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NUMERICAL ANALYSIS OF THE COMBUSTION PROCESS IN THE WOOD STOVE

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Today small-scale wood stoves becoming increasingly popular in Poland, and the use of wood logs in small-scale units stoves is expected to increase substantially towards 2020. Many new constructions are created and numerical modelling of combustion processes is an increasingly important stage in the design work of new constructions. The article presents the numerical study of a combustion process in a wood stove. The computational fluid dynamics (CFD) model include fluid flow, chemical combustion reaction, and heat exchange. The simulation was proceeded by experiment with the commercially produced fireplace by company Kratki.pl. The test bench was designed according to PN-EN 13240 codes requirements. The successful verification of results with experiment was a base to perform a series of simulations to achieve the optimal construction with increased efficiency and reduction of the harmful components of combustion.

Keywords: *CFD, combustion simulation, stove, thermal measurements*



EXPERIMENTAL DATA COLLECTION FOR NUMERICAL MODEL VERIFICATION FOR WOOD STOVE

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Ability to perform a simulation with reliable results require experimental verification of the numerical model and simulation methodology. To be able to make verification the test bench was designed and build according to PN-EN 13240 codes requirements with the additional data acquisition system. The bench data collected system consist of exhaust gas analyser with a probe placed in the chimney which measures CO, CO₂, O₂, NO, thermal imaging camera which monitors the temperature distribution outside the stove. To be able to monitor the heat distribution inside the combustion chamber the array of 36 thermocouples were placed inside. The data were recorded during entire wood burning cycle according to codes. Tested fireplace insert was the commercial product by company Kratki.pl. The successful verification of results with experiment was a base to perform a series of simulations to achieve the optimal construction with increased efficiency and reduction of the harmful components of combustion.

Keywords:*CFD, combustion simulation, stove, thermal measurements*



THE PHYSICO - CHEMICAL ANALYSIS OF BIOMASS PELLETS IN THE ASPECT OF EXISTING STANDARDS

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The paper presents biomass as the renewable energy alternative source to fossil fuels which combustion gives a neutral CO₂ emissions and therefore should be the main carrier of primary energy in Poland. The paper presents the combustion heat results, humidity, ash content, volatile matter and C, H, N, S of selected dry wood pellets (pellets straw, energy-crop willow pellets, sawdust pellets) with divided into factions: 0,5mm, 0,25mm, 0,125mm and below 0,125mm. In connection with the results analysis of these studies the standard requirements were discussed (PN-EN ISO 18123:2016-01 "Solid biofuels-Determination of the content of volatile matter"; PN-EN ISO 18125:2017-07 "Solid biofuels - Determination of caloric value"; PN-ISO 1171:2002 "Solid fuels - Determination of Ash Content"; PN-EN ISO 18122:2016-01: "Solid bio-fuels - Determination of Ash Content"; PN-EN ISO 18134-1:2015-11: "Solid Bio-fuels - Determination of Moisture Content - Drier method - part 1: Total Moisture - Reference Method", regarding the basic parameters determining the biomass energy.

Keywords: *Biomass - alternative renewable energy; combustion heat results, humidity, ash content, volatile matter*



LABORATORY-TEACHING BUILDING ENERGIS AS THE EXAMPLE OF INTELLIGENT BUILDING

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Since the second half of the twentieth century very rapid technological development of society is observed, it greatly contributed to the increased use of more electrical appliances by the man in everyday life. The use of very modern telecommunication installations and building automation in the construction enabled the users to profit from all held household appliances, electronics and other teletechnical devices unlimited assuming reliability, comfort and safety. The use of a such large installation number in newly built houses as well as their complexity has caused the need to manage these installations and devices. The consequence of these opportunities and needs are so called intelligent constructions in which embedded devices and installations surveillance is almost unlimited they give a very big possibility of the so-called building "configuration".

The article presents an intelligent building management system on the example of teaching-laboratory building - Energis which is the Department of Environmental Engineering, Geomatics and Energy seat in Kielce University of Technology.

BMS building Energis is equipped with automatic systems and communication networks which allow for full object's control. The system controls and manages the integrated heating systems (heat pumps, MPEC node, biomass boiler), installations, ventilation and air conditioning HVAC, lighting inside and outside the building. The second BMS basic function is continuous monitoring of all telecommunication systems, building's automation and security systems (controlled access to the premises) with the registration of the individual installation parameters. BMS also allows to generate and send alarms in case of irregularities in the each device operation as well as in exceeding the set points.

The paper also reviewed selected building's installations automation including the possibility of parameters registration by BMS (Building Management Systems). We also performed a detailed analysis of the selected measurement data recorded by the system in terms of energy.

Keywords: *intelligent constructions, building management systems, automation*



PRELIMINARY ASSESSMENT OF THE LOCAL SOLAR ENERGY CONDITIONS IN HEALTH RESORT RABKA ZDRÓJ - AS A POTENTIAL FOR USING PHOTOVOLTAIC MICROINSTALATION

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Rabka Zdrój is a health resort municipality located in Southern Poland. One of the basic requirements to awarded status of health resort is confirmed therapeutic properties of the climate. The therapeutic properties of the climate are atmospheric conditions favorable to preventing the deterioration of the health, treatment and mitigation of the impact of diseases. In order to assess the therapeutic properties of the climate, the following elements shall be taken into consideration: air temperature, sunshine duration, cloud cover, relative humidity of air, atmospheric and water vapor pressure, wind – speed and direction, atmospheric phenomena: fog, storms, snow cover, glaze frost.

The conditions of irradiation and sunshine duration are differentiated in Poland. Based on multiannual data, it may be identified that total horizontal irradiation is between 850 and 1200 kWh/m². In turn, the value of sunshine duration is in the range 1420 to 1660 h/a. In the case of Rabka Zdrój, these values are 1100 kWh/m² and 1500 h/a, respectively. Furthermore, Rabka Zdrój is located in an area where the photovoltaic power potential is one of the largest in Poland. It is 1050 – 1100 kWh/kWp-1 and characterizes the south-eastern part of the country.

The article presents the first results of data obtained from a monitoring station located in the health resort Rabka Zdrój. The assessment of sunshine duration in the health resort area is based on data for the winter period. It should be noted that the use of solar energy becomes more and more popular in Poland. This fact is confirmed by data for the photovoltaic microinstallation market in Poland. Total capacity of microinstallations in 2017 was 172,5 MW, while in 2016 it amounted to 91,2 MW. The number of PV installations connected to the electricity grid still grows; for this reason, the market of solar energy has a significant potential in Poland.

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Keywords: solar energy, health resort, photovoltaic microinstallation



ANALYSIS OF ENERGY STORAGE CAPABILITIES IN HYDRATED SODIUM ACETATE USING THE PHASE TRANSITIONS OF THE FIRST KIND

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Heating buildings account for a large part of our energy use. The amount of Solar energy is much higher in summer than in the winter periods when heating demands are much larger. That is why thermal energy storage technologies are needed to match the supply of solar energy to changing heating needs. Currently available thermal energy storage systems, using water as a storage medium, work well, but mainly for short-term storage, because heat losses limit the storage period. For longer storage periods, more advanced technologies are needed. Storages utilizing the latent heat of fusion of a material has been suggested for improving the performance compared to the storage of sensible heat. Phase Change Materials (PCM) in the latent heat storage has been taken into account as an energy storage in RES technologies. An example of such a material is sodium acetate CH_3COOHNa , which in room temperature is a solid body, and after exceeding the phase transition temperature ($T_{pf} = 55\text{ }^\circ\text{C}$), it turns into a liquid. The substance, when in a liquid state, characterizes with its ability to change into a supercooling state, until it reaches the temperature nearing $0\text{ }^\circ\text{C}$. It is possible to initiate the process of a phase transition while CH_3COOHNa is in the state of undercooling ($0\text{ }^\circ\text{C} \leq T \leq 55\text{ }^\circ\text{C}$) by switching on an acoustic generator (20 kHz). The phase transition that has been initiated in this way can be observed through crystallizing the substance, which was used as a specimen; and it indicates a phase transition of the first kind, during which huge amounts of latent heat are released. Therefore the occurring amorphous substance transition is an exothermic process.

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Keywords: Phase transitions, Hydrate sodium acetate, Latent heat, Energy storage



missivity of biomass mixtures and temperature distribution in the combustion chamber in the process of thermal energy production

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This article presents the results of research on biomass combustion process of vegetable origin in a 23 kW SAS boiler. The research material was prepared from sawdust and fruit pomace. The assembly of thermocouples in the experimental boiler allowed the reading of temperature values at individual levels of the combustion chamber. In addition, the composition of waste gases was monitored using the GASS 3000 flue gas analyzer. The obtained emission level was compared with the limit values in accordance with the Regulation of the Minister of Development in force. The physical parameters of the mixtures have been examined, which was subjected to the combustion process. The analysis of static and dynamic material characteristics of biomass aims at finding a low-emission and at the same time high-efficiency renewable fuel, adapted to V class boilers.

Keywords:*Biomass, emissions, combustion process parameters*



DYNAMICS OF CHANGES IN THE TOTAL CONSUMPTION OF MOST IMPORTANT RENEWABLE ENERGY SOURCES IN POLAND

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The strategic goal of Poland's energy policy is to take actions that will increase the share of energy from renewable sources in final gross energy consumption to 15% in 2020 and 20% in 2030. The effects of these actions will be: reducing greenhouse gas emissions, improving the security of energy supply, development innovative sectors of the economy and increasing employment in individual regions of the country. Based on Central Statistical Office data, the most important renewable energy sources were analyzed. Their consumption in 2006-2016 has been compiled in the global system for Poland. It was found that during this period the share of individual energy sources in the total consumption of renewable energy were respectively: 80.7% for solid biofuels, 8.2% for liquid biofuels, 5.3% for wind energy, 2.6% for hydropower, 2% for biogas and 1.2% for other renewable energy sources. In addition, the following indicators were determined at work: maximum relative changes in consumption, maximum changes in the share of consumption, periodic and annual rate of change in the consumption of these energy sources in Poland. The largest increase in energy consumption was established for solid biofuels and wind energy, while the highest dynamics of changes was established for: wind energy, other renewable energy sources (biodegradable municipal waste and solar energy), liquid biofuels and biogas.

Keywords: energy consumption, renewable energy sources, biofuels, biogas, wind energy, hydro energy



SOLAR POWER OUTPUTS FROM SOLAR COLLECTORS INSTALLED ON ROOFS

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Solar collectors are becoming increasingly more popular in Poland. Most often they are used to prepare domestic hot water, whereas they are also utilized in heating systems. Economic advisability of solar panels application depends on many factors including a building location, its roof area and shape, collector efficiency, the house surrounding, including high vegetation occurrence influencing on rooftops suitability for solar energy use.

Previous researches (Kolendo i Krawczyk 2016; 2017) proved that using Geographical Information Systems GIS and geographical data acquired by modern remote technics including Airborne Laser Scanning ALS accompanied with using multi-criteria decision making methods can be successfully used to estimate usefulness of roofs for solar collectors installation. Number of collectors installed on the roof depends strongly on the roof shape, available area for spatial positioning solar collectors, its facilities like chimneys, ventilation shaft outlets and roof window occurrence.

The main aim of this paper is to estimate power and energy outputs per roof square meter, depending of spatial orientation and chosen architectural conditions of analysed buildings, including rooftop complexity and a period when the house was constructed. Solar conditions of analysed roofs were estimated using r.sun model implemented in GRASS GIS software and long term climatic data for building energy calculations. The two single-family estates differing in spatial orientation of building, period of construction, architectural style and high vegetation occurrence were subject of comparative research. Based on suitability analysis of selected estates we developed the average Solar Output Factor values for climatic conditions of north-east Poland, that could be successfully used in further analysis.

Keywords: solar collectors, solar gains, GIS



RENEWABLE ENERGY SOURCES DEVELOPMENT IN BIG CITIES OF POLAND IN THE CONTEXT OF URBAN POLICY

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Development of renewable energy sources (RES) is a crucial factor, influencing diversification of energy sector. Popularization of renewable energy projects has a key significance in building energy security system in Poland, therefore most of strategic decisions concerning RES are taken on the country level, and basing on EU directives, general development directions are also formed there. Implementation of assumptions referring to RES is conveyed to administrative organs of lower level. Due to the fact that the most important challenges concerning energy sector transformation, including RES projects, refer to multifunctional urban areas, it is crucial to analyze, what way urban self-government authorities put these tasks of initiating and implementing pro-ecological enterprises of RES sector in practice. Taking into account the fact that renewable energy development in cities is a leading element of urban policy, implementing directives of sustainable development and the fact that action for RES promoting are indispensable factor influencing low carbon economy development, it is assumed that renewable energy is an important pillar of low-carbon economy in cities.

Taking the above into account, the research purpose is to make analyses of initiatives and actions within renewable energy development in big cities, taken up by self-government authorities, outlined in strategic documents. Present research will be carried out in reference to real RES structure and dominant directions of RES development in cities selected for tests. Study results will enable predicting RES sector development in urban areas, as necessary condition of low-carbon economy in Polish cities.

This work was supported by grant 2015/19/N/HS4/02586 from the National Science Centre, Poland.

***Keywords:**renewable energy sources, low-emission economy, urban policy, ecologization of cities*



THE MODEL OF HEAT AND MASS TRANSFER TO DETERMINE THE TEMPERATURE DISTRIBUTION IN THE GROUND

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The ground is an advantageous heat source for heat pumps. In comparison with the air it has a much more stable temperature and a high specific heat. The prediction of temperature distribution and heat transfer rates in the ground is of the great importance when assessing the heat pump's heat capacity.

The knowledge of the ground temperature distribution is important in the design, modeling and exploitation of ground heat exchangers and other devices related to the transport of heat in the ground (for example pipes transporting heat carriers).

When modelling horizontal ground heat exchangers, the following heat fluxes on the surface of the ground should be considered: convective heat flux, solar radiation heat flux, long-wave radiation heat flux, and a flux caused by the evaporation of water contained in the ground. A part of the solar radiation heat flux is reflected from the surface of the ground. Irrespective of the reflected flux, the ground radiates heat towards the sky. Moreover, the ground loses heat as a result of the moisture evaporation. This flux is caused by a difference in the partial pressures of water vapour on the surface of the ground and in the bulk of the gaseous phase (atmospheric air).

Thus, the simultaneous transfer of heat and mass takes place on the ground surface. The heat required for the evaporation of water is taken from the ground, which results in lowering its surface temperature, which in turn affects the equilibrium pressure, a driving force for mass transfer and the rate of the mass flow (moisture).

The inclusion of thermal fluxes associated with radiation and moisture evaporation in the boundary condition for the ground surface significantly affects the calculated values of the surface temperatures of the ground. These temperatures differ significantly from the ambient temperature.

As is known, temperature of the deeper layers of the soil is stable. Its value (the undisturbed ground temperature) can be determined from a correlation equation, presented in this paper. The dependence is of the semi-empirical nature. It is based on the heat balance equation on the surface of the ground and takes into account the heat flux caused by evaporation of moisture by linking the rate of this stream with the annual amount of rainfall.

The aim of the study is to analyze the size of heat fluxes occurring on the surface of the ground, especially in terms of variability of these fluxes over time.

Keywords: *heat transfer, temperature distribution, heat fluxes*



FUZZY MODEL OF WIND TURBINE CONTROL

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The article presents proposes a fuzzy model for wind turbine control based on the formulated assumptions.

