDGE

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The disposal of sewage sludge may be combined with its economic utilization. It depends on the physical, chemical and microbiological characteristics of the substance and the manner of sludge treatment. Organic, but also inhibiting substances (pathogenic microorganisms, heavy metals, etc.) included in the sludge may determine the manner of its management or disposal, eg through agricultural utilization or combustion.

In case of agricultural utilization, this manner of sludge management is also influenced by the specificity of agricultural cultivation and periods of the reclamation of agricultural lands. Thus, the problem of periodic storage and the possibility of its effects on changes of sewage sludge properties occurs.

The article presents results of research concerning changes of basic fertilizing and fuel properties of sludge during its year-long storage in field conditions and proposed the possibility of development after such storage period.

Keywords: *sewage sludge, fuel properties, fertilizing properties, combustion, agricultural utilization, storage*



EFFECT OF WOOD BIOMASS ON COMBUSTION PROCESS

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The use of renewable energy sources is becoming increasingly necessary, if we are to achieve the changes required to address the impacts of global warming. Biomass is the most common form of renewable energy, widely used in the third world but until recently, less so in the Western world. Biomass not only has a considerable practical potential but it also shows a reasonable cost level in comparison to other renewable energies. The practicable fuel types are both residual material from forestry and agriculture, such as wood, or straw, and especially cultivated reproducible feedstock such as poplars, or willows.

Intense European Union policy on the development of renewable energy sources, is a response to the increasing pollution of our planet and is associated with the introduction of additional independent sources of energy supply security. With the introduction of the relevant legal obligations regulating these standards, countries that do not have the appropriate percentage in obtaining energy from conventional sources need to implement appropriate projects to ensure that in a fairly short period of time the supply of energy from renewable sources.

The paper presents the ecological and economic aspects of selected materials, showing differences in the used fuel from forest biomass. Experimental results are presented on the emissions from biomass combustion. The research was able to show that dendromass has the best energy properties, as well as that of the selected forest biomass produces the least pollution.

Keywords: *biomass, dendromass, combustion, calorific*



EFFECTIVENESS OF THE HYDROGEN PRODUCTION, STORAGE AND UTILIZATION CHAIN

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The paper evaluates the effectiveness of a power-to-gas hydrogen chain, comprising the production, storage and utilization sections. The production section is based on PEM electrolyzers producing about 16 kg hydrogen per MWh supplied electric energy derived from renewable (wind) sources. Next, hydrogen is transported to an underground storage facility (UGF), assuming that the pressure of the produced hydrogen is sufficient to provide its transportation to the storage site. Energy demand required for hydrogen compression to the UGF is accounted for, and the maximum level of hydrogen losses is evaluated. Finally, two options for hydrogen utilization are considered: 1) hydrogen is co-fired in a gas turbine, 2) hydrogen is used for process purposes replacing the existing production based on steam methane reforming. Moreover, energy effects related to the replaced oxygen production are optionally taken into account. It has been shown that the choice of a scenario (co-firing/process application) and the possibility (or not) of using the generated oxygen strongly affects the overall process performance which may vary between extremely low values of 10% (or even negative) to more than 60% for full process application of the generated hydrogen and oxygen. In conclusion, the process may provide promising energy performance indicators if the whole system is designed properly.

Keywords: *hydrogen, power to gas, electrolyzers, energy storage*



ENERGY CHARACTERISTICS OF COMPACT BIOFUEL WITH STABILIZED FRACTION OF MUNICIPAL WASTE

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The paper presents an analysis of the energetic properties of compact biomass formed from the biomass of *Miscanthus giganteus* and the stabilized fraction of municipal sewage sludge, depending on the percentage of stabilization.

The study included the evaluation of the energy properties of five blends with a content of 5-25% stabilization for three moisture states of 12, 15 and 18%. PN-EN 14918 - 2010 and PN-ISO 540 2001 standards were used to assess energy performance. The biofuel was subjected to a combustion process to determine the pilot kinetic analysis of this process.

Based on the research, it has been found that the addition of a stabilized urban waste sludge fraction lowers the fuel properties of the projected biofuel. Studies have shown that the maximum limit for stabilization is between 10% and 15%. This range was determined on the basis of ash content in dry matter, its values for 10% of the mixture was 9.75% and for a 15% stabilization share of 11.37%. The moisture content of the test mix should not exceed 15%.

Keywords: *biofuel, stabilized fraction, municipal waste*



ENERGY, ECONOMIC AND LEGAL CONDITIONS OF ENERGY RECOVERY FROM MUNICIPAL WASTE WITHIN COGENERATION SYSTEMS

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This article presents a look at municipal waste as an element of modern and diversified Polish energy policy. The significant impact of waste incinerators on Polish municipal waste management and the energy grid is discussed, in particular on urban heat networks. In addition, basic legal considerations, both national and European, have been presented. They have a decisive influence on the contemporary development of Polish energy recovery infrastructure from waste. Examples of European countries have been cited, where waste incineration plants have been an indispensable and well-known element of energy and communal infrastructure. The place of Waste-to-Energy plants in waste management after materials recycling was highlighted.

Keywords: *energy grid, MSW, WtE, renewable energy*



EVALUATION OF SELECTED SPECIES OF WOODY PLANTS IN TERMS OF SUITABILITY FOR ENERGY PRODUCTION

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In Poland biomass is one of the most promising renewable energy sources its share in RES structure was over 98%. It is a raw material for the production of solid, gaseous and liquid energy carriers. The possibilities of using biomass determines its availability and relatively low processing costs for energy. This thesis evaluates results of selected parameters of five woody plants. On the basis of the results was carried out to evaluate these species' energy value. The research material was a energetic willow, poplar, alder, black locust and acer negundo. The research measured following variables: moisture content after collection and after drying, the ash content, the share of bark vs wood, calorific value and specific density. The research methods used in the majority, are consistent with the guidelines of the testing standards of quality parameters of solid biofuels.

Keywords: *biomass, energy crops, solid biofuels*



EVALUATION OF THE POSSIBILITY OF USE GEOTHERMAL ENERGY MICROPILES TITAN 73/53 TO OBTAIN LOW-TEMPERATURE HEAT ENERGY ACCUMULATED IN THE NEAR-SURFACE LAYERS OF THE GROUND IN POLAND AREA

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Rapidly increase in the usage of low-temperature energy sources such as atmospheric air, ground, groundwater or wastewater, which are freely available in the environment, lead to seek new methods and installations to obtain them. Low temperature heat energy accumulated near the surface of the Earth can be acquired by application geothermal heat pump. The aim of the study is to estimate the possibility of use geothermal micropiles TITAN 73/53 to obtain low-enthalpy heat energy from near-surface layers of the ground in Poland area. Assessment will be conducted based on Map of Geological-Engineering of Poland on a scale of 1: 500 000, enriched with information gained from literature data and from TITAN Polska Company. Geothermal energy micropiles are an innovative technology which was designed to exploit in more efficient manner heat, which potentially occurs in the ground. This micropile besides stabilizing the building is also used to collect heat energy accumulated in a medium. Geothermal micropile TITAN 73/53 is a foundation pile, within of which is placed heat exchanger. Modern assembly technology of micropile allows to be made in any conditions during one technological process. Threaded over the entire length of both the steel pipe drill string, the injection pipe and reinforcement rod. Injection carried out simultaneously with the drilling caused creation of grout cover around hole, which perfectly combines with the ground and provides a higher carrying capacity than the conventional method. In the last stage, after final injection, the inside of the reinforcement rod is leached out and the outflow line is placed in hole in the form of a 32mm diameter tube. Based on Map of Geological-Engineering of Poland on a scale of 1: 500 000 and literature data was found that in the most parts of the country occur powdery and cohesive soils, which depending of the degree of moisture, the structure of the soil and the local thermal parameters can be a cost-effective source of heat for low-temperature geothermal installations. Also, powdered by TRT data from 16 geothermal micropiles TITAN 73/53 (lengths 20,40 and 80 m) gained from TITAN Company can be concluded that use of these micropiles is a very promising technology for more efficient, even 50% more than conventional, acquisition of relatively large amounts of heat energy accumulated in shallow layers of soil in Poland area.

Keywords: *low-temperature geothermal energy, heat pump, geothermal energy piles, vertical exchanger*

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EXAMINATION OF THE SOLAR AIR HEATER OPERATING PARAMETERS EQUIPPED WITH THE SWIRLERS

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The aim of the solar air heater collector investigations was to conduct its operating parameters. The article shows the solution of its installation and presents the results of the analysis in real conditions. This type of device is equipped with the swirlers to increase the heat exchange and finally to gain more energy from the sun. This type of support elements are more and more popular in such devices. The air flow through the exchanger is forced by high flow ventilators. The test stand consists of inlet and outlet temperature data recorder and anemometer to control the air flow through the collector. The meteorological data such solar radiation, wind parameters, atmospheric pressure and the ambient temperature is obtain from Davies Vantage Pro2 weather station. The weather station was placed near the test stand. The analysis of the installation work was performed on the basis of monitoring of operating parameters conducted in time interval from April to September 2016.

The results of energy analysis show the validity of such installation.

It also helps to promote the other forms of energy generation and to reduce greenhouse gas emissions.

Keywords: *solar air heater, swirlers, renewable energy sources, operating parameters*

The study has been implemented from the resources of the S/WBiIŚ/4/14 statutory work financed by the Ministry of Science and Higher Education in Poland.



EXPERIMENTAL RESEARCH AND THERMOGRAPHIC ANALYSIS OF HEAT TRANSFER PROCESSES IN A HEAT PIPE HEAT EXCHANGER UTILIZING AS A WORKING FLUID R134A

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This article presents the experimental results of a heat pipe heat exchanger for the lower temperature range of $15 \div 50$ °C. It is worth noting that the heat pipes, thanks to the wide temperature range and high efficiency, can soon be used in building engineering. Recognizing the processes taking place in their interior and their work is essential especially in the era of striving to reduce heat loss and avoid unnecessary energy dissipation. The goal of this work was to carry out research and analysis of heat pipes and proces condition by the need to save primary energy in both civil engineering and industry.

The results show the effects of phase changes for the R134a refrigerant as well as the effect of its amount on the heat and power of the heat pipe. One of the main objectives of the study is to analyze the efficiency of heat pipes for different amounts of working fluid at different temperatures in both the evaporator section (heat delivery) and the condenser section (heat transfer).

The paper presents the results of research on real heat exchanger made from copper 1769 mm tube, 18mm diameter and 1mm wall thickness. The study involved placing a heat pipe in a tube heat exchanger in a tube to deliver and receive heat to and from a heat pipe. The cold water temperature at the inlet of the heat exchanger in the condenser section was 10 °C, while the hot water at the inlet of the heat exchanger in the evaporator section was in the range of $15 \div 50$ °C and was changed in increments of 5 °C for each subsequent measurement.

During the heat pipe test, the temperature of the inlet and outlet of the hot and cold water from the heat exchangers heating and cooling the heat pipe was measured. The pressure inside the tube and the wall temperature of the heat pipe at the measuring points in the midpoint of the condenser heater and the evaporator of the heat pipe were also measured. Previous studies on the heat pipe with the air and the inside showed that there was a slight heat flux transmitted through the walls of the heat pipe along its axis. When filling the tube with 50 g of R-134A fluid (that is, about 10% of capacity), a significant increase in the heat flux received and transmitted by the heat pipe occurs. In addition, the work presents the results of the performed thermographic analysis for the test agent.

Keywords: Heat Pipe, heat exchanger, R134A, thermographic



EXPERIMENTAL RESEARCH USING BATCH REACTOR AND THERMOGRAVIMETRIC ANALYSIS ON ENERGY CROPS TORREFACTION PROCESS TO OBTAIN OPTIMAL TORREFACTION TEMPERATURE, RESIDENCE TIME, CALORIC VALUE AND ENERGY DENSIFICATION

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Poland is on fifth place in European Union with the biggest biomass resources (68 thousands m³) which can potentially be use for energy production. Biomass in Poland is coming mainly from forests and wood waste but the biggest undeveloped potential is in energy crops. Lignocellulose biomass like energy crops have high caloric value and should be better use in local CHP plants in distributed energy systems. Biomass of agricultural origin has the biggest potential from all kind of renewable energy sources in Poland because it provide continuous electricity generation, and is the only widespread source of renewable heat.

Torrefaction or simply roasting of biomass is a thermal degradation of biomass structures by heating it a inert gas atmosphere like nitrogen under atmospheric pressure. This process removes low weight organic volatile components and moisture as well as depolymerise the long polysaccharide chains of biomass. To build up a demonstration plant for torrefaction process of energy crops a specific temperature of carbonization process should be know for specific type of fuel and residence time to obtain in fuel best C/H ratio which is responsible for High Heating Value, carbonization level and best physico-chemical properties as a new fuel for energy production.