Wind turbines can operate at fixed or variable speeds. The manner in which the rotational speed of a wind turbine is controlled is an important consideration. The power output of a wind turbine can be controlled with the involvement of two mechanisms, active stall and passive stall, and six major control methods (yaw control, active pitch regulation, etc.).

A fuzzy model of the control system is composed of three main modules: Fuzzification, Inference and Defuzzification.

A fuzzy model was used to describe a wind turbine whose output is controlled by changing the blades' angle of attack and rotating the nacelle to a position facing the wind. The input parameters in the developed control model were: wind speed, angle of attack, deflection from wind direction, and power demand. The output parameters in the developed model were: generated power, angle of attack, and nacelle offset from wind direction.

The values of input and output parameters were described in fuzzy terms, and the rules of a fuzzy system were developed. The model was described in the LabView environment, and it was tested with the use of various defuzzification methods.

The results of LabView simulations revealed that a model for controlling the power output of a wind turbine was successfully developed based on fuzzy logic. The control model responded appropriately to changes in the values of input parameters. An increase in power generation was observed when the angle of attack was increased to a given threshold value under stable weather conditions. Power generation decreased when that threshold value was exceeded.

The developed wind turbine model can be used to predict the electric power output of a wind turbine under various weather conditions.

Keywords: *wind turbine, model, fuzzy logic, control*



METHODS OF RECYCLING EXPIRED PHOTOVOLTAIC PANELS IN POLAND

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The rapid progress in photovoltaics increases the availability of inexpensive and reliable electricity for individual, industrial and commercial users. Photovoltaic systems offer a viable alternative to unsustainable methods of energy generation. Photovoltaic installations convert solar energy into electric energy, thus reducing fossil fuel use and lowering greenhouse gas emissions. The Polish photovoltaics market began to develop rapidly in 2013, and the installed capacity of solar-powered systems continues to increase every year. According to the Institute for Renewable Energy, the total installed capacity of photovoltaic systems reached around 199 MW at the end of 2016. More than 101 MW was installed in 2016 alone, including 73 MW in micro-generation systems. Polycrystalline installations are most popular, and they are followed by monocrystalline modules. Solar panels covered with amorphous silicon and thin film are less popular solutions. The dynamic growth of the Polish photovoltaics market is driven mostly by high levels of consumer awareness rather than a cohesive energy policy. Solar panels have an estimated life of 20-30 years, which means that expired modules will have to be effectively managed in the near future. Recycling appears to be the most cost-effective and environmentally-friendly solution, and it can be used to recover more than 90% of the components and materials in solar panels. Recycling delivers a host of environmental benefits by saving energy and raw materials, minimizing the release of harmful chemical compounds, and reducing the space for storing expired and damaged panels. The article discusses various solutions for recycling photovoltaic modules as part of a strategy promoting the sustainable management of waste from expired PV systems.

Keywords: *solar energy, waste management, photovoltaic panels, recycling*



AN ANALYSIS OF ELECTRICITY GAINS FROM VARIOUS PHOTOVOLTAIC INSTALLATIONS UNDER REAL-WORLD CONDITIONS OF NORTH-EASTERN POLAND

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The efficiency of photovoltaic systems is determined by numerous local factors, including technological solutions applied, materials used, orientation, shading, and angle relative to the horizontal plane. All of these factors are important for optimizing the operating conditions of photovoltaic systems in Poland where weather conditions are not conducive to the development of solar panel technologies.

The article discusses the efficiency of monocrystalline and polycrystalline photovoltaic installations under real-world conditions of north-eastern Poland. Photovoltaic systems located in the city of Olsztyn were analyzed from October 2017 to March 2018. The installations had a total power rating of 276.66 kWp, and it comprised:

- 111 Yingli Solar YL250P-29B polycrystalline panels installed on parking canopies;
- 63 Mono Black SW250 Solar World monocrystalline panels installed on a south-facing wall of an office building;
- 804 Bisol BMO290SW (290 Wp) monocrystalline panels installed on the roofs of warehouses and workshops and a social building. On the roof of a garage, each of 138 panels was connected to a P300 power optimizer, and the remaining panels (two panels in a series) were connected to a P600 optimizer.

The panels were installed on 7 buildings and 2 parking canopies, located on an area of approximately 3.02 ha. They were characterized by different orientations towards the sun (north-east, north-west, south-east and south-west), different tilt angles and vertical positions on the walls of buildings.

Measurements were recorded for 17 inverters. High variations in the operating conditions of the analyzed photovoltaic systems, resulting from changes in weather conditions, led to considerable differences in the amount of generated energy.

Keywords: *polycrystalline photovoltaic installation, monocrystalline photovoltaic installation, efficiency of a photovoltaic system*



ANALYSIS OF THE EFFICIENCY OF A PHOTOVOLTAIC MICROSYSTEM IN NORTH-EASTERN POLAND

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This paper presents the results of a two-year study investigating the efficiency of a photovoltaic system installed on a flat roof of a residential building in north-eastern Poland. The analyzed system, with a peak power rating of 4.77 kWp, comprised 18 polycrystalline photovoltaic modules and an inverter. This on-grid PV system was not connected to the electrical grid in the building. In the analyzed period, the PV system generated 8130 kWh of energy, and the average monthly power output was 338.75 kWh. The total power output of the analyzed solar system could cover the annual electricity demand of a residential building in 94.5%. The monthly electricity gains from the analyzed PV installation would be sufficient to cover the energy needs of the building in 100% only from the beginning of April to the end of August. The electrical energy gains from the analyzed PV system were compared with those from similar PV installations in Germany, located at similar latitudes.

Keywords: *solar energy, photovoltaic systems, solar micro-installations*



THE USE OF HEAT PUMPS FOR HEATING PURPOSES IN THE REGION OF WARMIA AND MAZURY IN NORTH-EASTERN POLAND

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The Region of Warmia and Mazury in north-eastern Poland is situated at a distance from conventional energy sources. Therefore, the Region is a Polish leader in power generation from renewable energy sources. This study investigated the efficiency of a heat pump system for heating a single-family house based on an energy balance and a cost-benefit analysis. Recent years have witnessed a growing interest in the use of heat pumps for heating purposes in the residential housing sector. Due to their lower running costs, heat pumps can provide considerable savings over other energy sources and contribute to mitigating adverse environmental impacts.

The University of Warmia and Mazury in Olsztyn has developed, in collaboration with the Warmia and Mazury Energy Agency, a renewable energy strategy for 2010-2020 in the Region of Warmia and Mazury. The strategy is consistent with the Polish Energy Policy and the national plan for the use of renewable energy sources, based on the results of studies investigating the use of heat pumps in 2000-2010.

In 2010, total energy consumption in the analyzed area reached 71 827.5 TJ. Renewable energy consumption was determined at 7 743 TJ, which accounted for 10.78% of total energy consumption, including all sectors and energy carriers. Heat pump power generation was 7.2 TJ, i.e. 0.093% of renewable energy consumption and 0.01% of total energy consumption.

According to the proposed strategy, heat pumps with heating output ratings of 3.77 MW will be installed by 2020, and the total amount of HP power will reach 40.68 TJ, thus implying an increase of 33.48 TJ (over 446%) relative to 2010.

Keywords: *heat pump, renewable energy, energy consumption*



DATA ACQUISITION SYSTEM FOR A GROUND HEAT EXCHANGER SIMULATOR

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As part of the search for effective ways of obtaining energy, a model of a ground heat exchanger was built. It is an element of the ventilation system of a residential building. In order to develop methods for designing ground heat exchangers, it was necessary to build a model to simulate the operation of such an exchanger in laboratory conditions. This article presents a data acquisition system dedicated to cooperate with a laboratory simulator of a ground heat exchanger. The data acquisition system uses a spatial grid of temperature sensors that allow obtaining information on the temperature distribution in the space of the simulator test chamber. The second set of measured parameters is the distribution of pressure drops along the porous bed filling the simulator test chamber. The data obtained from the sensors are registered in a system developed for the needs of the simulator with a one chip microcontroller with a Cortex core. The microprocessor system also performs simulator operation control functions. The design of the system provides the possibility of autonomous simulator operation with the simultaneous acquisition of measurement data that will be used to validate the simulation model used for computer simulation of ground heat exchanger operation.

Keywords: *ground heat exchanger, data acquisition, one chip microcontroller*



DIRECTIONS FOR IMPROVING THE STRUCTURE OF THE COMBINED ENERGY SUPPLY SYSTEM FOR AIC CONSUMERS WITH ALTERNATIVE SOURCES

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The method and means of increasing the efficiency of functioning of combined energy supply systems for AIC consumers are suggested. Using the provided methodology will allow to substantiate the technical parameters of devices for converting the energy of alternative sources and to predict the cost of implementing LSAES in the CSES, in which the consumer will have a positive economic effect.

Keywords: *energy efficiency, energy saving, alternative and renewable energy, combined energy supply systems,*



THE ESTIMATION OF ABOVE- AND BELOW-GROUND BIOMASS RESIDUES AND CARBON SEQUESTRATION POTENTIAL IN SOIL ON COMMERCIAL WILLOW PLANTATION

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Bioenergy (energy from biomass) is still the most used source of renewable energy not only in Europe, but also in most of other countries around the world. Lignocellulosic crops e.g. willow (*Salix* spp.) grown as short rotation coppice are a valuable option for diversification of biomass sources that provide bioenergy. Such crops should be neutral in terms of CO₂ emissions to the atmosphere; therefore, the amount of carbon supplied to the soil (and sequestered) along with residues after harvest must at least balance the amount of CO₂ emitted to the atmosphere during cultivation, harvesting and biomass conversion.

Therefore, the aim of this study was to estimate willow residues that enter into soil on commercial plantation cultivated in triennial harvest cycle and to determine the carbon sequestration potential in soil. The research was based on biomass yields of seven different clones and varieties, estimated post-harvest residues and carbon sequestration. In addition, net carbon sequestration was determined based on CO₂ emissions from crop cultivation on the plantation.

Results showed large differences in estimated residues and potential carbon sequestration between analyzed clones and varieties depending on biomass yield and emissions from cultivation. On the other hand, it should be emphasized that these analyzes were carried out on the basis of actual yields of different willow varieties and clones cultivated on a commercial plantation, therefore their value can be very useful for both researchers and practitioners.

Keywords: *bioenergy, willow, short rotation coppice, plant residues, carbon sequestration*



THE INFLUENCE OF COMPOST FERTILIZATION ON WOOD YIELD OF WILLOW SRC IN SECOND ROTATION

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Celem badań było określenie wpływu zróżnicowanego nawożenia kompostem, wyprodukowanym z odpadów zieleni miejskiej, na plonowanie dwóch klonów wierzby energetycznej - Sprint i Boks. Badania przeprowadzono na trzyletniej plantacji wierzby, w latach 2013-2015 (druga rotacja), zlokalizowanej na glebie mineralnej, kompleksu żytniego dobrego w RSD Lipnik.

W badaniach zastosowano trzy kombinacje nawozowe: bez nawożenia kompostem (0), 10 i 20 t·ha⁻¹ suchej masy kompostu. W doświadczeniu stosowano corocznie 100 kg N, 80 kg P₂O₅ i 100 kg K₂O na 1 ha. Doświadczenie założono w kwietniu 2010 roku, stosując rozstaw rzędów 70 cm, a w rzędzie zrzesy wysadzono, co 35 cm. Badania obejmowały: liczbę pędów na roślinie, średnicę pędów, mierzonych na wysokości koszenia (ok. 10 cm od powierzchni gleby) i długość pędów oraz plony surowej i powietrznej suchej masy.

Uzyskane wyniki wykazały pozytywny wpływ zastosowanych dawek kompostu z zieleni miejskiej na kształtowanie się badanych cech morfologicznych pędów oraz plon surowej i suchej masy. Oba klony wierzby reagowały podobnie na zastosowane kombinacje nawozowe, chociaż większą średnicą i długością odznaczały się pędy klonu Boks.

Keywords: *light soil, willow clones, fertilization with compost, raw and dry matter*



AN INFLUENCE OF CROSS-LINKING AGENT ON ELECTROCHEMICAL PROPERTIES OF GEL POLYMER ELECTROLYTE

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In recent years the most widely used electrochemical power sources are lithium accumulators and supercapacitors. In the field of chemical production prospective materials include gel polymer electrolytes, which now replace yet obsolete liquid electrolytes.

This article deals with gel polymer electrolytes, which are promising replacement for liquid electrolytes. The research reports how different crosslinking agents in polymer component of gel electrolytes affect their mechanical, electrical and electrochemical properties. For measurement were used impedance spectroscopy and cyclic voltammetry methods to calculate electrical conductivity and potential windows respectively. Results indicate which crosslinking agent is more suitable for further using gel polymer electrolyte in electrochemical cell.

Keywords: *cross-linking agent, gel electrolyte, polymer, electrical conductivity, supercapacitors*



FINANCIAL CONDITION OF THE MARKET OF RENEWABLE ENERGY SOURCES

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In the context of the current global economic crisis, the increasing attention of the world community is given to increased structural transformation of fuel and energy complexes of countries. The main content of these processes is to increase the economic efficiency of energy use and reduce the dependence on their imports, which is extremely relevant for Ukraine. Thus, it is evident that there is a need for in-depth scientific consideration of the above-mentioned processes in order to localize existing problems, as well as to develop recommendations for their solution.

The article generalizes the tendencies of development of the field of alternative energy in Ukraine and the world, conducted an analysis of the financial state of renewable energy sources, developed recommendations for the improvement and development of this industry.

In the course of the study, there were positive changes in the field of alternative energy were discovered, but to date there are still a range of problems that require a state settlement:

- regulating the alternative energy market needs to be revised by creating new incentive mechanisms for companies active in the alternative energy market and developing effective guidelines;
- elimination of bureaucratic procedures for obtaining state benefits, which is possible provided that the existing system of providing them is simplified;
- activation of bank financing programs for investment in renewable energy projects.

Large-scale development of energy from renewable sources will allow to create a new ecologically safe branch of energy, which will help to increase the level of diversification of energy resources and strengthen the energy and ecological safety of Ukraine.

Keywords: *financial condotion, alternative energy industry, financing, financial analysis, economic efficiency, renewable energy sources.*



INVESTMENT ATTRACTIVENESS OF THE USE OF RENEWABLE ENERGY SOURCES

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Alternative energy and the use of renewable energy sources are a priori attractive for investment, especially for Ukraine, which is an energy-dependent state. Investment attractiveness is a complex concept, which, in the context of the use of renewable energy sources, we consider at the macro level, that is, the state as a whole, on the meso-level, that is, separate regions and sectors of the economy and the micro-level - individual enterprises or households.

The scientific article summarizes the tendencies of development of investment support for the use of renewable energy sources in Ukraine and the world, as well as a map of investment attractiveness of renewable energy sources.

In the process of scientific research, we found a number of positive changes in the use of renewable energy sources, but we emphasize the importance:

1) assessing the levels of investment attractiveness of renewable energy sources, depending on the economic, financial, social, environmental and city-forming components;

2) determination of the procedure of state investment protection for the use of renewable energy sources that will determine the content, organization and conditions for the successful functioning of economic mechanisms for the conservation and efficient use of the energy component of national wealth;

3) development of a map of investment attractiveness of the use of renewable energy sources in Ukraine.

It is noted that activation of use and investment support of renewable energy sources are the key to energy, ecological, innovation and financial security of the state.

Keywords: *investment attractiveness, investment protection, renewable energy sources, energy security, financial security.*



MARKETING CONCEPTS IN THE FORMATION OF THE BIOMASS MARKET IN UKRAINE

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In recent years, Ukraine has experienced a gradual increase in the number of facilities and installed capacity for the production of thermal and electric energy from biomass, which is one of the most promising sources of energy in the world and in Ukraine. The source of biomass is waste and residues from agriculture, food industry, waste from harvesting and processing of wood, organic waste from home and housing and communal services. To obtain biomass, special annual or perennial energy crops are also used, which give a rapid increase in mass per unit area.

The purpose of the paper is to investigate the state of development of the biomass market and determine the areas for ensuring the most effective use of marketing opportunities in this area.

Bioenergy is one of the strategic directions for the development of the renewable energy sector for Ukraine, taking into account the great potential of biomass available for its production. In recent years, there has been a gradual increase in installed capacity of biomass and biogas plants.

One of the important directions of Ukraine's energy policy is to increase the use of biomass for the production of electric and thermal energy. To achieve the goals, an important place in the management system of this area of activity is this marketing concepts.

Marketing concepts are the general purpose of the whole business activity. According to the marketing concept, the company must meet the needs of consumers that do not contradict the long-term needs of society, through a coordinated set of marketing activities, which will also allow the company to achieve its goals.

The current state of development of the bioenergy sector in Ukraine and the planned future goals require the creation and operation of a civilized biofuel market. Today, this market is not developed sufficiently, which leads to problems of finding reliable suppliers, instability of prices and quality of biofuels. In order to introduce and develop a competitive market for fuel biomass in Ukraine, it is necessary to create a stock exchange for biofuels.

Each region of Ukraine has its own specifics and opportunities for bioenergy development: in the north and west there are peatlands, wood processing waste, and energy crops. In the east and south, the straw of cereals, sunflower processing waste is remarkable. Biogas can be successfully produced throughout the country. It is possible to make various types of fuel from biomass for using in heating systems.

Keywords: *marketing, biofuel market, bioenergy, biomass, biogas*



THE IMPACT OF SELECTED CONSTRUCTION PARAMETERS OF VERTICAL AXIS TRANSVERSE TWO-STAGE WIND TURBINE ON ITS OPERATING AND FLOW FEATURES

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WPLYW WYBRANYCH PARAMETRÓW KONSTRUKCYJNYCH DWUSTOPNIOWEJ POPRZECZNEJ TURBINY WIATROWEJ O PIONOWEJ OSI OBROTU NA JEJ CECHY EKSPLOATACYJNE I PRZEPŁYWOWE

Wiodącą rolę w budowie turbin wiatrowych o pionowej osi obrotu odgrywają turbiny Darieusa wykorzystujące do swego działania siłę unoszenia oraz urządzenia typu Savoniusa, wykorzystujące opór łopat dla napływającej strugi powietrza. Choć w swej podstawowej wersji mają niższą wydajność niż pierwszy typ VAWT (Vertical Axis Wind Turbine – turbiny o pionowej osi obrotu) to jednak zalety takie jak rozpoczęcie pracy przy niższej prędkości wiatru sprawiają, że coraz częściej są wykorzystywane przy słabych warunkach wietrznych a prace badawcze nad ich rozwojem i zwiększaniem wydajności tego typu turbin są coraz bardziej uzasadnione.

Badania w prezentowanym artykule skupiają się na konstrukcji, opartej na dwustopniowej poprzecznej turbinie przepływowej, działającej na zasadzie turbin Savoniusa. Jest to urządzenie składające się z rotora wyposażonego w dwanaście łopat oraz otoczonego taką samą ilością kierownic wiatru. W celu przeprowadzenia badań laboratoryjnych wykonano model turbiny, który umieszczono w tunelu aerodynamicznym z możliwością pomiaru podstawowych parametrów eksploatacyjnych oraz analizy przepływowej techniką PIV. Model zaprojektowano jako konstrukcję skręcaną pozwalającą na dowolne ustawianie wymienionych elementów konstrukcyjnych względem siebie w założonych granicach. Badania pozwoliły na zoptymalizowanie ustawień oraz pokazały ich wpływ na wydajność turbiny. Analizując przepływy śladu turbulentnego zaproponowano konstrukcje spirali spływowej, która umieszczona we wnętrzu rotora ma na celu kierunkowanie strugi powietrza przepływającej przez tę część turbiny i odprowadzenie jej poza wnętrze urządzenia. Wykonane badania pozwoliły na wykonanie prototypu pracującego w realnych warunkach wietrzności z optymalnym ustawieniem podstawowych elementów turbiny tzn. łopat kierownic, rotora z wykorzystaniem spirali spływowej.

Keywords: turbina wiatrowa, rotor, kierownica wiatru, struga powietrza, cechy przepływowe, cechy eksploatacyjne



ANALYSIS OF A VERTICAL GROUND HEAT EXCHANGER OPERATION COOPERATING WITH A HEAT PUMP

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Abstract: The article presents the results of the changes measurements in the temperature distribution of the lower heat source during operation of the brine-to-water type heat pump. The lower source for heat pumps with a heating capacity of 234.4 kW and cooling power of 191.8 kW installed in the building of the Bialystok University of Technology, Faculty of Civil and Environmental Engineering is a vertical ground heat exchanger with a total length of 5,200 m (52 wells of 100 m each).

The results of tests from the period of 3 years of work of the ground heat exchanger have been presented. Obtained measurements results in openings with working vertical probes in individual years of work were compared with the base profile of the soil to a depth of 100 m with unloaded operation of vertical ground heat probes of the same length.

It also presents the amount of heat generated in this period by heat pumps and the amount of electricity consumed by it along with the COP heat pump efficiency coefficient in the next weeks of its operation. The average annual heat pump efficiency coefficient was also determined in three heating seasons.

Due to the high costs of drilling wells and their measurement, this type of research is unique. There are practically no measurements of the temperature distribution in 100 m vertical ground probes loaded with heat pump operation in buildings in continuous operation. Computer simulations or smaller research stands are made more often.

Acknowledgements

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Keywords: *vertical ground probes, heat pump, ground temperature distribution profile, brine temperature Coefficient Of Performance (COP).*



USAGE OF LOW COST DIGITAL CAMERA FOR DETECTING OF SILICON SOLAR CELL ELECTROLUMINESCENCE

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This article analyses the existing methods both practically and theoretically used to detect defected surface area in solar cells. Various methods were used but by using an upgraded camera with CMOS sensor for carrying out the electroluminescence method, this has proven to have a very crucial impact on the results. Given the overall results and the acquired information, a procedure with a simple parameter can be setup to carry out the measurements. In addition to this a catalog was formed showing the defects occurring in mono and polycrystalline solar cells.

Keywords: CMOS camera, defect detection, diagnostic methods, elektroluminiscence, photovoltaics, photovoltaic cell, solar cell, silicon



ASSESSMENT OF THE IMPACT OF THE LOCAL GEOLOGICAL STRUCTURE ON THE EFFICIENCY OF GROUND-SOURCE HEAT PUMP

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Heat pumps, in particular ground-source heat pumps, are widely applied for heating and cooling, and also for domestic hot water production in residential, commercial and public buildings. The technology faces number of challenges consequent on the ever-increasing efficiency demand in parallel with environment-friendly usage of low-temperature energy sources for example ground or groundwater, which are freely available in the environment. The most commonly way of extracting heat accumulated in near-surface layers of the ground is to use vertical heat exchanger, also called borehole heat exchanger, with intermediary agent. In the most of the European countries the ground temperature changes seasonally in near-surface layers because of atmospheric impact, besides it increases with depth and is nearly constant from about 10 to 15m underground. The aim of the study is to assess the influence of local geological structure on the efficiency of the ground-source heat pump. Assessment will be conducted based on local thermal parameters, and more specifically on the properties of ground, which determine the heat yield of the vertical exchangers of the low-temperature geothermal installations. Based on the elementary computational assumptions, on the borehole data obtained from the National Research Institute and on the defined thermal coefficients, the heat transfer rate values in selected measurement points were determined. As a result, the efficiency of selected boreholes were determined in relation to the previously established power demand for selected building. In the most parts of area studied, in selected measurements point, sands, clay gravels and clays dominated with vary thickness of particular types of land. The thermo-physical properties significantly change with different types of geological materials. This medium, 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. Moreover, more favorable parameters for geothermal installations were specified in locations where the heat transfer coefficient of particular layers were lower, but the average heat transfer coefficient for borehole was higher, compared to the boreholes which possessed small-thickness ground layers with better heat transfer parameters.

The presented work was financed by AGH University of Science and Technology, grant No. 11.11.140.031 and 15.11.140.002.

Keywords: *low-temperature geothermal energy, ground heat pump, vertical exchanger, energy efficiency, renewable energy source*



DEVELOPMENT OF STABLE PEROVSKITE SOLAR CELL

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The main purpose of the work is to find the most appropriate preparation methods to achieve a stable perovskite photovoltaic cell. Twelve solar cells have been created with the active area consisting of $\text{CH}_3\text{NH}_3\text{PbI}_3$ and $\text{CH}_3\text{NH}_3\text{PbI}_3\text{-2Cl}_2$ solutions. It was proved that later structure is more stable against environmental influences (especially moisture) because of chlorine addition. During the research has been also found that films formed in 20% relative humidity have a different structure than perovskite manufactured in dry glove boxes filled with nitrogen atmosphere. The perovskite grains have unified and their volume has increased. Above described processes have led to more resistive perovskite solar cells, where the stability period was twice as long.

Keywords: *Perovskite solar cell, stability of perovskite solar cell, incorporation of chlorine atoms into perovskite structure*



THE ANALYSIS OF GEOTHERMAL WELL CONSTRUCTIONS DEPENDING ON EXPECTED PRESSURE CONDITIONS

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Geothermal energy is defined as the internal heat of the Earth and has a tremendous energetic potential. In Poland, geothermal energy is still underestimated in comparison to other renewables, although in recent years one can notice quite dynamic development of the sector. Currently, the Polish geothermal energy sector is based on deposits of low-temperature geothermal waters, which are used primarily in heating, recreation and balneotherapy. Nevertheless, several researches on the possibility of using the energy of hot dry/wet rocks as well as the prospect for producing electricity from a geothermal medium have been ongoing.

The use of geothermal energy is possible due to deep boreholes, which at the current stage of technology are the only rational solution for a geothermal medium extraction. Nevertheless, as it is well known, the stage of wellbore drilling is the largest financial burden of any geothermal investment. Therefore, it is a matter of great importance to properly design a borehole in relation to the expected operating conditions, among which the pressure conditions - artesian or sub-artesian, play a crucial role. Also, the possibility of a justified adaptation of existing explorative or abandoned petroleum wells for geothermal purposes is a preferable or even desirable solution of recent years.

Thusly, the paper presents the most important issues related to the construction of geothermal wells in dependence on the expected artesian or sub-artesian pressure. The authors focus mainly on wells that have been adapted (or are wanted to be dedicated) for geothermal energy extraction as a result of the reconstruction of old exploratory wells or abandoned petroleum boreholes. What is more, existing examples of aforementioned wells located in Poland are presented.

The paper has been prepared under the AGH-UST statutory research grant No. 11.11.140.031.

Keywords: *geothermal energy, well construction, reconstruction*



ECOLOGICAL EFFICIENCY OF WIND POWER PLANT. PART I: EVALUATION MODEL

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This study consists in the evaluation of the benefits and ecological costs that occur in the life cycle of a wind power plant. The study constitutes an attempt to expand upon previously conducted research on the analysis of costs and benefits in the stages of production, operation and post-consumer management of wind turbines. The aim of the study adopted research methodology, analysis and assessment of the benefits and environmental impacts of the Vestas V90/105m 2 MW wind turbine throughout its life cycle. Original assessment indicators of the benefits and ecological costs occurring throughout a wind power plant's life cycle were proposed and verified experimentally.

Keywords: *wind power plant, ecological efficiency, renewable energy, emission in life cycle*



ECOLOGICAL EFFICIENCY OF WIND POWER PLANT. PART II: CASE STUDY

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This study consists in the evaluation of the benefits and ecological costs that occur in the life cycle of a wind power plant. The experimental studies consisted of several stages, the first of which consisted of an analysis of material and energy in the life cycle and the determination of productivity. For ecological analysis, the LCA method as well as eco-indicator 99, CML, CED and IPCC models were used as a tool to determine environmental costs. The study shows that the integrated energy efficiency indicators of ecological costs are higher for recycling as a form of post-consumer management. Designated benefits and ecological expenditures allowed for the identification of the main components of the ecological efficiency indicator for the life cycle of a Vestas V90/105m 2 MW wind turbine.

Keywords: *wind power plant, ecological efficiency, renewable energy, emission in life cycle*



ELECTRIC CARS AS A FUTURE ENERGY ACCUMULATION SYSTEM. PART I: RESEARCH METHODOLOGY

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The aim of this study is to identify new opportunities for energy supply in Poland and in the world, on the basis of electric cars. It was assumed that being connected to the local power systems, they can accumulate significant amounts of energy and effectively prevent from occurrence of electric power deficit. To achieve the above mentioned goals the problem has been formulated in the form of the following questions: what are the conditions and technical potentials for energy use in transport?, what needs to be done in order to achieve the assumed satisfactory level of energy supply involving improving power availability in the Polish National Power System and prosumer use of electric cars, for example in Poland? What are the examples of implementation of different sources of electricity into the electric power system? Environmental compatibility of various ways and means (according to their own evaluation methodologies), as technical solutions for charging and discharging rechargeable batteries for the car own purposes and for the purposes of the local energy systems in case of a deficit, was defined.

Keywords: *electric cars, power deficit, accumulating the energy*



ELECTRIC CARS AS A FUTURE ENERGY ACCUMULATION SYSTEM. PART II: EXAMPLE

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The goal of this study is to indicate a possibility of providing Poland with power supply safety and efficiency with the use of electric cars. During the peak demand for power when the power availability is threatened the energy stored in batteries of electric cars can be transferred to the power grid. The proposed system, according to the described solution, is equipped with standard equipment: transformer (Tr), converters/controllers (PV), system of control adjustment, compensation and supervision (active monitoring system AMS), an additional source of energy (ASE), circuit breakers (cB) and it closely cooperates with the power system. Active monitoring system (AMS) is used for active control of electric power stored in batteries during the peak power demand or when power shortage occurs in the National Power System (NES). A decision-making strategy that takes into account the location of the battery (Ee-Mobile), the level of power stored in the battery, as well as the time of day, electricity prices and charging requirements needs to be applied. Thanks to this solution, the NES may maintain power supply availability. It can guarantee that, even in case of a peak power demand, the system will not run out of power.