In this paper a installation with batch reactor and thermogravimetric analysis were use to carry experimental tests on five different energy crops: willow, cane, millet, Pennsylvanian mallow, Jerusalem artichokes. This five types of energy crops were growing on low-grade soils, which are abundant in Poland and where torrefied to obtain the most optimal temperature under which carbonization process decrease 30 % of mass and 10 % of energy content (best increase of caloric value during torrefaction process).

A detail experimental analyzes using batch reactor was done and detail TG, TG-DSC, TG-MS analyzes of energy crops torrefaction process was investigate to obtain optimal torrefaction process temperature, residence time and fuel characteristic (by providing elemental and technical fuel analyze). The most promising torrefied energy crops with highest caloric value and fuel characteristic were selected as biocoal for next steps of experimental research and numerical simulations on co-combustion process of carbonize biomass with coal in commercial pulverized boiler of local CHP plant.

Keywords: torrefaction, batch reactor, willow, cane, millet, Jerusalem artichokes



EXPERIMENTAL STUDY OF SOIL TEMPERATURE VARIATION DURING OPERATION OF A HEAT PUMP WITH A VERTICAL GROUND EXCHANGER

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The paper presents experimental results of soil temperature distribution changes in a selected well 100 m in depth during a brine-water type heat pump operation (heating power of 234.4 kW and a cooling power of 191.8 kW) installed in the Bialystok Technical University.

Presented research results were made in the years 2015-2017 during the two-year exploitation of the WBiŚ building, where the heat generated by the heat pump was used for heating purposes of the building.

The purpose of the study was to determine the soil temperature distribution in openings with vertical ground heat probes to a depth of 100 m and to determine how the soil temperature changes at various depths during the heat pump operation and to compare the results obtained with the undisturbed soil temperature profile.

The monitoring results of the ground probes 100 m in depth operation can be a quality satisfaction of the lower source design and construction and its regeneration capacity after the heating season. It can also be used to verify the numerical temperature fields around the vertical ground probes and at the design stage of the ground heat exchangers.

Due to the high cost of boreholes and their metering, these tests are unique. Practically, measurements of the temperature distribution in vertical soil probes 100m in depth are not carried out while the heat pump is running, in buildings in continuous operation. Computer simulations or smaller test sites are more often performed.

The paper presents the base profile of the soil temperature distribution and the temperature distribution profiles in the wellbore with the working heat pump in the years of its operation.

With the development of energy-efficient buildings and the increasingly frequent use of heat pumps used for heating purposes, awareness of the importance of the proper operation of the lower heat source as well as the economical operation of the heat pumps increases.

Keywords: borehole, vertical ground probe, temperature distribution, ground, heat pump

The mean COPHP efficiency coefficient for the heat pump in the heating season is calculated from 2015 to 2017.



GEOLOGICAL, HYDROGEOLOGICAL AND TECHNOLOGICAL CONDITIONS OF APPLICATION OF PRODUCTION-INJECTION SYSTEMS FOR LOWER JURASSIC RESERVOIR HORIZONS IN THE POLISH LOWLANDS. SELECTED ASPECTS OF SUSTAINABLE DEVELOPMENT OF MICROREGIONS

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The paper discusses problems related to assessment of the possibility of development of the identified geothermal resources. Conditions connected with developments in geothermal water utilization were specified for the Lower Jurassic complex (formation) in the Polish Lowlands. Utilization of identified thermal water resources is conditioned by costs of completion of a geothermal installation and by an amount of recovered heat and efficiency of its development. The specificity of the variations in the geological setting of the given study area required reasoned analysis of structural, lithological, petrophysical, hydrogeological and hydrochemical conditions in order to appropriately select a geothermal system both in its underground and aboveground parts. Parametrisation of geological and hydrogeological conditions in the Lower Jurassic reservoir was carried out in terms of selection of geothermal installations. A geothermal installation based on a two-well geothermal system (so-called geothermal doublet) was presented, in which the first well operates as a production well while the other as an injection well. As a competitive solution that significantly reduces installation costs, concepts of a single-well geothermal installation with production-injection technological systems or with application of downhole heat exchangers were presented. Main criteria of application of double-well and single-well geothermal systems for geothermal water exploitation or geothermal heat recovery directly in a well were determined. Technological schemes of the aboveground and underground parts were presented with regard to doublet systems and single-well systems. The specific character of the technology of thermal water exploitation from the Lower Jurassic complex was taken into account. The specificity of the geothermal water injection was characterized, together with factors that reduce the water injection flow rate. On the basis of the carried out geological, hydrogeological and technological analyses, the specification of technical parameters of geothermal installations in selected locations were prepared. The parametrisation of geothermal installations allows determination of the level of heat production in the given state of the art, which determines utilization of the identified geothermal resources. Selected aspects of sustainable development of microregions in sites of the geothermal installation location were presented.

Keywords: *geothermal installation, geothermal water exploitation, geothermal reservoir characterization of Lower Jurassic complex*



GEOPHYSICAL METHODS IN THE RECOGNITION OF GEOTHERMAL RESOURCES – SELECTED PROBLEMS

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Geophysical methods are widely applied in geothermal issues. Seismic and magnetotelluric methods are most frequently used under Polish conditions predominant by low temperature geothermal associated with sedimentary complexes and crystalline rocks. In the work application of those methods to recognizing of geological medium structure and differentiations of petrophysical parameters is presented. The examples of hydrogeothermal investigation in sedimentary complexes of Polish Lowlands and crystalline rocks of Sudetes area are used. The results demonstrate that seismic structural interpretation and seismic inversion can effectively support the selection of areas optimal for future geothermal investments. Seismic inversion can be applied to porosity estimations. Within the crystalline rocks non – seismic methods are usually used, mainly different variants of magnetotelluric method.

A separate question important for recognition of geothermal resources is evaluation of geothermal field parameters based on results of surface geophysical survey. The example from Polish eastern Carpathians is discussed in this paper. Recognizing of the distribution of thermal field parameters inside geological medium is based on limited population of irregularly distributed boreholes. Local differentiation of thermal field parameters such as temperature, geothermal gradient and thermal flow density is depended on alteration of geological medium thermal parameters, for example thermal capacity of rocks or thermal conductivity factor. Geometrical interpolation of borehole data could thus generate uncontrolled errors in thermal field parameters estimation, especially important for geothermal borehole location. Mentioned above facts are the cause of undertaking of research into the possibility of application of geophysical data to estimate temperature distribution in geological medium and assess the variability of its thermal properties that modifies heat flow density and geothermal gradient.

Keywords: *geothermics, geophysical methods, geothermal parameters, seismics, magnetotellurics*

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GEOTHERMAL ENERGY - LOCAL SOURCE OF RENEWABLE ENERGY

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Geothermal energy is an energy generated and stored in the Earth. An article shows benefits of geothermal water and energy utilization for different purpose. The main advantage of using geothermal energy is reduction of existing pollution and help in creating clean environment. This is particularly important in connection with the growing pollution problems affecting many communities in Poland. This kind of energy is available 24 hours a day, 365 days a year. Geothermal water and energy could be used in many ways. Currently the key sector is heating, however using geothermal water for recreation or balneotherapy can results in very good social benefits. It is local source of energy which can be effectively development in many region where significant geothermal potential occurs. An article includes an overview of resources and utilization of geothermal water and energy in Poland.

Keywords: *geothermal energy, geothermal resources, benefits, Poland*



INCREASE THE ENERGY EFFICIENCY OF HYBRID RES INSTALLATIONS USING KNX SYSTEM

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Buildings are some of the largest consumers of electricity and heat. Therefore, it is imperative for research to be carried out, and action taken, to improve their energy efficiency. Renewable energy sources allow for a significant reduction of energy consumption from primary sources and result in reduced energetic dissipation. In order to maximise the utilisation of these alternative sources of energy, hybrid systems, or HSWs, have been introduced, combining several differing technological approaches to the generation of electrical energy both for lighting and heating purposes.

They are in effect combinations of complementary electricity and heat generating units, including differentiated primary (this including both renewable and non-renewable) energy sources, and/or containing energy storage systems. Their effective complementary function is made feasible via the usage of advanced energetic electronics in the coordination of these systems. Energy systems for buildings should be controlled automatically in such a manner as to facilitate full and comprehensive control of energy sources.

The control and regulation of efficiency ought to proceed on the basis of current and predicted weather data and the current energetic demands of the building in question. The task of the acquisition and analysis of data can be successfully performed by devices already operating within the KNX system. The greatest advantage of using these devices is the ability to acquire real-time data from sensors throughout the system in order to perform the functions necessary for the more efficient use of generated energy. KNX technology allows for the collection and analysis of information concerning the energy produced as well as its efficiency, profits and total savings. A suitable combination with elements of a building's automation enables for the management of required electricity, consequently increasing the energetic efficiency of the building.

Keywords: *energy efficiency, KNX system, hybrid RES*



INCREASING THE EFFICIENCY OF THE PROCESS OF BURNING WHEAT STRAW IN A CENTRAL HEAT SOURCE BY APPLICATION OF ADDITIVES

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Straw belongs to heavier combustible fuels as it has low ash melting temperature. This article discusses the properties and effects of various additives suitable for application to straw in order to increase the ash melting temperature. From the laboratory-determined results of the application of various additives, the most suitable additive was chosen to improve the process of incinerating wheat straw in real conditions. This additive was calcium oxide. Testing of the additive was carried out in real conditions on operation of drying system situated near Nové Zámky. The drying system receives the heat from burning straw bales on the heat source. In the combustion process there are various problems due to the low melting temperature of ash straw. For this reason, slags and deposits occur in different parts of the combustion chamber and on the heat exchanger. These deposits must be removed at regular intervals, which causes heat source shutdown and drying. Addition of the additive on the surface of the straw bait was performed manually. The influence of additives on slags formation, thermal performance and emission production were measured during the experiment. The results of additive testing have confirmed the positive effect of calcium oxide on the efficiency of the straw burning process.

Keywords: *straw, low ash melting temperature, additives, combustion*



INCREASING THE POTENTIAL OF BIOMASS PRODUCTION OF SPIRODELA POLYRRHIZA USING THE APOL-HUMUS STIMULATOR

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The increase in energy demand has stimulated research on new, economical and environmentally-friendly technologies of its acquisition. At present, one of the most important and widely developed methods to produce renewable energy is the use of plant biomass, including water plants (Lemnaceae). Therefore, the research work on the production of biofuels of II and III generation from water biomass has become very dynamic as it offers the possibility of gaining independence from fossil fuels and of reducing CO₂ emissions. In addition, Lemnaceae plants in the natural environment play an important ecological role, including phytoremediation of water, degradation of harmful substances, bioindication, and they can be a natural additive to animal feed. Spirodela polyrrhiza aquatic plants were cultured in vitro on a standard "Z" medium (Zehender in Staub 1961) supplemented with different variants of the Apol-humus stimulator (Poli-Farm Sp. Z o.o., Poland). Analyses of plant growth parameters, chlorophyll index, net photosynthesis, transpiration, stomatal conductivity, intracellular CO₂ concentration, fresh and dry mass were used to evaluate growth and physiological activity of Spirodela polyrrhiza, moreover, calorific value was also assessed. The results of the study showed high sensitivity of Spirodela polyrrhiza to Apol-humus stimulator, the tested plants were characterized by a stronger growth, higher chlorophyll index and increased gas exchange intensity compared to the control series. Stimulating impact on the Spirodela polyrrhiza growth could be caused by fulvic and humic acids and chitosan polymers in Apol-humus. However, in order to confirm the data, further research is required in the increased field scale (lagoon).

Keywords: biomass production, Lemnaceae, Apol-humus

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INFLUENCE OF INTERNAL DEPOSITS ON DIESEL ENGINE INJECTORS ON THE PARAMETERS OF THE HIGH PRESSURE COMMON RAIL SYSTEM (HPCR)

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The operating conditions of compression-ignition engines and the design of modern high pressure common rail fuel injection (HPCR) systems, high temperature, high pressure, small diameter of fuel injector openings impose the use of fuels with high thermal and oxidation resistance, reduced content of solid impurities, , Microbiological contamination resistance and, above all, efficient detergent-dispersant additives preventing the formation of IDJD (Internal Diesel Injector Deposits) and coking of injector tips. The introduction of 5% FAME into the biodiesel fuel oil causes the presence of sediment to intensify.

The significant impact on the process is:

- physicochemical properties of fuel;
- component composition;
- thermo-oxidative resistance.