Keywords: *electric cars, power deficit, accumulating the energy*



APPLICATION OF ASSESSMENT SHEETS IN THE VISUAL IMPACT IDENTIFICATION OF FACILITIES USING RENEWABLE ENERGY SOURCES

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Facilities which use renewable energy sources may visually impact the landscape and change its character, among others due to their cubature, the number of installations of which they are composed or the area covered by them. Many of these interactions may have the character of visual pollution. Proposals for evaluation sheets, which could be used to unify and facilitate the way of assessing the impact of objects using RES on the landscape physiognomy, have appeared for many years in Polish and foreign literature on the subject. In Poland, visual impact assessments are carried out in order to limit the negative impact of investments planned under the EIA and SEA procedures on the landscape. However, no detailed rules have been developed for conducting these assessments so far. The aim of this work is to review and compare visual impact assessment sheets described in the literature in terms of their suitability for the aforementioned procedures. As part of the research, an analysis of the structure of landscape visual impact assessment sheets has been conducted. They were classified due to the used criteria. Also analyzed was the usefulness of these sheets for the assessment of various types of objects using renewable energy sources. Results of this research will be used in further works on developing a methodology for visual impact assessments, which could be part of the EIA and SEA procedures in Poland.

Keywords: *visual impact assesment, renewable energy facilities, visual pollution, assessment sheets, assessment procedures*



ECOLOGICAL AND ENERGETICAL STUDY OF LIFE CYCLE OF A PHOTOVOLTAIC POWER SYSTEM

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The work analyzes the current state of knowledge and techniques on photovoltaic systems life cycles. Analysis of the ecologic and energetic efficiency of the present renewable energy source is based on the method of LCA (Life Cycle Assessment). The test subject is a photovoltaic power plant (1 MW), located in the northern area of Poland. The analysis uses three models: Ecoindicator 99, CED (Cumulative Energy Demand) and IPCC (Intergovernmental Panel on Climate Change). Specified levels of harmful impacts on the environment are examined at different stages of the life cycle of the photovoltaic power plant. Storage and landfill are two possibilities for post-consumer plastics, materials and components and their level of impacts on the environment, and has been examined and assessed. Based on obtained test results, there will be guidelines proposed for the pro-environmental management of the life cycle of the photovoltaic power systems

Keywords: *alternative energy sources, photovoltaic power plant, pro-environmental management, recycling*



STUDY OF PHYSICAL PROPERTIES OF RICE AND CORN USED FOR ENERGY PURPOSES

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Biomass has been used by humans since immemorial time to obtain heat. The current trend of using biomass and replacing it with coal is mainly related to the implementation of EU targets for reducing carbon dioxide emissions. In comparison with coal combustion, emissions of harmful substances, including CO₂, during biomass burning are much lower. As an energy source, it is also possible to use grains of commonly cultivated maize, rice, wheat and other cereals, unsuitable for processing for nutritional or fodder purposes. Many grains in whole or in a particulate form constituting waste from production processes could successfully serve as a valuable raw material or as batch in biogas plant.

The aim of the work is the analytical determination of physical properties (including energy) of granular biomass (rice and maize) for their further energy processing. Determination of the properties of crushed biomass, and at a later stage burned, is of key importance in the development of energy and environmental efficiency indicators for preparatory processes, eg grinding and, consequently, combustion.

Based on the analysis, it was found that rice and maize grains are a valuable source of energy and can be successfully used as alternative, renewable energy sources. The results of experimental studies have shown that rice grains are characterized by better energy properties.

The analysis of the literature regarding the properties of rice and maize grains as well as the results of own investigations of humidity, calorific value, heat of combustion, shape and size of particles form the basis for determining the influence of biomass properties on the processes of its further processing (including grinding) and in the further stages of the research procedure to develop energy and environmental efficiency models and the original CO₂ emission indicator.

The study financed from the Budget science funds in 2017-2021, as a research project under the "Diamantowy Grant" programme.

Keywords: *Biomass, rice, maize, energy values, renewable energy sources*



CREDITING OF RENEWABLE ENERGY PROJECTS FOR SMALL AND MEDIUM BUSINESS CLIENTS

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Ukraine is on the verge of a burst of credit for renewable energy projects. On the one hand, banks are actively looking for new niches, where resources can be directed, and on the other hand, more and more willing (and not only among business, but also the population) to earn on renewable energy sources, on which the future.

Solving the financing of alternative energy is aimed at solving climate change and improving energy efficiency. Credit programs are aimed at addressing the needs of energy efficient modernization of enterprises; modernization of lighting systems; vehicles for customers; equipment: real estate for clients; AIC and animal husbandry: biofuels, biogas, waste management, irrigation systems; agricultural machinery; business development; communal objects; energy efficient modernization; energy service contracts; "GREEN" energy; renewable energy, energy accumulation, biomass; for investment purposes: replenishment of working capital; overdraft.

Projects with which banks had to work focused mainly on replacing old equipment with new energy-efficient ones, installing solar collectors for their own business needs, purchasing boilers, etc. Renewable energy projects, like business, are not the target client segment for the bank, so we have a few credit projects in this direction. It should be noted that, for the most part, banks do not separate renewable energy programs among other credit programs. But with such clients, they cooperate, for example, in the direction of the transactional business. For corporate business projects, the demand for loans is high. In the portfolio of banks, there are already financed projects for almost all types of renewable energy - wind, solar, biomass thermal power station.

However, we can not say that the banks are ready to fill billions in renewable energy today. The issue of "Green tariff" over the last 5 years was very politicized. And this is not only the economic and political risks in the state, but also the regulatory limitations of the NBU. Credit "swing" - in the initial phase of the swing. At the moment, it is about the prospect of using significant potential. When financing renewable energy projects, the main difficulties are that such a business often does not have the ability to provide a liquid collateral, as well as expensive lending resources of banks.

Keywords: Keywords: loans, programs, business projects, financing, renewable energy



STRATEGY OF THE DEVELOPMENT OF AGRIBUSINESS AND ENTREPRENEURSHIP ON AN INNOVATIVE BASIS

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Comparison of the profitability level of the Chernivtsi region and Ukraine indicates almost the same indicators as a whole in the production of agricultural products. However, in Chernivtsi, crop production is growing more efficiently, and a slightly lower level in livestock production than the average in Ukraine, indicating the existing growth reserves.

The main task of the Chernivtsi Region Strategy for the period up to 2020 has been to ensure a high standard of living of the population in a harmonious combination of the development of entrepreneurship on an innovative basis with the development of culture, science, social sphere and save of the environment. Strategic Vision will be achieved through the achievement of strategic goals.

Strategic Goal 1 "Development of Entrepreneurship on an Innovative basis" combines spectra of interventions related to the economic sphere, the implementation of which will contribute to the sustainable development of the region's economy.

Strategic Goal 2 "Development of Culture, Science, and Social Sphere" combines the spectrum of interventions relating to cultural, educational, scientific, social and managerial spheres, the implementation of which will contribute to the development of human capital, institutional change in society..

Strategic objective 3 "Save of the environment" combines the spectrum of interventions related to the environmental field of the alternative energy sector, the implementation of which will contribute to the development of a safe environment.

The achievement of the strategic goal is possible with the proper use of the potential of the region. An absolute indicator of growth will be an indication of the positive result of the Strategy implementation, as well as outpacing the rates of improvement of indicators in comparison with the average Ukrainian indicators and indicators of the neighboring regions.

It should be noted that the basis of sustainable economic development is the functioning of entrepreneurship on an innovative basis, culture, science, social sphere as the basis for the development of human capital, transformation of the energy institutional environment and the save of the environment as a safe ecological environment, which are only tools for achieving the goal and building a strong, self-sufficient , energy - independent Ukraine.

Keywords: *Key words: innovation, strategy, agribusiness, development, purpose, energy independence.*



TECHNICAL-TECHNOLOGICAL MODERNIZATION OF AGRARIAN ENTERPRISES

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The current state of logistics of agrarian commodity producers in Ukraine suggests the need to update the material and technical base of agrarian enterprises, which will help to increase the production of competitive agricultural products and increase the level of own food security, and increase the efficiency of the agrarian sector.

Some scientist point out that when developing the agricultural development strategy of Ukraine it is necessary to rely on the development of large specialized high-tech enterprises that use the latest innovative technologies, have the opportunity to finance innovation research activities, and such enterprises should be considered as translators of innovations for small and medium-sized producers.

A neo-industrial model of economic development based on the principles of resource conservation, rational use of raw materials, materials, new biomaterials, energy efficiency improvements, introduction of new biotechnologies, reduction of waste volumes, development of alternative energy, development of programs and plans for maintaining ecological balance can be the main basis for the development of the industry and protecting the natural environment. Thus, there is a tendency towards the development of the knowledge economy as a basis that allows the use of innovative ideas and knowledge to transform into sustainable development and the competitiveness of the economy, that is, knowledge here has the property to enrich all sectors, bringing to the new level the neo-industrial development of participants in economic processes, sectors of the economy and the country as a whole.

Innovative modernization can also be achieved through the development of new advanced technologies of the sixth technological structure, for example, such as protein engineering and structural bioinformatics; development of scientific and technological foundations for the creation of the newest bioanalytical systems; development and use of photonics; production of "renewable biomass"; development of wind energy, solar power engineering; development of technologies of organic agriculture and livestock, etc.

We believe that the prospects for the revival of the industry are seen first and foremost in accordance with the transition to a new technological structure in the development of agricultural machinery, chemical and food industry, and the production of organic agricultural products.

Keywords: *Key words: neoindustrialization, modernization, resource saving, energy efficiency, innovations*



DIRECT ELECTRICITY PRODUCTION FROM LINSEED OIL

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Providing more and more energy is an essential task of today's energetic industry. In the last few years alternative energy sources have been fast developing. One of alternative energy sources is fuel cell (FC). Most often FCs are powered by hydrogen. However, a problem with the problems with storage of hydrogen is the reason for the search of new fuels for fuel cells. One of these fuels can be linseed oil. Powering high efficiency power sources (like FCs) with renewable fuels (like linseed oil) will allow development of renewable energy sources and elimination or reduce of toxic substances emissions. The paper presents the research of linseed oil electrooxidation. The work shows possible electrooxidation of linseed oil emulsion prepared on the basis of a nonionic surfactant on a smooth platinum electrode. The resulting current density reached the level of 4 mA/cm². So, the possibility of using linseed oil as fuel for FCs has been proved.

Keywords: *renewable energy source, biofuel, fuel cell, environmental protection, electrooxidation*



COMPARISON OF CU-B ALLOY AND STAINLESS STEEL AS ELECTRODE MATERIAL FOR MICROBIAL FUEL CELL

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Technical device that can combine energy production and wastewater treatment is a microbial fuel cell (MFC). One of the problems of MFCs is a low current density. So, it is possible to necessary to search for new catalysts for electrodes. The comparison of using the Cu-B alloy and stainless steel as cathode for microbial fuel cells is presented in this paper. The measurements included comparison of changes in the concentration of COD, NH₄⁺ and NO₃⁻ in the reactor with aeration and with using a MFC with Cu-B and stainless steel cathode. Moreover, measurements included electricity production with both types of cathode. The current density and amount of energy obtained in MFCs (with both types of cathode) are low. But, due to amount of wastewater and obtained amount of energy allows elimination of the energy needed for reactor aeration. It has been shown that effectiveness of MFC with Cu-B electrode is higher than effectiveness of MFC with stainless steel electrode.

Keywords: *renewable energy sources, microbial fuel cell, wastewater treatment, environmental engineering, clean technology, cathode*



THEORETICAL AND REAL EFFICIENCY OF THE SOLAR POWER PLANT IN A 2-YEAR CYCLE

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The photovoltaic panel project requires a preliminary analysis to assess the theoretical level of available solar radiation energy. Then, when assessing the potential amount of energy that can be produced, take into account the range of changes in the parameters of the solar modules during their operation guaranteed by the manufacturer. In addition, the production of energy during the use of the PV plant is also dependent on the conversion efficiency of the generated DC voltage to sinusoidal voltage in inverters and many other factors.

The paper analyzed the efficiency of 4.27 kWp photovoltaic power plant built of polycrystalline modules made in silicon technology. The modules of PV power were directed to the south and mounted at an angle of 32 degrees in relation to the horizontal plane. The research was carried out in a two-year cycle. This period covered the entire year 2016 and 2017. The analyzes carried out concerned the theoretically available amount of energy possible to obtain in the PV power plant, including: a) - PV panel rated efficiency, b) - PV panel and inverter rated efficiency, c) - PV panel rated efficiency and the inverter in the first year of operation, d) - the rated efficiency of the PV panel and the inverter in the second year of operation.

Next, based on the conducted tests, the actual amount of available solar radiation energy and its structure in particular months of the analyzed years were determined. This analysis was supplemented by the characteristics of the variability of the daily amount of available solar radiation energy at the location of the PV plant in individual months.

For the same period of time, calculations of the amount of energy produced in the PV power plant were made based on the indications of the AC energy meters. The structure of the actual amount of electricity produced in polycrystalline modules for individual months in a two-year cycle was also determined and the characteristics of the variability of daily electricity production in individual months were presented.

The analysis shows that in a two-year research cycle, both the average daily amounts of available solar energy in a given month as well as energy yields from polycrystalline modules do not differ significantly between 2016 and 2017. However, statistically significant differences between the amount of available solar radiation energy and the amount of generated energy in PV modules in particular months were observed.

Keywords: *PV plant efficiency, photovoltaic energy, PV plant lifetime*



ASSESSMENT OF THE VARIABILITY COMPOSITION OF LANDFILL GAS CAPTURED ON A USING MUNICIPAL LANDFILL

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In the article an assessment of the variability landfill gas components captured on a using landfill since the 1970s, was conducted. In the landfill there was more than 3-fold decrease in the amount of waste deposited during the period of 6 years, including organic waste affect-ing gas productivity of landfill gas. Despite the decrease after this pe-riod, landfill gas was characterized by significant average contents of CH₄ and CO₂, exceeding 50% and 30% respectively. This confirmed the landfill being in the methanogenesis phase. The waste deposit was dominated by anaerobic processes, which was demonstrated by the low average oxygen content of 1.185%, while the highest variability was confirmed by the result of the standard deviation H₂S (35,106 ± 69,915 ppm). In June, the highest values of emissions, CH₄, CO₂ were the most frequent, while the noticeable decrease it included the values of five analyzed indicators.

Keywords: *Landfill-Biogas-Emission-Municipal Waste*



A COMPARATIVE ASSESSMENT OF MUNICIPAL WASTE ACCUMULATION IN SELECTED RURAL COMMUNES

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A comparative analysis of the accumulation of municipal waste in two selected rural communes in the European Union showed, in a quarterly basis, substantial differences between the number of inhabitants and the amount of non-selective and selective waste collected. A significant increase in waste collected fell on the tourist and agricultural commune with a larger population. There was an asymmetry between municipalities which showed a wider generic range of collected waste, including metals, waste electrical and electronic equipment in a municipality with a smaller population. Generally, in this commune there was a four times higher amount of non-selectively collected waste in relation to separately collected ones. The occurrence of the highest values of collected waste confirmed the seasonal variability with the dominance of spring and summer. Waste accumulation rates were helpful in the analysis. One of them concerned the overall accumulation of municipal waste rate per capita per year, which showed the highest value of 50.4 kg in the commune with a smaller number of inhabitants. Analysis of another rate of plastic waste accumulation per capita per year showed the possibility of the commune's tourist impact on its growth. The fall in the value of the glass packaging waste accumulation rate and the lack of accumulation of metal waste and waste electrical and electronic equipment accumulation per capita per year in one of the communes, were ones of the factors, resulting in limitation of the waste recovery "at source".

Keywords: *Waste management-Municipal waste-Rate accumulation-Collection*



BENEFITS OF NEUTRALIZING OF WASTE PACKAGING MATERIALS IN THE PYROLYSIS PROCESS

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The prompt development of many industries, including food industry, generates large amounts of unwanted waste, the storage of which releases a number of disadvantageous changes in the natural environment. To prevent progressive degradation of natural environment, the efficient neutralization of waste becomes a serious challenge facing humanity. The thermal treatment of waste is becoming particularly popular. In present paper the possibilities of utilization of selected municipal packaging waste in the pyrolysis process are discussed.

Keywords: *waste, environment, pyrolysis, thermal treatment*



THE USE OF WASTE ENERGY OF EXHAUST GASES AS AN IMPORTANT ELEMENT OF THE ECONOMY FROM THE FURNACES IN THE HEATING OF STEEL CHARGE

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The article gives the possibility of using warm wastes of exhaust to preheat combustion air in furnaces for heating of steel charge. Demonstrates the calculations illustrate the combustion air temperature on the regards of value physical warm supplied to the heating process. The calculation of combustion process and the supporting calculations using their own computer programs was performed. The effect of recuperation on the warm economy in the heating units was presented. Analysis of savings resulting from the application of heated air to the selected heating furnaces have been carried out.

Keywords: *waste energy, heating furnaces*



ASSESSMENT OF THE VARIABILITY OF THE LANDFILL GAS COMPOSITION CAPTURED ON A USED LANDFILL

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An assessment of the variability of the landfill gas components captured on a used waste landfill since the 1970s, was presented in the article. The amount of waste deposited in the landfill has decreased more than 3 times during the period of 6 years, including organic waste affecting the productivity of landfill gas. Despite the decrease, landfill gas was characterized by average contents of CH₄ and CO₂ after this period, exceeding 50% and 30%, respectively. This confirmed that the landfill was still in the methanogenesis phase. The anaerobic processes were taking place in the deposit to a large extent, which was demonstrated by the low average oxygen content of 1.185%, while the highest variability was confirmed by the result of the standard deviation H₂S (35,106 ± 69,915). In June, the highest values of emissions, CH₄, CO₂ while the general decrease in values did not relate to emissions.

Keywords: Landfill-Biogas-Emission-Municipal Waste



PHOTOVOLTAIC PANELS IN A SINGLE-FAMILY HOUSE

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In recent years the production of energy for own purposes from photovoltaic panels enjoys growing interest in Poland. In 2016 and 2017, more than a dozen thousand micro-installations (in the vast majority the photovoltaic) have been yearly connected to the network. However, the share of micro-installations in the total electricity production in Poland is still very small. Total power below 200 MW gives a share in the order of tenths of a percent. Comparing the installed capacity in photovoltaic sources in our country with the average of the European Union (over 3550 MW) we can expect it to grow in the coming years. Will this increase be generated by prosumers and their micro-installations? Yes, if they would find that it is just profitable.

This paper discusses the key parameters, which are responsible for the profitability of investment in photovoltaics from the point of view of an individual customer – the owner of a detached house.

Keywords: *photovoltaics, PV micro-installation, profitability of the investment*



APPLICATION OF METHODS FOR SCHEDULING TASKS IN THE PRODUCTION OF BIOFUELS

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This work analyses possibilities of applying task prioritization methods in the production of biofuels, based on bibliometric analysis. The results of the bibliometric analysis have shown that studies on applying task prioritization methods in biofuels production have not been conducted on a large scale so far (only 96 indexed works have been published in the Scopus database). In the documents being analysed, the application of prioritization methods concerned mainly production (raw material optimisation and processing, classical and new production technologies, cost reduction, environmental impact reduction, and the like) and logistics (supply chain optimisation, including planting, harvesting, transport, storage, distribution etc.). Mainly advanced task prioritisation methods have been used: MILP (mixed-integer linear programming), Linear Programming Model, Stochastic Sequential Programming and Multi-Objective Genetic Algorithm.

Keywords: *scheduling problem, scheduling application, bibliometric analysis, research topic, scientometric, literature review, VOS viewer*



OPTIMISATION METHODS IN RENEWABLE ENERGY SOURCES SYSTEMS - CURRENT RESEARCH TRENDS

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The objective of the work was to determine the research trends and carry out a bibliometric analysis of publications concerning the application of the computational intelligence method in the research area renewable energy sources optimization. In this study the Scopus database has been used as a data source. Articles and conference papers published in the years 2011-2017 were analysed. The research consists of two research tasks: bibliometric quantitative analysis and bibliometric thematic analysis of publications. On the basis of the analyses conducted, one can state that: In years 2011-2017, the number of scientific publications regarding RES optimisation, indexed in the Scopus database, increased by 340%. However, it does not mean that optimisation studies become prevailing, since the number of RES-related publications increased as well (by 199%). A percentage share of publications concerning RES optimisation, in relation to all publications dedicated to RES, grew in years 2011-2017 by 177%. The authors of the highest number of publications (in the set of articles and conference materials searched, for years 2011-2017) were researchers from the USA, China, India and Italy. The majority of the studies described in the publications set concerned optimisation of solar energy and wind energy systems, often hybrid systems. For optimisation by means of artificial intelligence computational methods, algorithms belonging to a group of Evolutionary Computations (mainly Genetic Algorithms) and Swarm Intelligence (especially PSO) were applied most frequently. Neural networks and fuzzy systems were applied three times less frequently. The authors suggest new optimisation algorithms combining several artificial intelligence methods.

Keywords: *Optimization, renewable energy sources RES, Computational Intelligence, Bibliometric analysis*



THE MAIN FACTORS DETERMINING THE POROSITY OF GRANULAR MATERIALS OF BIOLOGICAL ORIGIN

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The porosity and bulk density of granular materials are closely related to the issues connected with the transport and storage of this type of materials. The article discusses the basic factors determining porosity and bulk density. Additionally, the influence of the two of these factors (moisture, shape factor) on the obtained values of bulk density and porosity was investigated. Non-linear estimation was performed in order to obtain an influence model of the analyzed factors. With respect to bulk density, the model was well fitted to the input data; yet, for porosity, the goodness-of-fit failed to be satisfactory.

Keywords: Granular materials, Porosity, Bulk density, Moisture, Shape factors



ANALYSIS OF PROPERTIES AND POSSIBILITIES OF ENVIRONMENTAL USE OF MUNICIPAL SEWAGE SLUDGE – A CASE STUDY

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The formation of sewage sludge is an inherent effect of the wastewater treatment process. Their composition is characterized by high variability and depends mainly on the properties of wastewater, technologies of their treatment and methods of processing sediments. Without knowing the properties of sewage sludge, it is difficult to choose the appropriate method for their utilization or disposal.

The aim of the study was to analyze the physical and chemical properties of sewage sludge from a selected municipal wastewater treatment plant and to assess the possibility of their use in environment. A municipal sewage treatment plant, located in mountainous terrain (Gorlice, Poland, Małopolska province) was selected for the study. The research were conducted on dehydrated sludge, after aerobic stabilization. The research was conducted in the years 2011-2016, while the samples were collected three times a year.

Analysis of the results showed a high variability and a relatively low level of the sludge pH, which could be the result of improperly performed stabilization process. Among the analyzed properties of sludge from the wastewater treatment plant in Gorlice, high variability was also demonstrated by the dry matter content and organic compounds. The conducted PCA showed that the pH and the content of calcium and dry matter (parameters depending on the method of treatment in the treatment plant) had the greatest impact on the properties of sludge.

The maximum contents of some of the analyzed heavy metals (chromium 246 mg·kg·d.m.⁻¹, copper 209 mg·kg·d.m.⁻¹, nickel 47.1 mg·kg·d.m.⁻¹ and mercury 10.5 mg·kg·d.m.⁻¹) were relatively high, but did not exceed the limits specified for sludge used to fertilize the land, utilized for agricultural purposes, which apply to the most stringent conditions. However, the maximum content of zinc (3430 mg·kg·d.m.⁻¹) significantly exceeded the limit value at the agricultural use of sewage sludge. This limits the possibility of using sludge and makes it necessary to look for other methods of utilization.

Keywords: *municipal wastewater treatment plant, sewage sludge, properties, management*



CURRENT DEVELOPMENT IN WASTE-TO-ENERGY 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*



MUNICIPAL WASTE GASIFICATION AS ALTERNATIVE FOR TRADITIONAL WASTE-TO-ENERGY PLANTS

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Municipal Waste-to-Energy plants are good know around the word technology for recovery energy from waste but in Poland it just starts to rise. Alternative way for combustion of waste is gasification process which uses small amount of oxygen and water vapour to change the organic fractions into a combustible gas. This method has advantages and disadvantages which are described in short way to compare finance and technological profits which can be achieved. Gasification has to be tested more before can be considered as alternative to traditional Waste-to-Energy power plant.

Keywords: *pyrolysis, reforming, syngas*



THE IMPACT OF KAOLIN INCORPORATION IN BIOPOLYMER MATRIX ON THE WATER VAPOR PERMEABILITY OF STARCH/NANOCLAY COMPOSITE FILMS

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Biodegradable packaging materials produced from renewable resources such as starches, are the propositions to replace conventional petroleum based products and fit with a real sustainable development approach. However, the hydrophilic nature of the starch, makes this promising material, have to be enhanced in order to be able to compete with conventional polymers. Due to the high requirements materials used in packaging must meet the basic conditions posed before the package, especially for food packaging, which must be a barrier between food and environment Food product must be protected from external factors by the packaging to ensure his: freshness, durability, and attractiveness during their life conditions of use. Packaging should prevent loss of desired properties: corruption, change colours, change consistency, evaporation, dirty, damaged. Exact characterization of material surfaces plays an essential role in research and product development in many industrial and academic areas. In order to improve the barrier properties and reduce the hydrophilicity of starch films, a nanofiller has been incorporated into the polymer network. The nanofiller roles are filled with kaolin clay which, unlike macrofillers already used in similar biopolymer composites, more accurately enters the polymer network creating a more homogeneous film. Kaolin clay is environmentally acceptable - non-toxic, plentiful in availability and cheap material, which makes it a very good addition to packaging materials.

Biocomposite films used in experiments were made of potato starch (polymer), glycerol (plasticizer) and kaolin clay (nanofiller) using a casting evaporation method. The films were prepared in four different clay content 0/5/10/15% respectively and for all samples, the plasticizer content was 20% relative to dry starch substance weight.

Water vapour permeability was determined using gravimetric method, WVP was calculated from the formula.

The objective of this study was to determine the impact of nanofiller incorporation in biopolymer matrix on the water vapour barrier properties of starch/nanoclay composite films.

Keywords: *Water vapour transmission, starch film, nanoclay*



THE PHYSICAL-MECHANICAL PROPERTIES OF FUEL BRIQUETTES MADE FROM RDF AND WHEAT STRAW BLENDS

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At present the energy recovery from municipal and agricultural wastes is one of the major element of the waste treatment for energy and heat production. Refused Derived Fuel (RDF) is the product of the treatment of Municipal Solid Waste (MSW) to create an alternative fuel possible to use in power plants. Mechanical treatment such as briquetting the waste results in a homogeneous biomass product of high density, therefore reduce the costs of handling, transport and storage throughout the supply chain. In present studies the properties and quantity of RDF and wheat straw briquetted blend in the proportion of 50/50 was experimentally investigated. The briquettes were manufactured in lab-scale EDZ-20 hydraulic -press with the use of the die set of diameter 50 mm at three compaction pressure 56, 66 i 77 MPa and two temperature of the die: 100 i 120 C. The physical parameters: density (kg m³), net calorific value – NCV (MJ/kg), fixed carbon (% wt), volatile matter (% wt), ash content (% wt) and mechanical parameters: resistance to compression (MPa) of the briquettes were analyzed. Moreover, the structural parameters of RDF and wheat straw and the briquettes ashes were examined. The crystalline structure has been measured by X-ray diffraction (XRD) method. The high – resolution X-ray Diffractometer (Empyrean, Panalytical) with Cu K-alpha radiation ($\lambda = 1.51874 \text{ \AA}$) and a Ni filter at a generator voltage of 40 kV and current of 30 mA was used for the structure characterization. The radiation was measured with a proportional detector. Samples were measured in θ -2 θ geometry over a range from 10 deg to 70 deg. All measurements were carried out at room temperature with step size of 0.01 deg and counting time 6 s per data point. The source divergence and detector slit were 1/2, and Soller slits were applied. The crystalline phase in the samples was identified using High Score Plus software package. Studies have demonstrated that the RDF and wheat straw mixture can be compressed to a density of 770-850 kg m³, with good resistance to compression. The study also indicated that heating rate of the die appear to affect density and durability of the briquettes. Thus, the RDF and wheat straw blend is feasible for feedstock in briquetting and could be used for waste management for energy purposes.

Keywords: RDF, wheat straw, briquettes properties, blending, structure characterization



USE OF WIND ENERGY IN THE PROCESS OF LAKE RESTORATION

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Pulverizing aeration with wind drive is one of the most effective and popular methods of lake restoration in Poland. This method was developed and implemented at the Institute of Biosystems Engineering at the University of Life Sciences in Poznań. The principle of operation of the pulverizing aerator consists in taking deoxygenated water from the hypolimnion layer, spraying it in the pulverizing segment and draining oxygenated water to the bottom layer. The pulverizing segment is driven by the energy obtained from the Savonius wind turbine. The spraying of the water sucked in allows for the removal of hydrogen sulphide, ammonia or methane and subsequent oxygenation. After this process, the oxygenated water returns back to the hypolimnion to the vicinity of the suction zone with the use of delivery hoses. additionally equipped so-called phosphorus inactivation system Pulverizing aerators are additionally equipped with so-called phosphorus inactivation system, allowing for dosing of the preparation (coagulant) to the water discharged to the bottom layer.

Keywords: *wind energy, lake restoration, pulverizing aeration*



UTILIZATION BIOGAS PLANT AS AN OPPORTUNITY FOR THE RENEWABLE ENERGY MARKET IN POLAND

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The amendment to the Renewable Energy Act creates great opportunities for the development of the biogas market in Poland. Many years of experience from Western Europe and the development of biogas installations in the country indicate the need to look for other substrates than for example, intentionally cultivated silage maize. One of the right solutions is certainly the use of biodegradable waste from agriculture or industry. Another source of waste used in biogas plants is waste collected at landfills. These substrates are characterized by high biogas production and first of all, their using is not burdened with high costs. Methane fermentation also allows safe digestate of waste. Consequently is a number of arguments for using them in biogas installations.

This article presents the possibility of effective use of waste from animal and vegetable production, from the agri-food industry and from municipal waste.

Keywords: *biogas plant, waste, agriculture, industry, biogas, methane*



STIMULATING EFFECT OF ASH FROM SORGHUM ON THE GROWTH OF LEMNACEAE - A NEW SOURCE OF ENERGY BIOMASS

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The worldwide increase in energy demand makes the development of innovative technologies to produce plant biomass crucial. The aquaculture of the Lemnaceae family is one of the most popular renewable energy sources (RES). Multidirectional use of macrophytes including biofuel production, recycling of post-industrial waste, animal feed, phytoremediation and bioindication are among the fastest growing methods supporting the energy industry. The use of energy plants, including Sorgho, as a sustainable biofuel, produces residual wood ash. This ash contains large amounts of macronutrients, such as phosphorus, potassium, calcium, as well as many micronutrients. The aim of the study was to investigate the possibility of using ash from Sorgho as a nutrient supplement for aquatic macrophytes from the Lemnaceae family.