The complexity of sediment formation on the components of the compression ignition engine in this high-pressure Common Rail injection system is becoming increasingly global. Knowledge of sedimentation mechanisms and their chemical composition is still insufficient, and therefore these processes require further investigation.

In order to ensure the cleanliness and efficiency of HPCR systems, diesel should meet not only the requirements of EN 590: 2013-12 but also the guidelines of injection molders presented in the 2012 Common Fuel Directive for Fuel Requirements for Diesel Injection System - Diesel Fuel Injection Equipment Manufacturers - Common Position Statement 2012 and World Fuel Charter for Diesel Category 4 - fifth edition of September 2013.

Keywords: HPCR, Common Rail, Biodiesel



INFLUENCE OF PARAMETERS OF THE TORREFACTION PROCESS ON THE SELECTED PARAMETERS OF TORREFIED WOODY BIOMASS

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One of the technology that allows to obtain solid biofuels with high quality is torrefaction, which is a process of converting biomass into solid fuel with properties similar to coal. It relies on thermal treatment of biomass in the temperature range 150 - 300°C under atmospheric pressure, in anaerobic condition. The results obtain is a completely dry fuel, with a higher calorific value relative to the raw material. In addition, the hydrophobicity of the resulting products of biomass torrefaction completely protects it against biological degradation. The products of biomass torrefaction is more brittle compared to untreated biomass which is transferred into a reduction of energy inputs for shredding.

Increasing of the energy density of biomass is mainly caused by the decomposition of the most reactive component which is hemicellulose, which amount is dependent on the species of biomass. Thus, the type of biomass varied in composition and parameters of the process (temperature, reactor residence time) have a crucial impact on the quantity and characteristics of the resulting products of biomass torrefaction.

The aim of this study was to determine the effect of time and temperature of torrefaction on selected parameters of torrefied woody biomass. The research material was willow and black locust biomass. First species representing the tree of soft wood and second is representative of hardwood trees. The selected species belong to a group of trees cultivated on energy purposes in so-called short rotation.

The biomass samples were dried to a humidity of 10% and then was specified the calorific value, heat of combustion, specific density, ash content and volatiles matter. Characterized samples were subjected to torrefaction process in a special research reactor. In the study was planned the torrefaction temperature range 200 - 300 °C and the duration of the process in the range of 1 - 3 h which resulted in products of biomass torrefaction about the different degree of the carbonization, which were characterized by the same parameters as before biomass torrefaction.

Keywords: *biomass, energy crops, torrefaction, willow, black locust*



INFLUENCE OF THE MATERIAL PROPERTIES AND PROCES PARAMETERS ON THE AGGLOMERATION OF REFUSE DERIVED FUEL (RDF)

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The current model of waste management in Poland assumes that the wastes are pre-sorted at or near place of their production. Such situation requires introduction of solutions for recovery from the waste stream with energetic potential (raw type RDF), which we can obtain from municipal wastes. One of the main recipients of this material is cement industry, however it is capable to use only $\frac{1}{3}$ of the total production potential of the RDF in Poland. Therefore, it is important that the resulting fuel will be seen as attractive in other sectors of the energy economy. RDF fuel is a very cumbersome material to use, due to the fact that most of it consists of flexible material like nylon, paper, and other plastic materials with very low bulk density. For this reason, it is quite hard to obtain good quality material with use of ball mill (used in power plants). Taking into account the variety of morphological, granulometric and physical properties of RDF, a very good way to improve the physical properties of the raw material is its agglomeration to form of pellets.

The paper presents studies focused on agglomeration of refuse derived fuel (RDF) Taking into account heterogeneity of wastes, the agglomeration seems to be good way to improve the physical properties of RDF. Studies were conducted in diversity of parameters concerning properties of material like fragmentation level (20, 15 and 10mm) and material dampness (10, 14 and 18%). On the process part parameters like densification pressure (50, 100, 150 and 200 MPa), temperature (80, 100 and 120°C) and the die holes diameter (16, 18, 20mm) were analysed. The study was conducted on a testing machine equipped with a agglomeration node. The resulting pellets were analysed to determine specific density and relaxation coefficient. As a result of the research, it was found that the temperature is major parameter of the agglomeration process for the quality of produced pellets.

Keywords: *RDF, agglomeration, fuel quality, specific density, relaxation coefficient*



INVESTIGATION ON MECHANICAL DURABILITY OF SOME VALONIA OAK AND CALABRIAN PINE PELLETS

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Valonia oak and calabrian pine residues, forest industry wastes and the wastes of tanning material production process from valonia oak have significant amount in our country. These materials can be utilized as a solid fuel and heat energy by pelletizing.

In this study, valonia oak industrial wastes' and calabrian pine residues' physical, pelletizing characteristics and their pellets' mechanical characteristics were determined. The pellets were classified as to surface cracks in 4 category and tested in laboratory conditions. Pellets' moisture content, average sizes, mechanical durability were calculated and the results were compared with EnPlus, PFI pellet certificate standards.

According to results of the analyzes, average of diameter(mm), length(mm), weight(g) were calculated as 9,90, 33,43, 3,16 respectively for 1:1 oak - pine mixture ratio and 9,89, 36,50, 3,33 for 3:2 oak - pine mixture ratio. The pellets' moisture content as a wet basis was founded %11,45(1:1 mixture ratio) and %12,83 (3:2 mixture ratio). The moisture content results have shown that all of the pellet types couldn't meet the requirements of 10% maximum standart rate.

The mechanical durability values was calculated as 97,23 % and 97,14 % as to oak-pine mixture ratio 1:1 and 3:2 respectively. Test results have shown that all pellet types couldn't meet the 97,5% mechanical durability limit of EnPlus Standards but they meet the minimum PFI (Pellet Fuel Institute) standard mechanical durability limit of %95. 1:1 mixture pellets' mechanical durability is higher than 3:2 mixture.

In the free fall tests, category 1 pellets didn't break into pieces easily but category 4 pellets broke into the pieces with the first fall and the loose of the weight was identified higher than the other categories, moreover, pellet surface crack photos were taken there days period and the changes of the cracks were identified acording to time period.

Keywords: *biomass, wood pellet, forest residue, valonia waste, mechanical durability*



LIGNIN–PVP MATERIAL AS A NOVEL SUPPORT FOR IMMOBILIZATION OF ANAEROBIC BACTERIA IN THE BIOGAS PRODUCTION PROCESS

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In studies on the feasibility of microbial immobilization in anaerobic digestion, various kinds of zeolites are a first choice. The primary objective of the experiments was to improve the methane yield and biogas quality. Zeolites have valuable properties, indeed, including porosity, ability to absorb ammonia and carbon dioxide. However, the tests with the use of zeolites have not provided comprehensive information or fully advantageous results.

In search for novel support matrices which are capable of bacterial flora immobilization and activation for anaerobic digestion, the present authors focused their attention on lignin. Lignin is a natural, readily biodegradable polymer material of which the valuable properties, such as porosity, very good surface area, structural properties and excellent absorption capacity, have contributed to the development of innovative, „green” applications of the material, for instance, as a sorbent of hazardous metal ions, component of enzyme immobilization supports, material for the construction of electrochemical sensors and detectors. Moreover, lignin and its derivatives have an important role in soil forming. Since the digestate was to be disposed of as a fertilizer, this was also seen by the present authors as an advantage in choosing the material for use in the experiment.

In these pilot-scale studies, kraft lignin was used by the authors after wet-combining it with the water-soluble polymer polyvinylpyrrolidone, PVP, which has excellent wetting properties and readily forms films. Such combination was intended to improve the cell adhesion to the support. In this paper, the performance of the lignin–PVP material as a microbiological support was verified based on process parameters which are essential for the anaerobic digestion process, for instance: changes of pH and VFA/TA ratio, variation of bacterial number and activity in the digestion mixtures as well as the biogas yield of the test substrates. Systems with and without the support were compared. The experiment was carried out with the use of waste wafers and raw sewage sludge. A digested sewage sludge with high buffer capacity was used as inoculum in both cases. The samples which were digested with the use of the lignin–PVP material provided a slightly improved bacterial number and evidently better bacterial flora activity; this resulted in higher biogas yields, especially for waste wafers (increase from 291.4 m³ Mg⁻¹ VS to 368.3 m³ Mg⁻¹ VS).

Keywords: *natural support, lignin, immobilization of bacteria, anaerobic digestion, organic wastes*



MARKET DEVELOPMENT OF RENEWABLE ENERGY IN UKRAINE

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Renewable energy has recently become one of the important criteria of sustainable development in the world. Searching for new and improvement of existing technologies, bringing them to the effective level and expansion sphere of use.

The main reasons for such attention is expected depletion of fossil fuels, a sharp increase of prices, inadequate and inefficient use of their technologies, impact on the environment, the effects of which are more and more trouble the world. Alternative energy become of the basic directions of development of technology in the world.

Different countries and regions prefer different types of renewable energy by adapting their use to local conditions. The most dynamically developing such types of renewable energy sources like wind power, bioenergy, solar energy and so on. Over the last decade in the world are developing technologies to get in a lot of energy from biowaste. Biogas produced in biogas plants everywhere where available biowaste and immediately consumed. Besides recycling waste in biogas plants, is possible recycle specially grown energy crops, such as rape.

The countries that are most rapidly developing technologies and markets renewable energy include the US, EU countries (primarily Sweden, Austria, Finland, Germany, Portugal, Spain), Japan, China. Recently active in this area Brazil and India. This will make it possible to accelerate technology development and its implementation in manufacturing.

Renewable energy plays a critical role in the Ukraine strategic objectives in the energy sector. Accessible capacity of renewable energy in Ukraine, its scientific and industrial potential in the near future allow to significantly increase the pace of increasing volumes of renewable energy in the country. But you need to create conditions to stimulate investment activity in this area, attracting both own and foreign investment by the experience of European countries. Large scale implementation of renewable energy sources in Ukraine will make a significant step in reducing the country's energy dependence, environmental protection and creating the conditions for integration into the European community.

Keywords: *alternative energy, bioenergy, energy, market, energy resouses, agricultural producers*



MATHEMATICAL MODEL FOR CALCULATING PERFORMANCE OF PARABOLIC TROUGH COLLECTOR

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The work deals with the transformation of solar energy into thermal energy through concentric solar collector. The subject of the research is the parabolic trough collector situated in Žilina. Solar collector including focal absorber was produced according to our own design. The absorber consists of two black coated contradictory pipes serving as inlet/outlet of heat exchanger. The reflector is made of bent polished aluminium sheet. Collector uses automatic tracking system and consists of firm frame attached to concrete floor, which limits the sun tracking to one axis. Trough of the collector is oriented as east-west position with a small deviation of approximately 10°. To determine the required output of collector is necessary to perform optical and thermal analyses. The aim of the work is creating mathematical model to get a theoretical performance of collector. Mathematical model with calculations for specific collector and its geographical position is created in program MS Excel. Although the mathematical model provides theoretical performance parameters it doesn't include the effect of environment and so the values differ from real conditions. The results of work will serve as an information basis for the following research of cogeneration system using a solar collector.

Keywords: *solar energy, parabolic collector, thermal analysis*



METHODS OF OBTAINING CELLULOSE FROM HEMP STRAW (CANABIS SATIVA L.)

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Introduction

The cellulose fibers is much longer than wood fibers, and naturally white, so, with the proper delignification process, the bleaching process can be omitted (bleaching process is the biggest environmental burden). Hemp has been found to absorb heavy metals and radioactive elements from soil at a very high rate, so they can be cultivated in contaminated areas, unsuitable for growing crops, even though reclaiming the crop region.

The aim of the study was to determine the digestion optimal methods of hemp straw to remove lignin from fiber structure. The methods had to demonstrate the highest possibility level increase of sugars in the liquid brewing liquids. These distilled sugars from liquids were to be subjected to an alcoholic fermentation process. This would result in the removal of carbohydrates from the fluids and, after further purification, return water to the circulation. In this study three methods have been used: sulphite, sodium and limestone.

Results

From the three methods used in the study, the best method was lime. $\text{Ca}(\text{OH})_2$ (calcium hydroxide) was used for this process. This method gives an orange mass that requires additional bleaching, and it is a very promising method, used in many previous studies. The problem of this method is very low solubility of calcium in water. To achieve the right concentration, it is assumed to add powdered calcium hydrate to the mass, which generating the problem of removing the excess after the process. The waste is a white lye, easy to clean. The graphs below present the Kappa Number since the pulping of fibers and harl $\text{Ca}(\text{OH})_2$.

Conclusions

The lime method shows the greatest potential for cannabis digestion. Application of this method allowed to escape the best pulp. However, problematic has been the removal of unreacted reagent from the mass, which translates into laborious process.