The experiment was carried out under laboratory conditions using plants from the Lemnaceae family derived from in vitro cultures of the Laboratory of Plant Ecophysiology, Faculty of Biology, University of Lodz. The plants were grown in a room with a phytotron at 24 °C, lighting (PHILIPS MASTER TL-D 2x18W/840) on previously prepared medium, and depending on the variant it was supplemented with various concentrations of ash coming from the Sorgho combustion. For all experimental series, Lemnaceae plant growth analysis was performed by counting the number of fronds, determination of chlorophyll index, gas exchange (net photosynthesis, transpiration, stomatal conductivity of the cells and intercellular CO₂ concentration), chlorophyll fluorescence, fresh and dry mass of plants as well as of important physical and chemical parameters of the medium i.e. COD, PO₄³⁻ phosphates, NO₃⁻ nitrates, pH.

The experiments showed high sensitivity of Lemnaceae family plants grown on a medium supplemented with various concentrations of Sorghum ash, and depending on the concentration, there was a proportional stimulation of plant biomass growth. The medium supplemented with ashes was characterized by high physico-chemical parameters. The above studies indicate the waste ash can be utilized as a supplement to the breeding media of macrophytes of Lemnaceae, which will become a new source of energy biomass.

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Keywords: energy biomass, ash, Lemnaceae,



THE USEFULNESS OF NANO-ORGANIC-MINERAL FERTILIZER STYMIOD IN INTENSIFICATION OF GROWTH, PHYSIOLOGICAL ACTIVITY AND YIELDING OF THE JERUSALEM ARTICHOKE BIOMASS

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Jerusalem artichoke (*Helianthus tuberosus* L.) is a very interesting perennial plant that can be cultivate to produce a large amount of shoots, used as the energy biomass, and tubers for the production of biofuels, as well as valuable raw material in the food and medical industry and human diet. Because it grows well and produces large biomass in a wide range of conditions, the researchers are looking for biological methods whose use would stimulate the growth and yield of biomass and at the same time would be an alternative to synthetic fertilizers contaminating the environment and plants. It is believed that one of such biological agents can be a new generation ecological nano-organic-mineral fertilizer Stymjod (PHU Jeznach Sp.J., Poland), which applied to vegetable plants of selected species and to maize stimulated their growth and yield and quality of crops. Therefore, the aim of the study was to determine the effect of this biostimulator on the physiological activity, growth and yield of fresh and dry biomass of Jerusalem artichoke grown in the field conditions. Obtained results show that the foliar double application at concentration of 0.1-3.0% increased activity of the essential for growth enzymes: acid (pH = 6.0) and alkaline (pH = 7.5) phosphatase, RNase and dehydrogenase and also the physiological activities in leaves, measured by the index of chlorophyll content, net photosynthesis, transpiration, stomatal conductance and intercellular CO₂ concentration. These improvements were associated with the increased dynamics of shoot growth and fresh and dry biomass yield. Double application of Stymjod to plants, at two week interval, at concentration of 1.5-3% was most effective in increasing the plant growth, fresh and dry biomass yield and physiological activity in leaves than lower dosages and disposable treatment. The stimulatory impact of Stymjod on physiological activity, growth and biomass yield indicates its usefulness in Jerusalem artichoke production, as a partial alternative to artificial fertilizers and therefore favoring the reduction of toxic substances in plants used for energy, medical and human diet purposes.

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Keywords: biomass, mineral fertilizer, Jerusalem artichoke



CHARACTERISTICS OF COMMERCIALY AVAILABLE CHARCOAL AND CHARCOAL BRIQUETTES IN THE LIGHT OF PETROGRAPHIC STUDIES.

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As of today, petrographic studies on charcoals and charcoal briquettes in Poland are rarely used as a source of information on the quality of fuels used for grilling. It should be noted that, according to the Polish Standard PN -EN 1860-2, petrographic analyzes of coals and briquettes are obligatory before placing the discussed fuels on the market. However, in the case of the majority of coal and briquette producers, these tests are carried out only once in order to receive a long-term certificate for the entire range of products. Most entrepreneurs believe that the process of producing grill fuels is stable and the parameters of wood used for their production are characterized by a very low variability. The same opinion prevails among the producers of charcoal briquette and is the reason why the tests, which should be carried out for each batch of a product entering the market, are rarely performed. Another argument in favor of the mentioned tests is the fact that fine coal and coal dust of both domestic and foreign origin are used in the production of briquettes.

The presented article, based on petrographic analysis for coals and charcoal briquettes, pays special attention to the differences in the content of impurities in the analyzed material from different production periods. The research material was obtained from producers at the beginning of the calendar year (previous year's production) and in autumn of the year in which the analysis was carried out (current-year production). In addition to the petrographic analysis, showing the percentage of solid contaminants, TOC and TS analyzes were performed for individual coals and briquettes. Furthermore, petrographic examination of grill ash was carried out. Additional examination of the material in terms of carbon content (TOC) has shown differences between the individual batches from different production periods. Supplementary petrographic analysis of ashes was carried out in order to show the amount of remaining solid impurities in the obtained material after the grilling process. The determination of the amount of remaining solid impurities in the ash was aimed at demonstrating their suitability as an additive to gardening soil. The ash admixture in soil is associated with its deacidification in the case of an unwanted pH change during the production of gardening soil and with additional mineralization of the product intended for balcony garden.

Keywords: charcoal, charcoal briquette, solid waste, waste management, barbecue ash



THE ASSESSMENT OF THE QUALITY OF WOOD PELLETS BASED ON PETROGRAPHIC RESEARCH

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To date, petrographic studies were focused on fossil fuels. With the growing demand for renewable fuels such as biomass for households and the industry, manufacturers are required to assess the quality of this fuel. The standard analyses carried out that are compliant with the PN-EN ISO 17225-2: "Solid biofuels - Fuel specifications and classes - Part 2: Graded wood pellets" standard include: technical analysis, which involves, among others, moisture, ash content, calorific value, and mechanical strength analysis. They are required in order to obtain the ENplus / DINplus certificate. Despite the parameters specified in the standard, which strictly define limit values, the production of wood pellet available on the market is not certified. Several cases of falsification of certificates have already been reported.

The article presents a petrographic method used to determine the degree of biomass contamination using microscopic methods. The microscopic analysis was aimed at determining the percentage of certified (ENplus / DINplus) wood pellets available on the market not meeting the quality requirements. The tests were performed on wood pellets samples from different manufacturers. The variability of petrographic properties of wood pellets was characterized. The changes in the variability of the percentage of organic and inorganic contaminants have been shown. The unacceptable organic inclusions in the analyzed samples are: fossil coals and their derivatives, coke, and polymeric materials of natural origin. Unacceptable organic inclusions determined in the analyzed samples were: glass, slag, rust, pieces of metal, stone powder, plastic, and polymeric materials of inorganic origin. It should be emphasized that, taking into account technical analysis, only fifty percent of wood pellets meets the quality standards. However, in the case of microscopic petrographic analysis, only 30% of wood pellets available on the market in the 2017/2018 met 90% of the quality standards. The remaining 70% of wood pellets did not meet the requirements as the content of unacceptable inclusions was exceeded from 10% to 65%.

Keywords: wood pellet, microscopic analysis, organic contaminants, inorganic contaminants



HAZARDOUS WASTE SOLIDIFICATION FROM CHEMICAL TECHNOLOGICAL PROCESS

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The project introduces a problem of hazardous waste that constitute a threat both the environment and human health. Particular attention is paid to waste in form of soil contaminated by mercury compounds and old discharge lamps. What is more, the project presents a processing line of waste solidification. This is one of the methods that neutralize hazardous waste. Its aim is to stabilize and transform waste into environmentally sound. Another essential aspect of presented technology is a waste processing, where waste and cement are both used in concrete production. Analytic Hierarchy Process Method (AHP) helped to choose devices used in the processing line. Moreover, this method allows to make decisions which fulfil many criteria and allows to select the best option. The whole installation is movable and can be easily moved from one place to another.

The final stage of the project deals with a simplistic economic analysis that shows costs of the installation use, annual profit possible to gain and discounted annual income which presents costs of the investment for the subsequent years of use.

Keywords:mercury, solidification, waste, neutralizing, installation



FURNACE WASTE IN RELATION TO EXISTING LEGAL REGULATIONS AND BASIC PHYSICOCHEMICAL TESTS.

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Current furnace waste management is regulated by a number of legal acts largely resulting from the source of waste through a combination with used solid fuel and potential further of their use (recovery) or disposal.

The applicable legal regulations refer to physicochemical tests, the results of which determine the further way of dealing with furnace wastes received in this way. An important problem is inaccurate classification of furnace wastes obtained in individual heating devices in relation to their physicochemical properties, especially for cases when the user has made a combustion process, co-combustion of legally admitted solid fuel with municipal waste or other wastes, e.g. hazardous waste.

The furnace waste generated as a result of such a combustion process in an individual heating device may pose a threat to human life and health and also the environment, which is confirmed by the results of basic physicochemical tests of waste obtained from individual users with the participation of authorized bodies controlling the application of environmental protection regulations.

This paper presents the obtained results of physicochemical tests on furnace wastes in relation to legal acts and an attempt was made to diagnose the phenomenon observed on the basis of own surveys.

Keywords: *furnace waste, co-incineration of waste, properties of furnace wastes*



ANALYSIS OF THE FLUE GAS PRODUCED DURING THE COAL AND BIOMASS CO-COMBUSTION IN A SOLID FUEL BOILER

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As the low emission of the particulate matter (PM, or 'floating dust') and gaseous pollutants from coal-fired boilers is the main source of air pollution in Poland, more environmental-friendly alternatives for coal combustion should be taken into account. Another important factor is the education and raising the awareness of the inhabitants of the given region about alternatives to coal burning. One of them is the co-combustion of coal and biomass. The following article describes the experimental co-combustion of different coal-biomass blends with the use of Galmet boiler, which is a part of a mobile educational installation designed by AGH University of Science and Technology and Galmet. The research concentrated on the flue gas composition changes, connected to the rising content of biomass in the blends. The flue gas composition was measured with the use of Testo 350 and Testo 380 probes. The combusted coal-biomass blends contained 10 wt.%, 20 wt.%, and 30 wt.% of biomass pellets. The flue gas composition was also compared to the flue gas produced during the coal combustion in the same boiler. The results show that with the rise of the biomass content in the blend, the NO and NO₂ content drops significantly, and in the case of blend with 30 wt.% of biomass, no NO₂ emission was detected. The SO₂ content in the case of 10 wt.% blend is slightly higher than the SO₂ content in flue gas from the coal combustion, but its content drops in the case of the 20 wt.% and 30 wt.% blends. No clear correlation between the PM emission and the biomass content in the blends was observed. As the results of the co-combustion are promising, they can become a part of educational programme about emission reduction, demonstrated with the use of the mobile installation.

Keywords: coal and biomass co-combustion, low emission reduction, mobile didactic rig



CHARACTERISTICS OF BIOMASS BOILERS AND PROPERTIES OF WOOD PELLETS IN THE LIGHT OF PHYSICAL AND CHEMICAL ANALYSIS

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Wood pellets, classified as solid biomass and formed as a result of mechanical compression of small particles of plant biomass and agricultural, forestry and industrial products and wastes (also used for the production of furniture), are listed among renewable energy sources.

During the process of biomass combustion, harmful compounds including: particulate matter, carbon monoxide (CO), organically bound carbon (OGC), polycyclic aromatic hydrocarbons (PAHs), dioxins, and furans, are released into the atmosphere. As a result of incomplete combustion of volatile matter released during the combustion, an increase in emissions of carbon monoxide, gaseous pollutants of organic origin, and PAHs is observed. Particulate matter, released during the biomass combustion, is divided into inorganic and organic aerosols. Reducing the emission of solid and gaseous particulate matter and PAHs is possible by controlling the combustion process. In the case of inorganic dust particles, the adjustment of the process has a limited impact on reduction of their emissions. Emission of harmful compounds to the natural environment depends on the quality of biomass used in the combustion process. The condition and quality of the chimney installation, the contamination of the heat exchanger in the boiler, and the quality of the central heating installation used with the boiler are of great importance.

The article discusses two closely related issues. In the first part, five biomass boilers, previously subjected to energy and emission analysis, are described. The obtained results have shown a decrease in the emissions of organically bound carbon (from about 6 g/GJ for a class 5 boiler to <1 g/GJ) and NO_x (from >260 g/GJ to <150 g/GJ). The emissions of particulate matter PM₁₀ and PM_{2.5} were not reduced significantly, while the emissions of CO varied depending on the boiler capacity (the lowest values for CO were obtained for a 50 kW (3.8 g/GJ) boiler). Based on physico-chemical analysis, it was found that the content of the examined parameters varies for each batch of wood pellets, regardless of their source. The greatest spread of results (0.02% to 4.00%) was observed for the chlorine content, indicating that this parameter significantly exceeds the limit values for each batch of wood pellets.

Keywords: wood pellet, chlorine, particulate matter emissions, biomass boiler

Keywords: pellet, biomasa, boiler



POSSIBILITIES OF APPLYING THE GASIFICATION PROCESS IN COFFEE GROUNDS TREATMENT

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In recent years technological development towards more rational and effective usage of biomass for energy purposes has been observed. A similar tendency has been noted for waste biomass or organic waste from various industries, including agro-food. A good example of such organic waste is coffee grounds, which has been recently generated in increasing quantities and, due to market changes (new commercial networks of coffee-houses), collected separately in significant amounts. The energetic usage of this waste is feasible, yet because of high moisture content (reaching 60%) an appropriate technology has to be applied. One of the possibilities is coffee grounds gasification, which transforms the fuel from solid to gas. The obtained gas can subsequently be combusted in more effective and environmental friendly manner. The article presents an analysis of subjecting coffee grounds to a gasification process as well as the results of physicochemical tests regarding energetic properties of the material (moisture content, heat of combustion, loss on ignition). Moreover, the article shows the results of applying coffee grounds as an additive to gasification of willow chips, i.a. the influence of the coffee grounds additive on process duration time, temperatures in the reactor as well as energetic effects of the process.

Keywords: *gasification, coffee grounds, waste treatment*



SELECTIVE CATALYTIC DEHYDRATION OF BIOETHANOL PRODUCED FROM RENEWABLE ENERGY SOURCES—BIOMASS

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Over the past decades, the consumption of bio-ethanol as a fuel or fuel additive has steadily increased, and by 2017 it amounted to about 100 million tons. An important role of bio-ethanol, an alternative to fossil energy resources, is due to the simplicity of its production, which does not require special equipment, and the possibility of using different natural raw materials and bio-waste; this has not a harmful effect on the environment. Significant volumes of production and low cost of bio-ethanol allow us to consider it as a valuable raw material for getting important chemicals. They include diethyl ether, ethylene, ethylene oxide, propylene, butadiene, acetaldehyde, vinyl acetate, and others. Dehydration of ethanol in the gas phase, depending on the experimental conditions and the used catalyst, takes place with the formation of ethylene and diethyl ether. The formation of diethyl ether is thermodynamically advantageous at temperatures below 160–180 °C, and with the increase in temperature, the yield of ethylene is much higher. One of the most active catalysts of ethanol dehydration is heteropoly acids, which differ from other catalysts with considerable acidity, high stability, and show a lack of by-effects, in contrast to mineral acids. Because of the low specific surface area when preparing the solid acid catalysts, heteropoly acids are usually immobilized onto carriers, which increase the dehydration efficiency by increasing the dispersity of heteropoly acids.

In this vein, in the present study, we proposed the activated carbon obtained from the wasted biomass taken from agricultural and food processing for preparing effective solid acid catalysts containing 0.1 mmol/g of phosphotungstic acid; this acid was immobilized in the catalyst surface layer. At the temperature of 110–145 °C, such catalysts converted bioethanol that produced from renewable energy sources—biomass, to diethyl ether. In the temperature range of 170–200 °C, the dehydration of bioethanol gave ethylene with 100% selectivity. By combining of the adsorption and catalytic studies, it was shown that oxygen-containing functional groups of the carbon surface supports the immobilization of phosphotungstic acid and are bioethanol adsorption centers supporting the selective dehydration.

Keywords: *Bioethanol; Selective catalytic dehydration; Activated carbon from waste biomass; Bioresource technology*



A NEW METHOD FOR DETERMINATION OF TOTAL ACID NUMBER IN DIESEL FUELS WITH 4-HYDROXYSTYRYL DYES AS INDICATORS

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The determination of the acid number plays a great role in the analysis of different objects, especially in industrial products and biodiesel. Biodiesel is gaining more and more importance as an attractive fuel due to the depleting fossil fuel resources. There are some advantages of biodiesel as nontoxic, high flash point, low level of pollutants, biodegradable, renewable energy source and others.

This work deals with the development of express and selective titrimetric method for determination of Total Acid Number (TAN) in biodiesel and diesel samples using 4-hydroxystyryl dyes (4-HSD) as indicators. We studied the absorption maximums of merocyanine forms in different solvents by spectrophotometric method. The transformation from the protonated to merocyanine form is accompanied by bathochromic shift near 100 nm. Absorption maximums of cationic and merocyanine forms and acidity constants (pKa) of investigated dyes have been determined by spectrophotometric method previously. We have described different properties of 4-hydroxystyryl dyes such as solvatochromic, protolytical, protocromic in the present works.

For the determination of the content of derivatives of fatty acids in diesel fuels and determination of TANs, commercial samples from gas stations were analyzed. For comparison, biodiesel (B100) was produced by the alkaline trans-esterification method. It has been found that direct IR spectroscopic investigations allow us to quickly establish the presence of higher fatty acid derivatives by the characteristic signals in the region of 1746-1654 cm⁻¹, which are almost absent in a number of samples of diesel oil of diesel origin. The proposed method for determination of TAN with pyridinium 4-HSD was compared with ASTM D664-11 standard and characterized by good reproducibility and correctness (n = 3-5). Optimal conditions of total acid number determination by using of 4-hydroxystyryl dyes as indicators were investigated.

The proposed method is: more environmental friendly due to the use of less costly and less hazardous solvents; simpler to be performed and more cost effective due to the decrease in consumption of expensive organic solvents. 4-hydroxystyryl dyes are making very important contribution in green chemistry analysis due to unique properties.

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Keywords: *Total Acid Number, Merocyanine Dyes, Industrial Oils, Biodiesel, Indicators, Titration*



POSSIBILITY OF USING BIOWASTE COMPOSTED WITH BIOCHAR FOR ENERGY PURPOSES

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Biowaste i.e. organic fraction from municipal solid waste (OFMSW) is potentially a valuable raw material for use in power generation. These wastes are characterized not only by good fertilizing properties, but also by the combustion heat over 10 MJ.kg⁻¹.

Composting is one of the most preferred methods of biowaste recycling in the world. The organic matter in this process is biodegraded by microorganisms in aerobic conditions. The purpose of bioprocessing of this waste is to receive fertilize (compost) or stabilized waste (to be deposited in a landfill). The process is conducted in order to limit the landfilled waste mass (particularly biodegradable waste) and to reduce greenhouse gases emission from landfills.

Sometimes, after bioprocessing of waste, the desired results are not obtained (i.e. too high organic matter and moisture content, too low nitrogen content, content of pathogenic microorganisms. Such waste may be probably directed to thermal treatment plants.

The aim of the study was to evaluate the impact of biochar addition (1.5%, 3%, 5% and 0% - control) to the biowaste composting on energy properties of those waste.

The research was carried out on a real object in Central Composting Plant in Brno, the Czech Republic. The processing time of the waste took 3 weeks (thermophilic phase). The changes in moisture, C,H,N, S content, ash content, heat combustion and calorific value were evaluated.

The most important conclusion from the conducted research was the statement that the thermophilic phase significantly reduces the heat of combustion (from 12 to 6 MJ.kg⁻¹) of bio-waste, but each of the used additives of biochar resulted in a higher calorific value than in the case of control. Biowaste after the bioprocessing process with biochar, are not suitable for energy production in power plants, but it can be used as alternative fuels in cement plants.

Keywords: biowaste, biochar, composting, energy



ANALYSIS OF SHALLOW GEOTHERMAL SYSTEM UTILIZATION IN THE AGH-UST EDUCATIONAL AND RESEARCH LABORATORY OF RENEWABLE ENERGY SOURCES AND ENERGY SAVING IN MIĘKINIA

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The AGH-UST Educational and Research Laboratory of Renewable Energy Sources and Energy Saving in Miękinia utilizes shallow geothermal heat by means of heat pumps. The article describes efficiency tests regarding two shallow geothermal systems based on borehole heat exchangers. Temperature parameters and power exploited from the ground was checked during two heating seasons. Additionally, the performance factor of the installations was monitored. In the second testing season effective length of borehole heat exchangers was reduced in two installations. It enabled checking changes of the seasonal performance factor of the system and the possibility of stable heat pump operation using only one of three borehole heat exchanger. Both tests brought positive results.

Keywords: *geothermal heat pump efficiency, borehole heat exchanger, shallow geothermal system, SPF*



SIMULATION OF THE TEMPERATURE DISTRIBUTION IN THE COMPOST USING THE AUTODESK CFD SIMULATION PROGRAM

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The purpose of the work was to determine the temperature course in the composting box intended for the organic recycling of dead poultry depending on the structure-forming material used. Wheat, barley, oat, rapeseed and maize straw were used as the structure-forming material. The condition for obtaining a compost with appropriate sanitary parameters is to achieve an organic temperature exceeding 70 ° C during the organic recycling process.

The simulation of temperature changes in the compost box was carried out using the Autodesk: Inventor and CFD Simulation programs. In Inventor, a geometrical model of a compost box based on an existing prototype was built. The CFD Simulation program analyzed the operation of the system in the field of air flow in a two-phase bed (air-structure-forming material) and temperature distribution in the bed. The program defines the materials from which the object is composed, boundary conditions and the initial operation of the deposit were defined. In order to optimize the work of the deposit, multi-variant scenarios with different initial parameters were designed: changing the temperature and structure-forming material. Section planes on which visualization of air velocity vectors and additional section planes with temperature field distributions have been defined. The obtained results of temperature fields from the multivariate simulation were compared to the actual temperatures in the deposit. The tests involved the use of a measuring system equipped with a probe with a temperature sensor with an accuracy of ± 0.15 ° C, a transducer and a data recorder.

Keywords: *organic recycling, compost, CFD simulation*



INFLUENCE OF TORREFACTION PARAMETERS OF CANADIAN GOLDROD ON PHYSICAL AND THERMOPHYSICAL PROPERTIES OF BIOCHAR

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Torrefaction is a promising pretreatment for biomass and its pyrolysis products upgrading. The purpose of the work was to analyze the possibility of using Canadian goldenrod (*Solidago canadensis*) for the production of biochar. The torrefaction process involved the vegetative and generative part as well as roots and rhizomes of the plant at temperatures of 250 and 275 [oC], for 2 and 3 hours. Next, the physical and thermo-physical properties of the raw material and biocarbon were determined in terms of humidity, ash content, volatiles, calorific value and heat of combustion. Volumetric density and loss of biochar weight were also determined. It was found that the highest calorific value (22.59 [MJkg⁻¹]) was characterized by biochar obtained from the generative part, in the process carried out at 275oC, for 3h, and the lowest giving roots and rhizomes with the same process parameters (15,4MJkg⁻¹). The highest percentage loss in mass was observed in the goldenrod in vegetative development (51.3% for the temperature of 275oC) The bulk density of the biochar was clearly lower than the bulk density of solid fossil fuels. The highest value was achieved by biochar obtained from roots and rhizomes (229 - 301 kgm⁻³).

Keywords: *Canadian goldenrod, biochar, bulk density, calorific value*



STUDY OF PAR INTENSITY DISTRIBUTION IN CYLINDRICAL PHOTOBIOREACTORS

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The production of microglons for energy purposes is difficult and costly. One of the important parameters influencing the efficiency of photosynthesis in photobioreactors is light radiation. In order to obtain information on the distribution of intensity of photosynthetic active radiation PAR in the PBR space measurements of the photon flux (PPFD) were measured at the nodes of the measured mesh. The tests were made for two cylindrical LEDs in designed photobioreactors. The measurements were made during the culture inside the culture medium using a Quantum MQ-200 Apogee Instruments Quantum Digital Meter. The tests were performed for the different intensity of light, light colour and the length of exposure time. Preliminary lighting studies have spearheaded the first stage of the modeling and lighting optimization process in the designed photobioreactors. They allowed the following conclusions:

No statistically significant differences were found between the instantaneous intensity of PAR radiation for the analyzed photobioreactors,

The increase in biomass of alga results in a change in the intensity distribution of photosynthetic active radiation PAR in photobioreactors,

The increase in optical density in the photobioreactor causes a decrease in light intensity within the reactor.

Keywords: photosynthetically active radiation (PAR), photosynthetic photon flux density (PPFD), microglons, photobioreactor



DRYING KINETICS OF SELECTED WASTE BIOMASS FROM THE FOOD INDUSTRY

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In recent years, biomass is one of the most important renewable energy sources. Most often it is a material with a high water content, which reduces its energy potential. Therefore, it is necessary to carry out the preliminary drying phase. The purpose of the work was to analyze the kinetics of drying of waste resulting from the production of juices obtained by extrusion. The drying process (forced convection, 1.5 m medium flow velocity • is the initial relative humidity of 5-10%) was carried out at various temperatures of 45-96 ° C, for apple pomace, formed in the form of cuboidal cubes. The influence of process parameters on the drying kinetics was determined. The drying curves and the drying rate over time and the water content in the sample at a given process temperature were analyzed.

Keywords: *drying kinetics, convection drying, apple pomace, drying speed, energy properties*



SIMULATION MODEL OF BIOMASS DRYING FOR ENERGY PURPOSES

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In recent years in Poland the largest share in the production of energy from renewable sources is biomass. Depending on the source of origin, the biomass differs in chemical composition, humidity, structure, as well as properties that determine its suitability for energy purposes. Therefore, the biomass is pre-treated and processed. One of the treatments is drying to lower the water content and thus the heating value.

Therefore, the paper attempts to develop a simulation model that allows the analysis of changes in water content and temperature in the biomass sample and the opal value, as well as the actual energy value of the sample after drying.

On the basis of heat and mass transfer laws from the sample: Fick's (mass diffusion) and Fourier-Kirchhoff's (heat diffusion) and balance based on the first and second law of thermodynamics, the mathematical structure of the model was developed, then in the MatLab environment simulation calculations were made based on the prepared algorithm of the model's operation. The formulated model was verified in terms of logic, and the results obtained from simulation calculations were validated, comparing with the results of the energy willow drying process - in pieces and wood chips in a layer, and apple pomace formed in cubes in a laboratory dryer, with forced ventilation at three temperatures: - 100oC. The logical verification of the model confirmed its compliance with heat and mass transfer laws and thermodynamic principles. Based on the performed validation, good consistency of the results (changes in water content, temperature, calorific value and heat of combustion) obtained from simulation calculations in relation to measurements was found - the relative error ranged from 5% for pomace to 7% for wood chips.

Keywords: *model, drying, biomass*



INFLUENCE OF THE PV POWER PLANT SIZE ON EFFICIENCY AND OPERATING PARAMETERS

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Currently built PV power plants are included in the national energy system, giving the opportunity to energy "storage" in this system, provided that they are pico power plants, below 40kWp. The concept of storage refers to the fact that energy surplus is put into the system and in later period we can charge from the grid less than 80% of what was given depending on the age of installed power of the PV plant. The power plant exploitation is settled in a half-year periods.

Running the PV power plant, on terms of prosumer settlements, can bring notable benefits in both financial and environmental aspects. However, to evaluate such investments a simple methods of efficiency analysis with guidelines of the PV power plant size and the inverter power cooperating should be applied. Currently used methods and models for the selection of the PV power plants size are based on the energy consumption per year. That is an economic criterion for cost analysis in the full capacity range.

The goal of the work was simple methodology development for determination of the energy efficiency utilization, which was generated in a PV micro-power plant for the needs of prosumer users. The research was performed in the vegetable farm located in the Kazimierza Wielka district on three independent PV installations, which were used to cover the energy demand of the household and the vegetable store.

Regardless of the PV power plant installation over sizing on the DC voltage side, the operating point is very rigidly maintained and varies in unfavourable range of $747 \div 760$ V of direct voltage.

Over sizing the PV installation on the DC side results in a proportional increase in average costs without the effect of an average efficiency increase of the produced electricity.

Keywords: PV modules, photovoltaic power plant, operation of a power plant, energy, efficiency



MULTIDIMENSIONAL COMPARATIVE ANALYSIS OF THE DEVELOPMENT OF RENEWABLE ENERGY SOURCES

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The policy of sustainable development, also in the field of energy, takes effect in all European Union countries. In the past, sustainable energy with energy obtained from renewable sources was equated. And although this is not the case today, renewable energy sources are still a fundamental pillar of a sustainable energy policy.

There is a need to monitor the impact and consequences of the policy of sustainable energy development on the development of renewable sources. In this area well-chosen aggregated indicators are a very helpful information and diagnostic tool. The results of the research on the same problem, but based on different synthetic indicators, may differ significantly, because they depend on the selection of individual indicators, the type of aggregated measure and its ability to differentiate, classification criteria, etc.

The calculations and analysis carried out at work allowed to propose an aggregated indicator that well reflects the level of RES development and its diversification. It was found that in the Kujawsko-Pomorskie and Pomorskie voivodships the situation in this respect can be considered as beneficial, while 10 years ago, it was impossible to say that about any voivodship. Unfortunately, in half of the regions, the level of RES development is low. In addition, over the last 10 years, apart from the Kujawsko-Pomorskie and Opolskie voivodships, there is no progress, and in two provinces (Mazowieckie, Wielkopolskie) the development of renewable energy sources is even threatened.

Keywords: *renewable energy sources, sustainable development, sustainable energy, aggregated indicators*



ECONOMIC ANALYSIS OF DOMESTIC HOT WATER PREPARATION USING AIR-SOURCE HEAT PUMP

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The heat pump as an ecological solution can be an option for using conventional hot water preparation. The article presents an economic analysis of domestic hot water (DHW) preparation using an air-source heat pump. The operation of the heat pump and the consumption of electricity during the one-time heating of the hot water tank were analysed. The test was carried out under real conditions. Basic parameters and test conditions were based on European Standard EN 16147:2017. Fuel and electricity prices have been determined for available energy tariffs and fuel prices in the region. Different configurations of energy tariffs were taken into account to analyze costs of DHW preparation using heat pump. Obtained costs were compared with the costs of DHW preparation using conventional heat sources: a gas boiler and an automated coal-fired boiler. Annual cost comparison were presented. The results show that average Coefficient of Performance (COP) of the heat pump working under real conditions is 2.06. The most expensive heat source for DHW heating is heat pump which works during a 24-hour tariff and the best economic solution is heat pump using 100% night tariff. However, annual costs of DHW preparation are still equal to the cost of DHW preparation using gas boiler.