Keywords: *obtaining cellulose, hemp, methods*

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MICROHARDNESS AND X-RAY DIFFRACTION CHARACTERIZATION OF DIFFERENT MELTED WOOD ASHES

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Microhardness and x-ray diffraction characterization of different melted wood ashes

Recent development of biomass fuels demands more intense characterization of their combustion process residuals - as melted wood ashes, for example. In this work, we study four different kinds of melted ashes from: oak, poplar, twigs of woods and sludge.

The fuel samples were ashed at 550 °C over a period of 24 h. Ash fusion was performed under oxidizing atmosphere. The ash melting was done at temperature up to 1600 °C.

Indentations were made on the oak and poplar using Anton Paar MHT-10 hardness tester fitted to a Carl Zeiss "Axiotech" metallurgical microscope with Cannon camera. 4N load was used for indentation time of 10 s. The offset of diagonal tip was < 0.25 µm and the load resolution was 0.001 N. Indentations on the samples were made at controlled humidity below 40% at 22 °C.

Average microhardness measured on a sample were about 6.4 GPa for the oak sample, 6.5 GPa for the sludge sample, 8.3 GPa for the twigs of woods sample and 6.0 GPa for the poplar sample.

The high-resolution X-ray diffractometer (Empyrean, Panalytical) with Cu K-alpha radiation ($\lambda = 0.154$ nm) and a Ni filter, at a generator voltage of 40 kV and current of 30 mA was used for structural characterization. The radiation was detected with a proportional detector. Samples were measured in the theta-2theta geometry over a range from 10 to 80 deg. All measurements were carried out with step size of 0.01 deg and counting time 8 s per data point.

X-ray diffraction profiles revealed different structure of the samples, however, profiles of the sludge and twigs of woods samples had few broad diffraction peaks at similar positions and intensities, whereas profiles of the polar and oak samples show more complicated structure with several narrow peaks at different positions.

Results will be compared with those obtained by other authors and the structure of the samples will be discussed in detail.

Keywords: wood ash, x-ray diffraction, microhardness



MODELLING OF PV POWER STATION EXPLOITATION PROCESS, SUPPORTING WASTEWATER TREATMENT PLANT ENERGETIC SYSTEM

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Usage of PV power station directly integrated with technological system e.g. wastewater treatment plant, municipal light systems etc. is very well known issue from energy production point of view. The only practical problem is optimal and direct usage of generated current by integrated systems. What is more, weather conditions influence not only energy production but also quantity and quality of sewage treatment, by changes of parameters in running technological process, including power demand. The goal of the study is sewage treatment process optimization allowing full energy usage produced by PV power station, consequently overcoming costs of the upkeep. The goal implementation is possible by two criteria optimization: 1) direct usage of the generated current by solar panels for the needs of technological process e.g. increase of energy consumption during production hours, 2) storage of PV generated energy surplus, resulting in expanding the energetic self-sufficiency of the works e.g. filling the tanks with compressed air and later extruding into the reactors at the aeration stage. The research is conducted in one of localities in foothills region, where during energy production by solar panels the analysis of consumption was performed. Moreover, the possibility of the sewage treatment intensity regulation by controlling of the buffer tank capacity was considered. The year energy balance of the purification system is approximately in 30 % covered by the solar power.

Keywords: photovoltaics, solar energy, PV system

MUNICIPAL SOLID WASTE IN POLAND - ANALYSIS OF MAJOR PARAMETERS IN TERM OF QUALITY PELLETS PRODUCTION FOR POWER PLANTS

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The paper presents research carried out according to the framework of the grant “EkoRDF - an innovative manufacturing technology of alternative fuel from municipal waste for power and heating plants - a key component of the Polish waste management system” financed by Polish Centre for Research and Development (GEKON Programme) aimed at determining the Municipal Solid Waste (MSW) potential not only in terms of use in power generation, but mainly from the point of view of technologies of converting the waste into granulated fuels for power generation units.

MSW due to its morphological composition which includes mostly combustible material (plastics, paper, textiles, etc.), can be potentially treated as a valuable raw material for use in conventional power plants, based on combustion of solid fuels. On the other hand, content of incombustible fraction (glass, metal, rocks, etc.) can significantly decrease this potential, especially when material must be processed into the form of granulate as in case of co-combustion with coal in pulverized-fuel or fluidized-bed boilers. The process of granulation could lead to reduction of the logistic processes costs such as transport, storage and handling.

The test material comprised oversize and undersize fractions of municipal solid waste obtained from four sources (sorting plants). The morphological and grain-size analyses were carried out, and the parameters important from the point of view of power generation were determined (moisture content, calorific value, volatile matter content, ash content). The impact of those parameters on key stages of RDF production from waste (drying, comminution and granulation) were analysed. The analysis led to determination of acceptable raw material parameters for use in production of fuel granulates dedicated to burning in power generation units.

Keywords: *RDF, pellets, Municipal solid waste*

This research are financed by Polish Centre for Research and Development and National Fund for Environmental Protection and Water Management under the GEKON Programme – project name: “EkoRDF - an innovative manufacturing technology of alternative fuel from municipal waste for power and heating plants - a key component of the Polish waste management system”



OXY-FUEL COMBUSTION OF COAL SLURRY PELLETS IN A LAB-SCALE FLUIDIZED BED COMBUSTOR

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Oxy-fuel combustion is one of the leading technologies considered for capture CO₂ from power plants with CCS (Carbon Capture and Storage). This technology can reduce significantly emissions of NO_x and improve the thermal efficiency of the combustion process by reducing the flue gas volume. In this technology, fuel is burnt in a mixture of pure oxygen and recycled flue gas. Because nitrogen is eliminated from the oxidizing gas, the flue gas that leaves the combustion chamber is highly enriched in CO₂, which implies that the combustion process occurs in an O₂/CO₂ environment.

Circulating fluidized bed (CFB) boilers are ideal for efficient power generation. They are capable of firing an extensive variety of renewable and waste fuels in small combined heat and power plants (CHP) and large utility power plants. The well-known benefits of CFB technology, such as the superior fuel flexibility, inherently low emissions and high availability can be completely utilized for this purpose.

Combustion of coal slurry pellets in air versus O₂/CO₂ mixtures with oxygen concentrations in the range of 21% to 40% vol. was conducted at a temperature of 850°C in a 12 kW lab-scale CFB combustor. The main objective of this study was to investigate the combustion behaviour of coal slurry pellets, in terms of temperature profiles, ignition time, volatiles combustion time and the total combustion time. The results of the tests show that the composition of the oxidizing atmosphere highly influences the combustion process of waste fuels.

Keywords: coal slurry, oxy-combustion, pellet, CFB



POLLUTING WATER WITH A VERITABLE SOURCE OF ENERGY: A SITUATION IN THE URBAN CITY OF LAGOS, NIGERIA

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The thrust of this paper is to explicate the repercussions of wanton sewage disposal into the Lagos Lagoon and to highlight the potential which Lagos has to generate massive energy from sewage waste in order to meet its energy challenges. From ten separate stations across the Lagos Lagoon, water samples were collected and analyzed to ascertain the existence of pathogenic entities using the techniques of sedimentation, microscopy and culture. These pH levels and Biochemical Oxygen Demand (BOD) of the samples were tested using the pH meter and BOD test apparatus correspondingly. This paper shows that sewage disposal into the Lagos Lagoon has made the water body ecologically unhealthy for aquatic plants and animals. It has also decreased the visual appearance of the environment. Further, this cruel practice has exposed some persons that come in contact to the lagoon's waters to pathogenic infections. Extant studies have pointed to the fact that sewage waste is a key energy source, with 1 kilogramme of dry faecal sludge having a calorific value of 17.3 millijoule. This paper strongly recommends the dynamic use of faecal sludge to save the Lagos Lagoon from sewage pollution and upscale energy supply in Lagos.

Keywords: *sewage, energy, water, lagoon, sewage tanker*



POSSIBILITY OF USING ENERGY CROPS FOR PHYTOREMEDIATION OF HEAVY METALS CONTAMINATED LAND – THREE YEARS EXPERIENCE

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Heavy metal soil contamination is a worldwide problem. The affected sites could be either sites of a former industrial activity or arable land located in their vicinity. The presence of heavy metals in excessive quantities makes these sites either left idle or underused due to contamination and lack of efficient ways to restore. Phytoremediation driven energy crops production may be a promising alternative for the management of these sites.

A four-year field experiment has been established on heavy metal (HM) contaminated sites located in Bytom, Upper Silesian Industrial Region, Southern Poland (arable land, high level of bioavailable HM) and Leipzig, Germany (post-industrial site, low level of bioavailable HM) to find the optimum energy crop species with respect to both: energy crop yield and phytoremediation potential. It involves testing of selected plant species: miscanthus (*Miscanthus x giganteus*), virginia mallow (*Sida hermaphrodita*), cordgrass (*Spartina pectinata*), and switchgrass (*Panicum virgatum*). Experimental trials were established in May 2014. Both sites were treated as follows: (i) K – Control, no treatment; (ii) NPK- NPK standard fertilization, applied to the soil before the experiment; (iii) INC - Commercial microbial inoculum Emfarma Plus®, ProBiotics Poland. Presented data were collected after the third growing season, heavy metal uptake and total biomass yield for each of the species and experimental options was determined.

Level of the bioavailable content of heavy metals in the soil seems to be the main factor responsible for the differences in metal uptake by the plants. Plant species cultivated at the former sewage sludge deposit site were characterized by low metal concentration in shoots, except *P. virgatum* which accumulate high amount of zinc, even if the bioavailability of this metal in soil is low. The highest lead uptake was observed for *M x .giganteus* and *P. virgatum*, while the highest cadmium content was found for *S. hermaphrodita* grown on contaminated arable soil. Cultivation of energy crops on HM contaminated lands could be a solution for restoration and increasing of economical value of such areas.

Keywords: *heavy metals, phytoremediation, energy crops*

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POSSIBILITY TO UTILIZE FISH PROCESSING BY-PRODUCTS IN THE CONTEXT OF MANAGEMENT OF NON-RENEWABLE RESOURCES

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Fish processing generates considerable amounts of waste which constitutes a potential threat to the environment. The aim of this paper was to assess the possibility to use processing waste for anaerobic digestion and to use the generated digestate for fertilization purposes. This research involved evaluation of chemical composition of waste from a carp processing plant and of the digestate after methane fermentation. The content of dry matter, organic carbon, nitrogen, and other macroelements was determined in the samples. Moreover, the content of trace elements was determined. Dry matter content in the studied waste was 40%. Nitrogen content was approximately 5.56%, phosphorus -1.758%, calcium - 0.4%, whereas mean potassium content was 0.502 g · kg⁻¹. As a result of conducting methane fermentation, a reduction in nitrogen content by about 50% and a considerable increase in quantity of almost all elements were observed. A high zinc content was recorded in the digestate, whereas concentration of other microelements was at a level close to the one in natural fertilizers. Concentrations of heavy metals did not exceed permissible values for organic fertilizers. The studied material can be a component for fertilizer production, and its fertilizing value depends mostly on nitrogen and phosphorus content.

Keywords: *fish processing waste, anaerobic digestion, digestate, organic fertilizers*



POWER GENERATION FROM BIOMASS, ORGANIC AND SCRAPE TIRES WASTES

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This paper presents the comparison between two power plants using different thermodynamic cycles, with an installed power capacity of 25MWel. The power plants use as a primary energy source three types as biomass and wastes, consisting in beech wood residues, organic residues from meat processing industry, and scrap tires. The steam turbine installation is fed with solid biomass and waste. The gas turbine installation is fed with synthesis gas obtained by air gasification of the same biomass and waste. The air gasification of the feedstocks, along with the synthesis gas composition are partly presented in a previews research conducted by the authors [Tîrtea R. N. et al., 2016, Analysis of syngas production from biomass and waste, COFRET'16, Bucarest, UPB - 29 - 30 juin 2016]. In the present simulations, the gasification processes were conducted at atmospheric pressure, at a temperature of 800°C, and an equivalence ratio of 0.25, 0.30, and 0.35. In order to compare the two power plants the fuel feed rate and emission factors were computed.

Keywords: biomass, emissions, power generation, waste



REVIEW OF ASH DEPOSITION COEFFICIENTS FOR SELECTED BIOMASSES

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Ambitious EU environmental policy decreasing CO₂ emissions from combustion of fossil fuels impact on whole EU economy. Utilization of biomass as carbon neutral fuel helps to address these challenges. Combustion and co-combustion of biomass, especially agriculture residue biomass, is associated with many technical problems such as: bed agglomeration, slagging and fouling, chlorine corrosion, decreased boiler efficiency which do not occur in conventional fossil fuels combustion. For many years different ash behavior predictive coefficients were developed including: Basic to Acidic oxides (B/A), Bed agglomeration index (BAI), Chlorine content (Cl), Silica content (SiO₂), Babcock index (Rs), Ash fusibility index (AFI), Fouling index (Fu), Slag viscosity index (Sr), Ash fusion temperature in oxidation conditions (IDT, ST, HT, FT), Fouling index (Fu), Slag viscosity index (Sr). However they not always show the real ash deposition tendency.

In this study six fuels were investigated in certified laboratory (2 types of straw pellets, miscanthus briquettes and herbaceous pellets, RDF - Refuse-Derived Fuel and reference coal). Biomasses were selected as the most commonly used in Polish and German power industry. Analysis includes proximate and ultimate analysis of fuel, ash oxides analysis and ash fusion temperature. The main objectives of this work were to predict ash deposition tendency of chosen fuels, compare it with reference fuel and investigate weaknesses of selected indicators.

The results of investigation contribute to develop mathematical model for ash deposition tendency.

Keywords: *biomass, ash deposition, slagging, fouling, combustion*

The research was funded by BioEffGen project (Advanced pretreatment and characterization of Biomass for Efficient Generation of heat and power) funded by National Centre of Research and Development in STAIR program "Polish - German sustainability research call".



SOME ASPECTS OF APPLICATION OF MAGNETOTELLURIC METHOD TO GEOTHERMAL SURVEY IN INDIA, AREA OF GUJARAT

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The magnetotelluric survey was made in north-western India in the area of Gujarat State by the PBG Geophysical Exploration Company, within the framework of geothermal project performed by the University in Gandhinagar (PDPU- Pandit Deendayal Petroleum University, CEGE- Centre of Excellence for Geothermal Energy). The geological structure of the north-western part of India, where the Gujarat state is located, qualifies this area as prospective for obtaining geothermal energy. In this tectonically active region, the relatively young rift zone occurs, which is buried under a thin cover of wet sediments. This area is the subject of the mentioned above research performed by the PDPU financed by an international research project.

Measurements using the natural electromagnetic field was carried out in three regions: Dholera, Gandhar and Unai, where the favorable conditions for the location of geothermal installations were expected. The methodology of remote reference data acquisition and processing was applied to avoid or mitigate influence of artificial noise on results of magnetotelluric data interpretation. The detailed magnetotelluric survey was carried out in two stages. The first stage included the acquisition, processing and interpretation of magnetotelluric data along the measurement profiles. The results of 2D research i.e. resistivity cross-sections obtained us effects of magnetotelluric soundings inversion, allowed for the identification of the areas with the highest geothermal potential. Based on them, the decision to perform the second stage using the 3D methodology was taken, allowing for spatial identification of geological structures. The additional magnetotelluric soundings, which complemented 2D survey up to 3D distribution were performed at the preselected geothermal field- Unai. In collaboration with scientists from the University of Salt Lake City in Utah, the three-dimensional magnetotelluric data inversion was made. As the result of computation 3D model of resistivity distribution inside geological medium was obtained. This model significantly improved the imaging of low-resistivity structures associated with the zones of favorable geothermal conditions and allowed for indication the expected optimal conditions of the production borehole location.

Keywords: *geothermics, magnetotellurics, 2D inversion, 3D inversion, Gujarat*

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STRAW COMBUSTION – PILOT STUDIES ON POLYCYCLIC AROMATIC HYDROCARBONS EMISSION DURING KAOLINE ADDITION

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Biomass tends to be leading source of renewable energy in Poland, what is connected with the major share of solid fuels combustion units in the production of heat and electricity. For decades main source of heat and power was hard coal or lignite, what led to significant pollution on many areas of the country. Rising prices of fossil fuels, depleting natural resources, climate changes and increasing awareness of the air pollution issue, are main factors that promote usage of biomass at the beginning as supplementary source of energy. Across last years significance of this feedstock was rising, and nowadays biomass tends to be one of main players in Polish energy policy. In such situation, usage of spent types of biomass tends to be reasonable way to utilize such materials for energy purposes.

In combustion of fossil fuels as coal or lignite, as well as in waste incineration processes, emission of polycyclic aromatic hydrocarbons is well-known problem. Nevertheless during biomass combustion, when the process is not conducted in accordance to Best Available Techniques (BAT) it could lead to formation of these substances. PAHs as most dangerous substances, benzo[a]pyrene as main representative as well as particulate matter (PM 2.5 and PM 10) are main problems in nowadays air quality policy.

Paper presents, research on influence of kaoline addition on emission of PAHs and PM during combustion of different types of straw. The research was carried out on laboratory stand, which corresponds to combustion in technical scale. As results shows, addition of Kaoline, could have not only positive influence on ash fusion characteristics, but also on emission of toxic substances, what seems to give rise for further research on biomass fuel supplemented with kaoline.

Keywords: *straw combustion, PAH emission, solid biofuels*



STUDY OF A STEAM PISTON ENGINE IN A SUPERCRITICAL CONDITIONS

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Summary: The aim of the study is the intelligent development of cogenerating micro power plants that are ultimately driven by biogas, biomass or any other fuel (aspect envisaged in the prototype development system) with a pulsed piston steam engine, a generator or a water brake (modelling, simulating, replacing workloads). The research system included the following core elements:

- Induction supercritical steam generator (eventually replaced with steam boiler powered by biogas, biomass or other solid or liquid fuel)
- piston steam engine powered with steam of supercritical parameters with a patented steam feed system with impulse injection valve,
- electricity generator (alternatively with water brake),
- steam regeneration system.

As a result of the research, an injection valve design has been developed which fulfils the intended functions and enables the engine to function smoothly, as evidenced by the basic engine characteristics developed. The average power output on the motor shaft was over 20 kW, which, with the power supplied by the 45 kW steam generator, gives an expected overall efficiency of 44%. According to the estimates from the steam regeneration system, 45% of the condensation heat of steam exiting the engine can be recovered, which increases the overall efficiency of the micro power plant to 89%.

The results for intelligent development allow us to formulate conclusions and patent descriptions for the innovative design of a new generation steam engine and to protect the industrial design of a micro power plant with this steam engine.

Keywords: *Steam engine, supercritical steam, micro-thermal power plants*



STUDY THE PHYSICAL PROPERTIES OF THE FRUIT POMACE FOR ENERGY USE

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The world economy is the production of electricity and heat, are increasingly based on the use of renewable energy sources to replace partially or totally fossil fuels. Biofuels provide an opportunity for energy production in many sectors while maintaining ecological conditions. Having regard to energy security in all regions of the country and guarantee sufficient resources for energy production, must constantly seek new and locally available raw materials for the production of environmentally friendly fuel, the physico-chemical parameters will fully to implement efficient combustion or incineration. Fruit processing plants offer post-production waste, which can be used as biomass. At the turn of the last years they developed a number of kilns, whose job is to get the plant product with a humidity below 15%. The dried pomace, and mixtures thereof with sawdust having a low moisture level, at the same time characterized by high performance energy performance. Laboratory tests conducted at Kielce University of Technology, demonstrated the possibility of using agro as a component of the mixtures of waste wood for their energy efficiency. Studied analytical moisture, heat of combustion, calorific value, ash and participation. It is shown difference in the residue of the same mix at two temperatures of incineration. The possibility of increasing the amount of biomass as a renewable source of energy becomes a reality, both in industry and in private farms. To stop the process of environmental pollution, which have recently intensified more and more, be more broadly interested in the use of post-production waste of plant origin, are available on the domestic market.

Keywords: *forest biomass, pomace fruit, testing combustion heat, moisture study*



TECHNOLOGICAL ASSUMPTIONS FOR ESTIMATING THE EFFICIENCY OF BIOGAS INSTALLATION USING INNOVATIVE TECHNICAL SOLUTIONS

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On the Polish market there are no original solutions for biogas installation dedicated to the small farms that take into account their specific characteristics. The concept of modular biogas installation has been developed in the Institute of Technology and Life Sciences, a solution in the form of two types of biogas installation for processing liquid substrates such as pig manure and bovine manure.

In the first variant, a mono-substrat reactor was used. The second study was conducted under the Biostrateg 2 project "Developing innovative technologies complex utilization of waste generated during the fattening pigs" with reactor, with the pump for lifting liquid which is patent protected solution. In order to estimate the energy efficiency of these two variants, the theoretical balance of energy needed to efficiently carry out the fermentation was compared and compared to the standard biogas installation.

Keywords: *biogas installation, innovated technology, energy efficiency, biogas*



THE EFFECTS OF BIOMASS TRANSPORT BETWEEN PLANTATION AND INDUSTRIAL FACILITY ON ENERGY EFFICIENCY OF BIOFUEL PRODUCTION SYSTEM

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Production of biofuels requires transportation of substantial amounts of biomass between plantations and industrial facilities that converts this biomass onto biofuel. This transport might strongly affect energetic effectiveness of the whole production system. Basing on computer model developed in our earlier works, the contributions of the energy consumed in various transport solutions are analyzed, and their effects on the energy efficiency are estimated. The dependencies of the energy efficiency upon technical characteristics of transportation means are shown for several solutions of production organization. Conclusions suggest optimal choices of transportation means, and transport organization as dependent upon the type and the size of a plantation.

Keywords: *biofuel, biomass, production system, energy efficiency*

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THE ENERGY EFFICIENCY IN A COMMUNE. THE FORMAL AND LEGAL REQUIREMENTS AND EXAMPLES OF A GOOD PRACTICE

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Currently, the improvement of energy efficiency together with the utilisation of renewable energy resources as well as the implementation of the low emission economy constitute the complex of coherent and significant challenges for the member states of the European Union. In the prospect of the increasing energy demand, all countries, as the community and as individuals, are obliged to lead the sustainable economy as well as to aim at the fulfilment of the appointed economic and environmental targets. Poland as a member of the EU Community, has adapted the national legislation so as to ensure the total deployment of legal regulations concerning the energy efficiency as well as the low emission economy. One of the most important legal acts is the Energy Efficiency Act, which obliges the local administration to pursue actions to increase energy efficiency, as well as defines the tasks and principles of their realisation.

The tremendous potential associated with the improvement of the energy efficiency is believed to be obtained in communes – urban and rural. The communes have a crucial role in the heightening awareness, among the local society, about the importance of pursuing for the enhancing of the energy efficiency. Also, they are responsible of the initiation and introduction of basic changes in the each sector of the economy – energetic, construction, transport, waste management, etc. However, in order to carry out any actions aimed at the transformation of the present economy into the low emission and resource-efficient economy, the possession of the knowledge form scopes of the national law, formal requirements and the possibility of obtaining financial means for the planned investment is a vital issue.

The paper presents the most important formal and legal regulations that have an influence on the improvement of energy efficiency at the borough level. It is focused on obligations arising directly from the Energy Law and the Energy Efficiency Act as well as from several related documents such as the Plan for Electricity, Heat and Gas Supply and the Low Emission Economy Plan. Also, the particular examples of projects that have been realised in Polish communes, together with the indication of benefits gained in terms of the energy efficiency as well as the environmental and social aspects, are presented.

Keywords: *energy efficiency, low emission economy, commune, legal framework*

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THE ENVIRONMENTAL AND TECHNOLOGICAL EVALUATION OF DYED DSSC CELLS PRODUCTION

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The growing demand for electricity and decreasing fossil fuels resources are a driving factors for research on the technologies that use renewable sources of energy. Solutions that allow using photo-conversion, processing solar energy into electricity are currently going through dynamic development. It could be stated that during the operation phase photovoltaic modules are wastes-free technology, but production and processing after withdrawn from exploration are sources of different sorts of wastes. One of the best solution that gather focuses from scientists are dye-based photovoltaic cells DSSC. During the last decade, many researches gave many specific results that can be used in optimization of this technology. This manuscript discusses a method to expand the lifetime of the module, method to maximize its efficiency as well as reducing the amount of waste during production, use and final waste stage. Natural alternative materials which are possible to apply in current DSSC production technologies and modifications to each individual components of the photovoltaic cell are shown as well.

Keywords: *DSSC cell, photovoltaic cell, solar energy*



THE FINANCIAL EFFICIENCY OF THE BIOSTATIONS IN POLAND

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The goal of the research is to study financial condition and efficiency of biogas plants in Poland. The focus of the research is made on profitability and liquidity relations of research objects.

The study was based on the generally accepted methods for data quantification, processing, presentation, statistical observation, summary and grouping of observation materials, correlation and regression analysis. Liquidity, and profitability ratios, asset management ratios and debt ratios were used.

The research presents the analysis of selected biostations in Poland such as Biogazownia Drozdowo Sp. z o.o., Biogazownia Jezierzyce Sp. z o.o., Biogazownia Ostrzeszów Sp. z o.o., Biogazownia Prusinowice Sp. z o.o., Spółka Rolna Dretyń Biogazownia Sp. z o.o.