Keywords: Heat pump, hot domestic water,



WYKORZYSTANIE KOMPOSTU Z DODATKIEM ODPADÓW Z FARMY DROBIU W UPRAWIE ZIEMNIAKA

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The aim of the work was to study potato crop yielding as a response to fertilization with compost with the addition of litter from rearing and dead poultry. The research was carried out in 2015-2017. The object of research was potato plants (*Solanum tuberosum* L.) of the Vineta variety. In the cultivation of potato plants, fertilizer was applied in the form of mature compost coming from a poultry farm. A dried wheat straw was used as the structural fraction. Various combinations used in the proportions of the components of the charge (structural fraction, litter and dead poultry). There were statistically significant differences between the experiment combinations. The use of fertilizer in the form of compost created with the addition of mulch and fallen birds affects the yield of potato plants of the Vineta cultivar.

Keywords: *waste, composting, potato, yield*



PROCES STOPNIOWEJ DYSFUNKCJI SILNIKA O ZS POWODOWANEJ TWORZENIEM SIĘ OSADÓW CZĄSTEK STAŁYCH PM POCHODZENIA FAME

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Optymalizacja procesu spalania paliwa w silniku o ZS przy wieloetapowym wtrysku HPCRS wyznacza główne kierunki badań w zakresie stabilności termodynamicznej paliw z dodatkiem FAME, w tym również procesów powstawania PM. Wskazano etapy wieloaspektowego wnioskowania diagnostycznego odnośnie przyczyn uszkodzeń układów funkcjonalnych silnika w wyniku zalegania osadów PM. Dokonano oceny parametrów pracy silnika z wykorzystaniem dedykowanego testera wykazując znaczenie przeprowadzania procedur diagnostycznych w okresach przeglądowych pojazdu, zapobiegając występowaniu stanów awaryjnych sygnalizowanych kontrolką MIL. W testowanym silniku M9R system EDC Bosch steruje czasem i fazami otwarcia wtryskiwaczy układu HPCRS, nadzoruje pracę turbosprężarki VTG, pełni kontrolę nad funkcjonowaniem układu DPF oraz układów pomocniczych. Jazda próbna pojazdem wyposażonym w ten silnik wykazała spadek dynamiki przy zaznaczającym się wzroście zużycia paliwa, pomimo braku sygnalizacji kontrolki MIL. Procedura diagnostyczna wykazała stopniową dysfunkcję wtryskiwacza przyczyniając się do powstawania PM, co wymaga wcześniejszej interwencji obsługowej. Zaleganie osadów PM prowadzi do niewłaściwego rozpylenia i dawkowania paliwa w układzie HPCRS co jest przyczyną postępującego stanu uszkodzeń układów VGT i DPF a w przypadku braku interwencji przeglądowych skutkuje zapisem kodów błędów w systemie OBD II.

Analizy widma XRF w odniesieniu do wyznaczenia udziału pierwiastków tworzących PM wraz z widmem IR spektroskopii w podczerwieni, wykazały udział związków organicznych pochodzenia FAME w osadzie stałym PM.

Zaprezentowane etapy testów i wnioskowania diagnostycznego w procedurach przeglądów pojazdu pozwolą na uniknięcie wielosymptomowych stanów niesprawności silnika sygnalizowanych kontrolką MIL.

W procedurach testów diagnostycznych z wykorzystaniem dedykowanego testera należy dążyć do pełnego zobrazowania parametrów roboczych układów współzależnych silnika a nie skupiać się na pojedynczych symptomach stanu obniżonej funkcjonalności układów lub dokonywać wymiany elementów wg wykazu kodów błędów.

Keywords: FAME, Biodiesel, Diesel Engine



COSTS COMPARISON OF HOUSE HEATING BY HEAT PUMP AND SOLID-FUEL BOILER

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The aim of paper was to submit an issue of detached house heating costs dependent on the type of chosen heating system. The demand for the heat was defined with Audytor OZC software. Basing on the obtained results the heating device was selected: heat pump and the automatic solid fuel boiler with a feeder of coal. Heat pump was chosen with Vito-WP software, where seasonal performance factor was calculated. The role of selected devices was to heat and prepare hot domestic water for a family of four. Costs of energy purchase and heat generation were calculated for each solution on the basis of current market prices for eco-pea coal and electricity supplying to the area. The results of the calculation were summed up and compared with each other. Furthermore, the amount of annual operating costs usage made way to define economic effect and simple payback time out for the investment. Economic analysis also took into account different price of purchasing heating devices. For chosen heating sources the ecological effect was also demonstrated, which made possible to determine the amount of harmful substances emitted to the environment during normal use for each of analyzed systems.

Keywords: heat pump, solid-fuel boiler



INFLUENCE OF AG AND CU NANOSTRUCTURES ON GROWTH INHIBITION OF MICROORGANISMS DURING SEASONING OF WOODCHIPS FROM WILLOW AND ADLER

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Nanotechnology is dynamically developing area which influence on daily life rapidly rises. Especially, inorganic nanoparticles such as silver, copper, platinum, titanium, zinc, gold or iron are one of the most interesting systems due to their applications and positive impact on pathogenic microorganism. Nanotechnology produced materials of various types at nanoscale level. NPs are tiny materials having size ranges from 1 to 100 nm. They can be classified into different classes based on their properties, shapes or sizes. However still is going on discussion about the influence and the risk of adding nanomaterials to the consumer products and their influence to the living organisms. Inorganic nanoparticles are also investigated for their antibacterial and antifungal properties.

The aim of the research is to show antimicrobiological activity of silver and copper nanoparticles obtained by chemical synthesis. The tests were performed against bacteria, fungi, yeasts, actinobacteria contained in prepared woodchips. The bacteria were grown on TSA medium, fungal culture were grown separately in Sabouraud agar medium, yeasts on YEPD (yeast extract peptone dextrose) and actinobacteria on Gauz's medium. Fungi and actinobacteria strains were cultivated on Petri dishes for 120 hours in 28oC, 72 hours in 28oC for yeasts and 48 hours in 28oC for bacteria. The best inhibition of growth of fungi has been observed after using copper nanostructures. Ag nanostructure had worse effect on growth of tested microbes. It has been proved that not only the concentration of the nanoparticles but also exposure time has a significant influence on the inhibition of tested microorganisms. It may have been influenced by different cell wall structure of microorganisms, however this requires further research.

Keywords: woodchips, willow, adler, microorganisms, antimicrobial activity, metal nanoparticles



THERMOGRAPHY - NEW APPROACH TO BIOMASS COMBUSTION ANALYSIS

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Currently, biomass-derived energy constitutes two-thirds of renewable energy and, as provided by the forecasts, will also play a key role in future environmental-friendly European energy system. Therefore, it would be necessary to introduce efficient utility chains – starting from raw material production stage, through the energy transformation and ending with the energy consumption by the end users.

Material consisted four mixtures of corn silage and apple pomace in a different percentage which was the mass of digestate from the laboratory installation for the production of biogas situated in Faculty of Production and Power Engineering (Kraków, POLAND).

The aim of the study was to determine the behavior of the biomass samples under an oxidizing atmosphere. As well as analyze the possibility of using digestates from biogas production as biomass for energy purposes, by determining their physical and chemical properties.

The study carried out an analysis of the biomass combustion process in the air atmosphere. Combustion process has been observed using FLIR Thermal Imaging System. Registered thermal images were subjected to digital image analysis. Analysis shows that biomass combustion process takes place in three stages: drying, devolatilization and char combustion.

Keywords: *Thermography, biomass, combustion*



RENEWABLE AND NON-RENEWABLE ENERGY RESOURCES AND THEIR CIRCULATION IN NATURE

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Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. In contrast a non-renewable resource is a resource that does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human time-frames. An example is carbon-based, organically-derived fuel. The original organic material, with the aid of heat and pressure, becomes a fuel such as oil or gas. Earth minerals and metal ores, fossil fuels (coal, petroleum, natural gas) and groundwater in certain aquifers are all considered non-renewable resources, though individual elements are almost always conserved.

Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits. On the other hand non-renewable energy sources in the form of fossil fuels are the basic source of energy for industry, energy, transport and households. In connection with alarming reports on the depletion of fossil fuel resources (eg Peak Oil), many countries promote the use of renewable energy sources.

The work compares geothermal energy and biomass energy with natural gas and oil.

Keywords: *renewable energy resources, non-renewable energy resources,*



APPLICATION OF ELECTROMAGNETIC METHODS IN RECOGNIZING OF HYDROGEO THERMAL CONDITIONS INSIDE CRYSTALLINE MASSIFS

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Geophysical methods are widely applied in geothermal water reservoirs prospection as well as in recognition of its resources and geological conditions of occurrence. In general they are used as methods of initial phase of prospection before selection of potential drillings location. However, in recent years they are more and more frequently applied in detailed recognizing of structure and retention conditions of hydrogeothermal reservoirs and deposit parameters necessary for resources evaluation. There could be distinguished three areas of radically different geological characteristics that demand separate methodology of geological surveys with use of geophysical methods. These are areas of: Polish Lowlands with predominant sedimentary formations of relatively simple geological structure, Flysch Carpathians with intensive fold and thrust type tectonics typical for accretionary prism and Sudetes region with predominant role of crystalline rocks in geological structure. Hydrogeothermal reservoirs usually occur inside crystalline massifs in Sudetes area, the most frequently as fractured zones accompanying faults. Such conditions demand specific selection of geophysical survey methods and survey methodologies. The Sudetes Region that include Sudetes Mountains and Fore Sudetic Block is characterized by diverse and highly complex geological structure. On the other hand this is the very interesting area for mineral resources exploration. Important from economic and ecological points of view are geothermal energy and mineral water resources. High level of geological structure complexity causes strong difficulties in prospection works or, more generally, in geological and geophysical subsurface recognition. Particularly, magmatic and metamorphic orogeny of Sudetes as well as crystalline basement of its foreland are thankless area for application of seismic method, that is the main tool for structural investigations of sedimentary formations. In such circumstances the place for application of alternative geophysical methods in prospecting works and structural investigations is opened, particularly electromagnetic methods are useful, including magnetotellurics which is the most universal among them. Recently, magnetotelluric surveys were made in the Sudetic area in small scale but with good results. Four basic methodological variants of the method were applied: deep magnetotelluric soundings (MT/AMT, in wide frequency range of natural field), audiofrequency magnetotelluric soundings (AMT, in high frequency range of natural field), continuous MT and AMT profiling as well as soundings and profilings with use of artificial source of primary field (CSAMT, Controlled Source Audiofrequency Magnetotellurics). Results of survey with use of magnetotelluric methods in recognizing of thermal and mineral water illustrate works made in Cieplice Śląskie Zdrój, Polanica Zdrój, Łądek Zdrój and Nysa areas. The mentioned above investigations as well as other surveys made on the commission of individual private investors confirm effectivity of MT



methods in recognition of relatively deep (up to 3-4 km) fault zones as prospective for thermal mineral water occurrence.

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Keywords: *electromagnetic methods, crystalline massifs*



OPTIMIZATION OF THE PARAMETERS FOR THE PROCESS OF GRAIN COOLING

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Among the classical technologies, which apply elevated temperatures for preserving of grain and cereal products, there are two the most effective ones, currently used all over the world. They are effective from the standpoint of maximum possible preservation in terms of the indicators for nutritional value. The indicators are storage of cooled fresh raw materials in adjustable or modified gas environment and a long-term storage in a frozen state.

The study dealt the first technology which employed active ventilation by the flow of refrigerant. Cooling of food products with subsequent storage at appropriate low temperatures is one of the best methods for preventing or slowing down product damage, ensuring the most complete storage of their original natural properties. Qualitative parameters for optimization of the investigated process included the mass fraction of gluten, moisture in raw materials, volume of air supplied, and the product processing temperature. On the base of a rootable, central-composite planning of a multifactorial experiment, a mathematical model for the data distribution was obtained.

This enabled to build a bar chart to illustrate the distribution of qualitative and power characteristics of the investigated process. The obtained mathematical models, which are presented in the form of a multiple regression of the second order, allowed to describe the process of grain products storage adequately.

As a result, we determined the optimal technological parameters for the equipment operation while studying the humidity of the processed materials, volumetric flow of air as well as the temperature of the working agent.

To describe the investigated process of grain products storage adequately, we designed the mathematical models which included a multiple regression of the second order and employed the results of the multivariate experiment. The application of the presented models allowed to obtain optimal technological parameters for the considered equipment. The moisture content in the processed material was 12.5 ... 14%; volume of air supply made up 5200 ... 5700 m³ / hour and the temperature of the heat agent was 7 ... 11 0C. According to the presented results, we could claim that gluten content during long-term storage would be 24% for power consumption of 9.15 kW / t under stated technological regimes.

Keywords: grain, optimization, cooling, storage, process, parameters



PROSPECTS FOR AUTOMATION OF ENERGY WILLOW PLANTING MASHINES

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Existing machines for planting energy crops cuttings are characterized by the low productivity because of the speed restriction to hand stowing into a plant setter. Therefore, establishment of mechanisms for the cutting autostowing into a plant setter is a current scientific and production task.

The research is set against the analysis of the known planting machine constructions that are used for setting the potted plants and forest seedlings. In this research, the methods of structural and factorial analysis with regard to the mechanisms' arrangement were used, as well as peculiarities of the working processes occurring at each stage of the overall technological process of the cutting relocation from the reservoir to the land area were highlighted.

Having analyzed various designs, we came to the conclusion that in order to increase the productivity of planting machines, the process of feeding the cuttings from the containers to the planting machine needs to be improved. Also it is necessary to use intermediate cutting pools, which creates a buffer that compensates for the discrepancy between the planting machine productivity and human capabilities. But this solves the issue of productivity increasing and reducing the proportion of manual labor only partially.

Creating mechanisms for automated cutting feeding to the planting machine or directly to the planting site is an important scientific task in increasing the productivity of planting machines.

As a result of the design analysis of existing means of planting automation and implementation methods of automated process of the planting material feeding, we managed to allocate possible ways of organizing different methods in the technological process, which is reflected in the structural and logical process scheme.

Keywords: *planting machine, plant setter, feed gearing, planting head, cassette mechanism, energy willow*

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ANALYSIS OF TECHNICAL SOLUTIONS OF PLANTING MACHINES, WHICH CAN BE USED IN PLANTING ENERGY WILLOW

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Energy willow planting process requires the use of highly efficient and productive machines. The analysis of construction of machines for planting energy crops, forest plantations and seedlings and the processes which take place in the process of planting made it possible to systemize the accumulated experience in the design of planting machines, and highlight the most effective technical solutions. The revealed features of planting machines for different types of planting material are compared with the designs of energy willow planting machines. This study found a number of characteristics and advantages of different machine types, which will ultimately lead to an increase in productivity of planting aggregates and will facilitate the work of a planter.

Keywords: *planting machine, plant setter, seedling planter, forest planters, energy crops, cutting, planting material*

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