The hypotheses of the research states that the biogas stations with higher profitability ratios are characterized by higher level of liquidity.

In Poland, recently, the most popular is the usage of biomass among renewable energy sources. Biomass is used to produce biogas in large and small agricultural biostations. The production of biogas takes place under anaerobic conditions involving the usage of a number of microorganisms.

In Poland high profitability of biogas plants is ensured by the simultaneous production of highly efficient organic fertilizers. It explains the rapid (1-2 years) payback of biogas plants.

The location of Polish biostations is produced only in large livestock farms or in close proximity to several small farms. The location of biogas plants in such areas allows greater funding from the EU, Ministry of Agriculture and Rural Development or European Biogas Association which support the development of agricultural biogas stations. A biostation which produces biogas from animal manure allows to receive large amounts of biogas and, therefore, ensures shorter payback period.

Under condition of complex use of biogas plant products, first of all, electric power in the enterprise the payback period of the project is about 3-7 years. The larger biogas plant is, the higher its profitability and the shorter payback periods are. Results of economic studies carried out for the biogas plant based on organic waste from agri-food industry sounds that NPV amounts to €1,221,213 while its IRR stands at 28% this calculations based on data from the Polish Energy Exchange. In general, biogas projects are characterized by a high IRR value and their payback does not depend much on inflation.

Keywords: financial efficiency, biostations, biogas production, agro-industrial complexes, renewable energy sources, profitability.



THE FORMATION OF PARTICULATE MATTER DURING THE COMBUSTION OF DIFFERENT FUELS AND AIR TEMPERATURES

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Particulate matter (PM) belongs to significant pollutants threatening human health. Therefore, it is important to pay attention on these solid emissions. Several factors, such as type of fuel, quantity and temperature of the combustion air, operation conditions and design of heat source etc., influence on their formation. The aim of this work is investigation of fuel type and various inlet air temperatures on PM formation. The above mentioned parameters were measured in wood stove. In the first stage of the research, there were measured following fuels: beech, spruce wood, birch with bark and birch without bark. The results show that higher PM concentrations were measured during the combustion of birch with bark. The outcome of these analyses is the negative effect of bark on PM formation. In the second stage, there was investigated the effect of different combustion air temperatures on PM formation. Based on the measured results, it can be concluded, that temperature of combustion air has influence on PM concertation.

Keywords: *particulate matter, fuels, combustion, air temperature*

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THE IMPACT OF ENGINE TUNING ON THEIR LIFESPAN

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The influence of chip-tuning aiming to improve the performance of mass-produced engines is shown in this article. The results of analysis graphs obtained on dynamometer allow to pre-determine the effects of its adjustment program engine control. The final effect will be observable only after prolonged operation of such vehicle. Method of exploitation of reinforced drive unit has also a great importance. In case of frequently use almost 100% of the maximum engine performance, time to product failure becomes dramatically shorter. In this article there is no reference to a larger failure rates of vehicle suspension because it is not possible to make a reliable tests in several repetitions.

Keywords: *tuning, engines, engine service life*



THE INFLUENCE OF WEATHER CONDITIONS AND OPERATING PARAMETERS ON THE EFFICIENCY OF SOLAR POWER COLLECTORS BASED ON EMPIRICAL EVIDENCE

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This study evaluates the influence of weather conditions and selected operating parameters of a heating system on the efficiency of liquid solar power collectors.

The analyzed system is composed of an evacuated tube collector and flat-plate collectors connected to a buffer storage tank from which heated water is distributed to radiators and underfloor heating tubes. The active surface area of the absorber is 4.64 m² in flat-plate collectors and 3.23 m² in the evacuated tube collector. The collectors are mounted on the roof of the Institute of Building Engineering of the University of Warmia and Mazury in Olsztyn with a roof pitch of 45°. The collectors have a tilt angle of 30°, and they face west of true south. Data are acquired in hourly intervals with the use of sensors, and they are stored in a computer database. The average hourly intensity of solar radiation is measured with a pyrometer installed on the surface of solar power collectors. The temperature of ambient air and the average hourly difference in the temperature of the glycol solution at the inlet and the outlet are also measured.

The measurements were conducted between May and September 2016, and they covered a total of 3552 hours (data for 6 to 11 July 2016 are not available), including 1371 hours with zero irradiation and 366 hours with irradiation values higher than 800 Wh/m². The average hourly temperature of ambient air was 17.5°C, the minimum temperature was 5.4°C, and the maximum temperature was 32.1°C.

The experiment was conducted under favorable weather conditions which supported a reliable evaluation of the efficiency of the two most popular types of liquid solar power collectors in the real-life environment of north-eastern Poland. The flow rate was kept constant (at 5 l/min in flat-plate collectors and 7 l/min in the evacuated tube collector) to determine the influence of weather conditions and operating parameters on the efficiency of solar power collectors. The results obtained in both types of collectors were compared with empirical data relating to water temperature in the buffer storage tank, temperature of the glycol solution at the outlet, and difference between the temperature of the glycol solution at the outlet and ambient temperature. The results were analyzed statistically to determine the presence of correlations between the analyzed factors.

Keywords: *Solar energy, liquid collectors, vacuum collectors, energy efficiency*



THE PHYSICAL AND MECHANICAL PROPERTIES OF BIOFUELS COMPACTED WITH THE CONTENTS OF A BIOSTABILIZED FRACTION OF MUNICIPAL WASTE

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The paper presents the results of physico-mechanical study of compressed fuel consisting of *Miscanthus giganteus* and biostabilized part of municipal waste.

The purpose of the study was to determine the effect of moisture content and percentage of municipal waste on the strength of the obtained biofuel and its specific density. The calorific value, combustion value and ash content of the produced fuel were also determined.

The mechanical strength analysis showed an increase in mechanical resistance with an increase in the percentage of stabilizate additive in the sample tested. On the other hand, the increase in the moisture content of the pellet fuel caused a decrease in its mechanical resistance. Analysis of ash content showed a significant increase in the amount of residue after fuel combustion, with an increase in the share of stabilized fraction of municipal waste in compacted fuel. Studies have shown that the increase in the percentage of the stabilized fraction of municipal precipitation in pellets has reduced its calorific value. Produced alternative fuel with a stabilized fraction of municipal waste up to 15% meets minimum fuel requirements (calorific value, moisture content, ash content) for clinker production facilities. Fuel with stabilization stability can be used in cement plants. When analyzing the fuel used in power generation and heating, all blends had the required minimum calorific value for fluidised and pulverized coal boilers. For the lignite dust boiler, only the 5%, 10%, 15% for each tested moisture content and the 20% moisture content of 12% were required for the minimum calorific value.

Keywords: *biostabilisation, biofuel, undersize fraction, physical-mechanical properties*



THE POSSIBILITY OF DETERMINATION OF THE PARTICLE SIZE DISTRIBUTION OF GRANULAR MATERIALS BY DIGITAL IMAGE ANALYSIS

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The granular materials, in particular fragmented biomass and cereal grains, are widely used in the power industry, the food industry and agriculture. These materials are subjected to various processing and automated transport processes. This forces implementation of fast tools (methods) for evaluation of the basic physical properties of these materials. The particle size distribution is one of the basic characteristics of granular materials. The classic measurement methods are very time consuming. Digital image analysis (DIA) gives new possibilities for fast, real-time measurements. The paper presents the study of the possibility of using DIA to determine particle size distribution of granular materials. The results obtained with DIA showed correlations with the actual granulometric composition at the level of 0,63 to 0,89 R^2 values.

Keywords: granular materials, digital image analysis, particle size distribution



THE VISUALIZATION OF COMBUSTION AIR FLOWING INTO THE DENDROMASS COMBUSTION PROCESS USING CFD SIMULATIONS

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At present, air quality significantly affects the state of the environment, human health as well as individual ecosystems and biomass burning contributes significantly to it. In order to decrease the concentrations of emissions, therefore the European Union is pushing on manufacturers of boiler to produce heat sources with lower and lower emissions limits. Due to this, the manufacturers try to improve, modify and innovated their products. The aim is to not only to reduce emissions but also to increase the efficiency of the heat sources. This article focuses on a particular type of wood-gasifying boiler. Many factors directly or indirectly affect the burning quality, which enter the process of incinerating solid dendromass. One of the main conditions affecting efficiency and emissions in a small heat source is the distribution of combustion air. The assessed heat source has a supply of primary air to the chamber with wood and secondary air is supplied to the combustion chamber for combustion of the formed wood gas. During the operation of the heat source, unequal wood burning-of was found out. The combustion in such a boiler is less efficient and produces higher emissions. Therefore, it is necessary to analyse the air flow in the heat source. The actual distribution of combustion air to the dendromass combustion process is impossible to detect by real-time measurement and therefore a suitable alternative of his detection is CFD simulation, which used to optimize the distribution of combustion air in a small heat source. In the first step, it was analysed the combustion air distribution under various input conditions and consequently the optimization measures of the combustion air distribution were solved. Later, the CFD simulation data will be analysed using non-invasive visualization measurements using by the PIV method.

Keywords: *emissions, burning, air distribution, small heat source*

This work has been supported by the the project VEGA No. 1/0864/16 Analysis and optimization of the factors entering into the process of burning dendromass in small heat sources.



THERMAL SYSTEMS USING CONCENTRATED SOLAR RADIATION

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Various solar radiation systems are used to generate heat. To improve the efficiency of such systems, different methods of concentration of solar radiation are used, like conventional lenses, fresnel lenses, parabolic or longitudinal mirrors. The conversion of solar energy to thermal energy takes place in energy systems equipped with systems for converting concentrated sunlight into heat.

This paper will analyzes the possibility of using a longitudinal mirror (gutter) to obtain hot water for a family of four in Poland. The dependence between the length of the gutter mirror on the intensity of solar radiation was calculated. Concentrated solar radiation can be used in either hot and cold water heating systems seasonally all-year, water heating in open or indoor swimming pools, water heating for agricultural purposes and in agro-food processing.

Keywords: *Lenses, mirrors, concentrated radiation, hot tap water*



THERMOPHYSICAL PROPERTIES OF SELECTED TYPES OF BIOMASS

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Willow is a valuable species for the energy industry in Poland. It undergoes agglomeration processes in order to convert the biomass into compact biofuel: pellets or briquettes. Knowledge of the thermophysical properties of these products is relevant for a better understanding of the heat exchange process when designing energy systems and technologies for thermal processing of raw materials and for optimization of thermal processes. The subject of the present paper is an analysis of thermophysical properties of energy-crop willow depending on temperature and water content. For the research the *Salix Viminalis L.* variety of willow was selected, which was then shredded into the forms of chips and pieces of shoot. On the basis of the measurements, the following coefficients were set for each form: thermal conductivity (λ), thermal diffusivity (a), density (ρ). The received results were subjected to statistical analysis. On the basis of this analysis (ANOVA, Fisher's LSD test), at the significance level 0,05, demonstrated was a significant effect of both the process temperature and water content in the material on thermophysical parameters. Chips were characterised by higher values of the analysed thermophysical properties as compared with pieces of willow.

Key words: *Thermal conductivity, Thermal diffusivity, Density, Salix Viminalis L.*



MODEL MATEMATYCZNY SPALANIA CZĄSTEK BIOMASY W WARSTWIE

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Biomass of plant origin is still used as a source of energy in energy systems. This is most often a non-homogeneous material, with a complex structure and often high humidity, and therefore requires appropriate technologies to carry out the combustion process. It is therefore very important to know the course of combustion kinetics and the processes of transport heat and mass during thermal processing of different types and species of biomass. The mathematical and simulation models are used to analyse and explain the phenomena that occur during combustions. The paper attempts to formulate a mathematical model of biomass combustions in a layer of biomass. The 3D decomposition model was developed based on the laws of thermodynamic process, heat and mass transport, mechanics of fluids, describing solid and gas phase processes, taking into account the initial boundary conditions. This model was used to create a simulation model of the process in three stages: drying, pyrolysis and biochar. Simulations were made from applications for differential analysis of partial elementary balance methods. The simulation was performed in an EXCEL environment using the KM3R method. The results of the simulation calculations were subjected to validation. For this purpose, experiments were carried out at laboratory benches in a fixed grate, helping to measure the temperature in the layers and gas components. In addition, an experiment was performed to improve the regression of mass losses. Additionally the experiment which measured the loss of mass was performed. The results of all performed calculations were compared with empirical results which determined the correctness of model.

Keywords: *biomass, fixed-bed model, combustions*



ENERGY AND ENVIRONMENTAL POTENTIAL OF PERMANENT GRASSLANDS IN POLAND

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Permanent grasslands play a significant role in the environment. They are a source of animal food, a shelter for various species of plants and animals. They also prevent any water and wind erosion of soils and reduce the emission of methane and carbon dioxide deriving from the decomposition of the organic mass in the soil. The cultivation of mixtures of grasses and legume plants with respect to the remaining agriculture crops reproductively affects the organic matter in the soil. In the past five years the agriculture has witnessed a tendency to reduce the permanent grasslands by 5 per cent per annum. The fundamental reason for this fact is a change to the animal production systems, which, leads, over the time horizon, to the conversion of the permanent grasslands into arable lands. The objective of the research is to estimate the amount of carbon dioxide reduced by the permanent grasslands and the amount of the unutilised biomass. The research was conducted on the basis of the collective data of the Central Statistical Office and of the collective data of the Agency for Restructuring and Modernisation of Agriculture. The calculations for the years 2013-2016 include the number of farm animals (ruminants), the areas of permanent grasslands along with the management structure and the production of fodder plants. The research resulted in selecting regions of Poland with the greatest potential of unutilised biomass with an option to use it to produce energy and the reduction of the emitted carbon dioxide has been estimated. It has been stated that due to the diminishing area of permanent grasslands in the agriculture, it is necessary to take actions to develop solutions that ensure the profitable economy in permanent grasslands in order to increase their area.

The study was conducted as part of the 2016-2020 Multiannual Programme under the Resolution of the Council of Ministers No 154/2016 dated 12 December 2016.

Keywords: *grassland, renewable energy source, emission of carbon dioxide*



TORREFACTION OF PERENNIAL GRASS BIOMASS - INFLUENCE OF PROCESS PARAMETERS ON THE PROPERTIES OF OBTAINED BIOCHAR

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Biomass of perennial grasses is one of the sources of biomass harvested annually from energy plantations. A characteristic feature of this type of biomass is its low bulk density. In order for the efficient use of energy contained in this biomass, it is necessary to process it into compacted solid biofuels. Moreover in spite of high degree of processing, each kind of biomass are still biologically active and react strongly to humidity. One of the ways to improve the hydrophobicity and elimination of biological activity of biomass is its torrefaction.

During biomass torrefaction take place processes of decomposition, and carbonization of lignin, cellulose and hemicellulose. As a consequence that, biomass to become more hydrophobic and have more energy. That technology allows obtain high quality biomass with properties similar to coal. It relies on thermal treatment of biomass in the temperature range 150 - 300°C under atmospheric pressure, in anaerobic condition. The type of biomass varied in composition and parameters of the process (temperature, reactor residence time) have a crucial impact on the quantity and characteristics of the resulting products of biomass torrefaction.

The aim of this study was to determine the effect of time and temperature of torrefaction on selected parameters of torrefied biomass from grass.

The research material was biomass of giant miscanthus (*Miscanthus × giganteus* Greff et Deu.) and biomass of tall wheatgrass (*Agropyron elongatum* (Host) P. Beauv). First species representing grass with C4 photosynthetic type and second is grass species with C3 photosynthetic type.

The biomass samples were dried to a humidity of 10% and then was specified the calorific value, heat of combustion, specific density, ash content and volatiles matter. Characterized samples were subjected to torrefaction process in a special reactor. Torrefaction temperature was in range 200 - 300 ° C and the duration of the process in the range of 1 - 3h. In result was obtain torrefied biomass about the different degree of the carbonization, which were characterized by the same parameters as before biomass torrefaction.

The analysis of obtained results allowed to determine the optimal process parameters for torrefaction (minimum duration and temperature), to obtain a product with the highest energetic parameters. The results provide a basis for the development of biomass torrefaction technology, taking into account the properties of the feedstock.

Keywords: *biomass, energy crops, torrefaction, giant miscanthus, tall wheatgrass*



TORREFACTION OF THE BLACK LILAC (*SAMBUCUS NIGRA* L.) AS AN EXAMPLE OF BIOCOAL PRODUCTION FROM THE GARDEN MAINTENANCE WASTE

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Torrefaction of the Black Lilac (*Sambucus nigra* L.) as an Example of Biocoal Production from the Garden Maintenance Waste

The paper presents the conversion of the black lilac (*Sambucus nigra* L.), which is an example of garden plant residues coming from the garden maintenance works, into valuable energy carriers by using torrefaction technology. A laboratory reactor was built in order to perform the torrefaction process, which allowed black lilac chips to be roasted in the temperature range from 250°C to 300°C for several dozen minutes. The black lilac's properties and structure were investigated before and after material torrefaction to identify the effect of this process on this plant. The average higher heating value (HHV) of the raw black lilac increased from 17.2 MJ/kg to 24.0 MJ/kg after torrefaction. The average mass yield amounted to 39%-65%, while the energy yield amounted to 58%-96%. The moisture of the black lilac after the cutting and grinding was up to 50%, while after torrefaction it did not exceed 4%. A scanning electron microscope and optical microscope analysis revealed the black lilac's fibrous and annular structure with spherical inclusions, which were changed following the torrefaction process into a flatter, more even structure with fewer inclusions. Elementary analysis revealed a significant decrease of the O/C ratio as a result of the torrefaction process. It was also found that the spherical inclusions were composed to a high degree of Ca, Al or Si elements. TGA analysis showed high volatile matter content in the raw black lilac, which decreased significantly after torrefaction. The study performed shows that torrefaction technology is a valuable process for the production of biocoal from the garden maintenance residues.

Keywords: torrefaction, biomass, bioenergy, biocoal, garden residues



USEFULNESS OF BIOTESTS IN EVALUATION OF METHANE FERMENTATION WASTE SUITABILITY AS FERTILIZERS IN JERUSALEM ARTICHOKE BIOMASS PRODUCTION

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The aim of the presented experiments was to investigate the suitability of waste from methane fermentation as fertilizers in the production of Jerusalem artichoke (*Helianthus tuberosus* L.) biomass, using the laboratory biotest Phytotoxkit. The commercial bulbs of Jerusalem artichoke were sown in Phytotoxkit-modified containers filled with a universal substrate and fertilized 1-3 times with the waste from the methane fermentation in doses ranging from 133 up to 53333 L · ha⁻¹. Based on daily measurements under the greenhouse environment, the growth rate of the roots and above-ground parts of the plants was assessed, as well as their condition in the five-degree scale and their health. During plant development, the physiological activity was assessed by measuring index of chlorophyll content in leaves, net photosynthesis, transpiration, stomatal conductivity, intercellular CO₂ content, and at the end of growth – fresh and dry biomass.

The obtained results showed that the studied waste from methane fermentation could be used as fertilizers in Jerusalem artichoke plant cultivation because they increased their fresh and dry biomass yield, as compared to the control. The research also confirmed that the used biotests are useful to assess these wastes suitability as fertilizers, they are not time-consuming and can be carried out under laboratory conditions which makes them an alternative to laborious and long-term field studies. The roots and above-ground parts of the plants fertilized with these wastes grew faster than controls and showed higher physiological activity, reflected by higher chlorophyll content in leaves, net photosynthesis, transpiration, stomatal conductivity and lower intercellular CO₂ content. Moreover, they were more vigorous, of higher quality and less affected by pathogenic microflora. The doses of 13333-26666 L · ha⁻¹ were most favorable for the growth of plants and biomass production. The beneficial impact of the studied waste on growth and health of plants offers the prospect of their use in Jerusalem artichoke biomass production and solves the problem of their utilization or disposal. Their natural use in crop production can be an alternative to synthetic fertilizers, which are toxic to environment.

Keywords: biomass production, methane fermentation, Jerusalem artichoke

The research was financed by National Center for Research and Development in Poland, Grant BIOSTRATEG2/296369/5/NCBR/2016.



USEFULNESS OF PHYTOTOXKIT BIOTESTS IN INDICATING STIMULATORY IMPACT OF APOL-HUMUS AND STYMJOD ON SORGHUM SEED GERMINATION AND BIOMASS PRODUCTION

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The effects of a new generation ecological soil improver Apol-humus (Poli-Farm Sp. z o.o., Poland) and a nano-organic-mineral fertilizer Stymjod (PHU Jeznach Sp.J., Poland), applied to seeds and to substrate on germination, growth of roots and upper parts of plants and physiological activity in sorghum (*Sorghum bicolor* L.) were studied in order to explore the possibility of increasing energy biomass yield by treatment with these compounds and to see the suitability of Phytotoxkit biotests in studies on plant development evaluation instead of long-term field investigations.

Apol-humus and Stymjod applied to the seeds or to the substrate in modified Phytotoxkit plates, increased dynamics of germination, number of germinated seeds and growth of roots and upper parts of plants. These improvements were associated with greater activity of the selected physiological events which make the essential impact on plant development and production of biomass, including activity of acid (pH = 6.0) and alkaline (pH= 7.5) phosphatase, RNase and nitrate reductase. The enhanced growth of seedlings was also related with the increased physiological activities in leaves, measured by the index of chlorophyll content, net photosynthesis, transpiration and stomatal conductance and decreased intercellular CO₂ concentration. The increased growth of sorghum plants and their biomass yield were determined by dosages of the applied biological compounds to the seeds or to the substrate and the frequency of their application to the substrate in which the plants were grown. Application of Apol-Humus to the substrate was more beneficial than to the seeds. Moreover, triple application was more effective in improving growth of sorghum plants and their physiological activity and biomass yield than single one.

Stimulating impact on the plant growth could be caused by fulvic and humic acids and chitosan polymers contained in Apol-humus and by iodine, macro and micronutrients, including amino acids and other organic compounds present in Stymjod. The performed research showed that Phytotoxkit tests can be used to assess the benefits of Apol-humus and Stymjod application concerning higher sorghum biomass production. However, the confirmation of these compound applicability on a commodity scale needs further research under field condition.

Keywords: biomass production, *Sorghum bicolor* L., Apol-humus, Stymjod

Research were supported by National Centre for Research and Development Grant No. BIOSTRATEG2/296369/5/NCBR/2016.



USING PHOTOVOLTAIC CELLS FOR THE LARGE-PANEL URBAN FABRIC REVITALIZATION, BASED ON SELECT NEIGHBORHOODS

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The aim of this paper is to present possible ways in which the process of large-panel urban fabric revitalization can be combined with renewable energy technologies. The social studies conducted in recent years confirm that the residents are interested in the above solutions. Alternative energy sources may help create a new brand of prefabricated apartment blocks. The geometry of modular apartment block buildings allows for uninhibited distribution of the cells on roofs and side walls of specific structures. Additionally, thanks to their South-Western position, the performance of the cells should be perfectly satisfying. The energy surplus would mainly be used to illuminate the intersections, such as hallways and entrances. This would help save money, which would benefit the entire community. Another benefit of the solution is aesthetics. The cells on the side walls can help add an interesting layer to the large-panel buildings that have become so infamous over the years, while also averting the overabundance of mismatched pastel colors. The studies conducted confirmed the assumptions and the implemented solutions will help not only add to the innovative aspect of post-modern buildings, but also protect the natural environment.

Keywords: *photovoltaic, revitalization, large-panel urban*



UTILIZATION OF WASTE FROM METHANE FERMENTATION IN LEMNACEAE PLANT BREEDING INTENDED FOR ENERGY PURPOSES

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The most rational management of waste from the agro-food industry is to process it by methane fermentation into biogas. In more and more countries, government programs are being created to support the construction of biogas plants and the processing of biogas into electricity. It is expected that this will reduce pollution of the environment as well as increase the country's energy balance. Large quantities of digestate effluent which are produced as the side effect of this process can be effectively utilized as an economic nutrient ingredient in the Lemnaceae aquatic plant culture. Water biomass can be readily available in rural areas not interfering with the priority role of agriculture as food production.

The research was carried out under laboratory conditions with the use of aquatic plants of the family Lemnaceae (*Spirodela polyrrhiza*) from in vitro cultures of the Plant Ecology Division of the Biology Department of the University of Lodz. The plants were cultivated in a phytotronic room at 24 °C on a prepared medium containing variants of methane fermentation effluent and a control series. The following physiological parameters were measured: net photosynthesis, transpiration, stomatal conductivity and intracellular CO₂ concentration, moreover, plant growth factor, chlorophyll index, fresh and dry biomass were determined.

The studies indicated the possibility of using leachate produced by methane fermentation as an economic substrate in the production of farm media for Lemnaceae. This method can be an effective way to recycle biogas waste and an economical high-quality biomass production system with a wide range of applications in bioenergy (liquid and gaseous biofuels) and agriculture (feed, fertilizer), which will significantly reduce costs and contribute to reducing pollution. Further research in the increased field scale (lagoon) is required to confirm the results.

Keywords: *waste, methane fermentation, Lemnaceae*

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VARIABILITY OF SOIL TEMPERATURES DURING 5 YEARS OF A HORIZONTAL HEAT EXCHANGER OPERATION CO-OPERATING WITH A HEAT PUMP IN A SINGLE-FAMILY HOUSE

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The paper presents the results of measurements of the temperature distribution of the ground source heat with the brine-water heat pump and a horizontal ground heat exchanger. The research was carried out for a period of 5 years. The horizontal ground heat exchanger is a ground source for a heat pump with the measured average heating output of 9.53 kW and cooling capacity of 7.8 kW, installed in a single-family house located in the north - eastern part of Poland. A heat exchanger with the area of 253 m² is located at a depth of 1.9 m in the groundwater layer being in hydraulic contact with the waters of Lake Elk.

During the first four years, each year it can be observed that soil of the ground heat source is chilling at a depth of 1.9m, due to working heat pump. Between January and April heat pump was working with the ground source frozen, where the temperature ranged from - 0,6°C to - 2,1°C. Subsidence and cooling of the soil was caused by a relatively small active area of ground source of heat which was 253 m² with the dimensions of 11 m × 23 m, as well as inadequate spacing between sections of the spiral heat exchanger amounting to 0.1 m.

After operational testing of the heat pump and the ground source of heat, the "microBMS" a control and optimization system, working independently from the heat pump control was introduced into the building in January 2014. Its introduction has significantly increased that lower minimum flow temperature of the heat exchanger to + 0.3 ÷ 0.9°C. There was also an increase of the minimum temperature of the ground source heat exchanger by the value of +1.3 ÷ 3.0°C and decrease in cooling of the soil in August - an increase of temperature by about 0.7°C.

Operational tests of heat pump system working with an unusual and original application of horizontal spiral heat exchanger have shown that in the first period introduction of an additional heat exchanger was considered. In subsequent years of heat pump operation and after the introduction of its independent monitoring and optimization, the study showed good properties of ground source and its complete recovery in the summer. Ground source, chilled properly to a temperature of about 0°C became a very good cooling reservoir during periods of spring and summer heat.

The use of the Earth's heat helps to improve the environment, while in some way it violates the natural thermal and agrophysical condition of the ground.

Operation of ground source heat pump affects the periodic changes of agro-thermal parameters of soil. The delay of the vegetation period above the horizontal heat exchanger of heat pump is about 13 days and is caused by postponed thawing of ground observed at 0.05 m.



Keywords: temperature distribution, horizontal ground heat exchanger, ground, heat pump

WALIDACJA PROTOTYPÓW NAWOZÓW NA BAZIE SUROWCÓW ODPADOWYCH DO NAWOŻENIA WARZYW

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W ramach projektu EKO-BIONOM wytworzono prototyp nawozowy na bazie stałej frakcji pofermentu oraz popiołu z biomasy. Możliwość wykorzystania nowego produktu, jako nawozu, zależy od jego oceny w zakresie zawartości składników mineralnych i tempa uwalniania składników mineralnych do gleby oraz reakcji testowanych roślin. Ocena przydatności prototypów nawozów z recyklingu polega na określeniu optymalnej w nawozie proporcji pomiędzy pofermentem a popiołem z biomasy, a następnie dawki, spełniającej w/w wymogi. Do walidacji prototypów nawozów na bazie surowców odpadowych stosuje się warzywa, głównie ze względu na zawartość metali ciężkich w częściach jadalnych oraz szybkie tempo wzrostu. W przeprowadzonym doświadczeniu testowano wpływ dawki dwóch prototypów na bazie popiołu z biomasy i pofermentu o udziale składowych: popiół z biomasy/poferment, jak 1:2,1 (prototyp A9) oraz 2,1:1 (prototyp A3). Dawki prototypów wynosiły: 0,0; 0,2; 0,4; 0,8; 1,6; 3,2 t/ha. Warzywa zastosowano w następującej kolejności: rzodkiewka I, fasola szparagowa, rzodkiewka II. Zgodnie ze schematem doświadczenia, stan zasobności gleby po 2-tygodniowej inkubacji z nawozami wskazał wzrost zawartości składników mineralnych oraz metali ciężkich. Wzrost dawki nawozu wpływał na wzrost plonu korzeni rzodkiewki I. Fasola szparagowa tylko w stanowisku A9 wykazała reakcję na dawki, uzyskując największe plony na kombinacji z 0,2 t/ha nawozu. A dalszy wzrost dawek powodował spadek plonów. Plony korzeni rzodkiewki II były mniejsze od rzodkiewki I, a do tego wykazały spadek w stanowisku A3 aż do dawki 1,6 t/ha. Przekroczenie dopuszczalnej zawartości ołowiu nastąpiło tylko w korzeniach rzodkiewki I, w stanowisku nawożonym prototypem A9, w dawkach 1,6 i 3,2 t/ha. W stanowisku A3 wyczerpanie dostępnych składników mineralnych wpływało na brak reakcji plonotwórczej fasoli oraz spadek plonów rzodkiewki II. W stanowisku A9 występowała ta sama zależność, ale przewaga pofermentu w składzie tego prototypu miała wpływ na lepsze zaopatrzenie roślin w składniki pokarmowe. Zbyt duże dawki prototypu A9 mogą stanowić potencjalne źródło metali ciężkich. Podsumowując, w uprawie warzyw mogą być stosowane jednorazowe dawki nawozów na bazie pofermentu oraz popiołu z biomasy, jednakże w dawkach małych (do 0,8 t/ha), przy odpowiednim poziomie zasobności gleby. Część organiczna z prototypu A9 prowadzi do szybkiego uruchomienia zasobów glebowych, ale także do ich głębokiego wyczerpania przy intensywnie prowadzonej produkcji.

Keywords: nawóz, poferment, popiół z biomasy



WIND ENERGY. CAN A WELL- CONDUCTED INVESTMENT PROCEDURE HELP AVOID CONFLICTS BETWEEN LOCAL AUTHORITIES, AN INVESTOR AND A LOCAL COMMUNITY?

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The increasing development of wind energy is accompanied by social scepticism stemming from certain apprehension connected with its potential influence on the environment and humans. Therefore, that may dispel or diminish these doubts and anxieties, are an extremely crucial element, which is also required and regulated by law. According to the Polish Society of Sociologists such consultations should involve three elements: the information as to the range of the planned investment, counselling based on the opinion of local residents gathered earlier and participation, i.e. active contribution of the recipients in the decision-making process. The research presents the investment procedure conducted in Kramsk Municipality and the results of the survey which was conducted among the local community on completion of the investment.

They lead to a conclusion that conscious society members generally speaking want to extend their knowledge. Thus, owing to an extensive education policy conducted by a local self-government, residents may acquire certain knowledge on the subject of wind energy and consequently they stop being just passive recipients sometimes hostile towards the investor. On the contrary, they may actively participate in the investment procedure and adopt friendly approach towards RES and other future investments.

Keywords: *development of wind energy, social consultations*



WPŁYW INSTALACJI SOLARNEJ NA ZMIANĘ STRUKTURY PALIWOWEJ CIEPŁOWNI

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Polska jako członek Wspólnoty Europejskiej zobowiązana jest do zmiany struktury paliwowej na rynku energii. Jest to konsekwencją przyjętych zobowiązań międzynarodowych, jak również troski o środowisko naturalne. Zmiana struktury paliwowej powinna być ukierunkowana na zmniejszenie udziału węgla, a jednocześnie zwiększenie udziału odnawialnych źródeł energii. Spalanie węgla jest źródłem emisji szkodliwych zanieczyszczeń, natomiast wykorzystywanie w coraz większym zakresie odnawialnych źródeł energii przyczynia się do poprawy stanu środowiska.

W pracy przedstawiono zastosowanie układu kolektorów solarnych jako elementu wspomagającego proces wytwarzania ciepła w tradycyjnej ciepłowni węglowej. Omówiono efektywność pracy ciepłowni w poszczególnych miesiącach roku. Dokonano oceny wpływu instalacji solarnej na zmianę struktury paliwowej ciepłowni.

Keywords: *instalacja solarne, kocioł węglowy, paliwa, OZE*



WYKORZYSTANIE INSTALACJI SOLARNYCH JAKO SPOSÓB OGRANICZENIA NISKIEJ EMISJI

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W Polsce głównym paliwem energetycznym i ciepłowniczym jest węgiel. Spalanie węgla jest jednym z podstawowych procesów odpowiedzialnych za zanieczyszczenia powietrza atmosferycznego, wód, gleb. Od połowy lat dziewięćdziesiątych ubiegłego wieku w energetyce zawodowej w Polsce przeprowadzono bardzo wiele działań, które w znaczącym stopniu przyczyniły się do ograniczenia emisji z tego sektora gospodarki. Skutki podobnych działań można zaobserwować również w ciepłownictwie. Natomiast wytwarzanie ciepła w gospodarstwach indywidualnych jest prawie katastrofalne pod względem ekologicznym. Nabiera to szczególnego znaczenia w dobie dyskusji o szkodliwości niskiej emisji, ponieważ spalanie węgla w gospodarstwach indywidualnych jest, obok emisji komunikacyjnych, podstawową przyczyną powstawania tego rodzaju zanieczyszczeń powietrza.

W pracy przedstawiono zastosowanie instalacji solarnej jako elementu wspomagającego produkcję ciepła w tradycyjnej ciepłowni węglowej. Aby ograniczyć emisję zanieczyszczeń z palenisk gospodarstw indywidualnych, zaleca się rezygnację z tego typu ogrzewania i, tam gdzie jest to możliwe, przyłączenie do sieci centralnego ogrzewania, zasilanych z ciepłowni. W ten sposób rozdrobnione wytwarzanie ciepła, w przypadku którego kontrola procesu spalania jest mało efektywna, zostanie zastąpiona centralnym wytwarzaniem ciepła w miejscu, gdzie jego uciążliwość dla lokalnych społeczności jest ograniczona, a sam proces spalania jest kontrolowany. Ponadto zastosowanie instalacji solarnych pozwala ograniczyć ilości spalane go węgla i tym samym ograniczyć szkodliwe emisje zanieczyszczeń.

Odnawialne źródła energii charakteryzują się losowością w zakresie możliwości ich wykorzystywania. Często jest tak, że potencjalne możliwości ich wykorzystania (wiatr, Słońce) nie pokrywają się czasowo z zapotrzebowaniem na energię. Instalacja solarna pracująca jako element wspomagający kotły węglowe wydaje się być dobrym sposobem rozwiązania wyżej opisanego mankamentu energetyki odnawialnej.

Keywords: solar, kocioł węglowy, niska emisja, OZE



COST PRICE OF A UNIT OF ENERGY, OBTAINED BY THE TECHNOLOGY OF METHANE FERMENTATION OF AGRICULTURAL BIOMASS CONVERSION

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Residues of agricultural production need appropriate utilization and conversion into energy products to rise production efficiency, on one hand, and to protect environment, on the other hand. Production of agricultural products results in appearance of a considerable amount of biomass residues, which can be used as raw material for production of different kinds of energy (thermal, electric, mechanical). It can be differently utilized, obtaining different energy products, i.e. solid, liquid and gas fuel. Development of the methodology of efficient utilization of agricultural production residues for energy purposes is complicated by the fact that the biomass is different by its kind and origin, processing technologies and capacity of processing enterprises, etc. Thus, development of a unified methodology is a problematic process. Issue of methodology of efficient agricultural production residues utilization for energy purposes should be solved separately for each kind of biomass, way of processing and production capacities. Methane fermentation is one of efficient ways to converse biomass into energy products. The fermentation results in obtaining of biogas, which can be used as fuel for internal combustion engines, operating in cogeneration regime and supply 90% of conversion efficiency, besides, with generation of electric energy, which is high quality energy. Usually, droppings of animals and poultry are used as primary raw material for such processes, because its utilization is ecologically and economically needed. Under such conditions, it is possible to supply a minimum cost price of a unit of obtained energy. Generally, cost price of an energy unit is calculated as a ratio of total expenses, but costs of by-products and additional financial revenues, and amount of produced energy. The indicator will substantially depend on enterprise's capacity, kind of anaerobic fermentation process, primary raw material. Methane fermentation produces biogas and large amount of organic matter, which can be specially processed and used as high quality organic fertilizer. The mentioned technology can supply high energy efficiency, comparing to other kinds of biomass utilization, which is revealed in a correlation of the obtained energy and total energy expenses.

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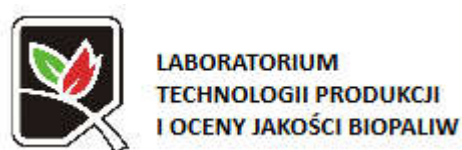
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