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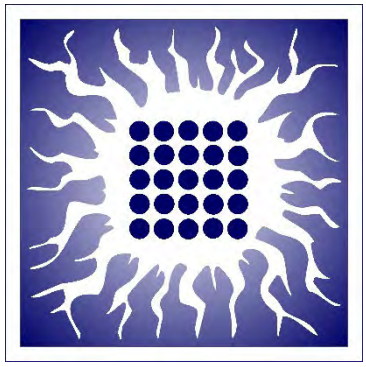

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I.Plenary session

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THERMO-HYDRAULIC DRIVERS OF THE GLOBAL CLIMATE SYSTEM

Miodrag Mesarović

Abstract: A lot of effort is required from the humanity to preserve the global climate from changes that could make the living conditions on Earth unsustainable. Decarbonization of the energy sector is meant to give the key contribution by humans to keep the global temperature rise by the end of this century below levels determined by the Paris Agreement. Transition from fossil to renewable and other energy sources that do not emit greenhouse gases is an inevitable goal for the humanity to preserve natural cabon cycle from a risky inbalance. As the climate system on Earth is extremely complex, there is no possibility for climate change phenomena to be examined in a laboratory like the majority of the thermo-hydaulic phenomena is, the thermal engineers and scientists are left to depend only on historic records and mathematical simulations of an extremely large quantity of climate change drivers studied within several tens or hundreds of scientific disciplines. Still, many of the inter-relations or feedbacks among climate phenomena remain quite uncertain or entirely unknown, so that many of the climate change drivers need to be identified and explaned to make humanity aware of all the risks to be prevented in fighting against climate change beyond repair. The paper lists the major known thermo-hydraulic and other drivers of the climate system and related open questions in the field of the thermal science as a pathway for further research and studies of thermal and hydaulic kind in the climate system.

Keywords: *Climate change, Thermal science, Solar radiation feedbacks, Climate models.*

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ENERGY SYSTEMS IN TRANSITION AND POST-TRANSITION

Vojin Grković

Abstract: Short overview of the most significant theoretical concepts of transition is presented. Concept of the energy system as cluster of the structures surrounded with external structures is also presented and discussed. The indicators of the individual structures, as well as of a surrounded (environment) structure are proposed and discussed. A short overview of the most significant theoretical concepts of energy transition is also presented. The indicators of energy transition are presented and discussed too. The problem of energy just transition based on literature survey is particularly considered. Further is introduced a concept of the power system's competitiveness on the energy transition trajectory with appropriate indicators. Two types of indicators are considered. First one comprises costs, carbon dioxide emission and energy produced, while the other indicate power system's dispatchability. The concept, as well as, appropriate results of competitiveness analysis of real power systems in nine European countries in hypothetical energy transition are presented and discussed. The results point out that in each considered country power system is more competitive, regarding both indicators, on transition trajectory from fossil fuels to nuclear power plants than on the trajectory from fossil fuels to wind turbines. Problems of secondary and final energy storing in energy transition are considered too. The concept of energy post-transition is explained. The concept of energy technology competitiveness in energy post-transition is presented and discussed. The results of competitiveness analysis of five energy technologies in post-transition are presented and discussed. The results point out that in post transition the best competitiveness is obtained after the energy transition from fossil fuels to nuclear power plants.

Keywords: *Energy system, Transition, Post-transition, Competitiveness in transition, Competitiveness in post-transition.*

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II.Energy sources and potentials

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THE IMPACT OF CBAM AND VARIABLE RENEWABLE ENERGY INTEGRATION ON ENERGY SYSTEMS AND CROSS-BORDER ELECTRICITY TRADE

Boris Ćosić, Neven Duić

Abstract: This paper explores the energy system planning for Croatia and Bosnia and Herzegovina (HR-BA zone) in response to the Carbon Border Adjustment Mechanism (CBAM) and the growing need for renewable energy integration between 2025 and 2035. Using the Dispa-SET unit commitment and dispatch model, three scenarios, NECP, LRES, and HRES, were developed to evaluate how different levels of Variable Renewable Energy Sources (VRES) integration and CO2 pricing impact the region's energy system. In the NECP scenario, Bosnia and Herzegovina's electricity exports decrease from 3.39 TWh in 2025 to 1.29 TWh in 2035, driven by CBAM implementation and the rise in renewable energy use. The HRES scenario shows aggressive renewable energy deployment, resulting in 2.35 TWh of electricity export in 2035, but also reveals substantial curtailment issues, with a maximum hourly curtailment value reaching 3,926 MW and occurring over 4,114 hours during 2035. These findings underscore the difficulties of integrating large amounts of renewable energy without significant upgrades to grid infrastructure and storage solutions.

Keywords: *CBAM, Dispa-SET, ETS, NECP, VRES.*

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ECOLOGICAL AND ENERGETIC OPTIMIZATION OF THE OPERATING PARAMETERS OF THE PROCESS OF THERMAL PLASMA GASIFICATION OF SEWAGE SLUDGE

Jovana Anđelković, Aleksandar Erić, Nikola Ćetenović, Nikola Živković and Dejan Cvetinović

Abstract: In this paper, the effects of the main operating parameters of the gasifier, such as temperature, gasification medium selection and two parameters related to the gasification medium – equivalence ratio and steam-fuel ratio - on the performance of the thermal plasma gasification process of sewage sludge with high moisture content are investigated. A one-dimensional thermodynamic equilibrium model for thermal plasma gasification was developed to perform a parameter study. The model is based on the principle of the minimum of the Gibbs function. The input to the model is only the data from the ultimate and proximate analysis. The output of the model provides the equilibrium composition of the gasses produced. A comparison of two different gasification media, air and steam, showed that steam provides a higher yield of hydrogen and carbon monoxide in the produced syngas. The analysis showed that the optimum conditions are T=1200 K and ER=0.2 for air plasma gasification and T=1200 K and SFR=0.1 for steam plasma gasification. The syngas produced in steam plasma gasification has the following composition: 64.7% H2, 9.16% CO, 23.9% CO2 and 2.22% N2. The results obtained can serve as a basis for a multicriteria optimization based on ecological aspects, the reduction of energy production and the possibility of using the syngas produced for energy recovery in the process.

Keywords: *Sewage sludge, gasification, thermal plasma, thermodynamics equilibrium modeling.*

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EROI DETERIORATION FOR OIL AND GAS AND IMPLICATIONS FOR IMMEDIATE ENERGY OUTCOMES IN EUROPE

Saša Marković, Boban Nikolić, Nikola Petrović and Dragan Marinković

Abstract: Energy Return on Investment (EROI) or Energy Return on Energy Invested (EROEI) is a ratio used to measure the amount of usable energy that can be extracted from a particular energy source compared to the amount of energy required to extract, process, and distribute that energy source. More than a century ago, EROI for oil in the USA exceeded 100. Since then, EROI for oil has decreased by at least five times. Despite the significantly higher global oil production today, the decline in EROI for oil poses considerable challenges for global energy sustainability in the near future. While natural gas is expected to play a crucial role in the upcoming energy transition, EROI for gas is also decreasing. This implies less net energy available, even as the global energy demand continues to grow. This paper offers an overview of EROI values for both fossil fuels and other energy sources, including renewables. The summary provides a prediction of the upcoming energy perspectives globally, with a specific focus on Europe, considering the decline in EROI and the reduction of global oil reserves.

Keywords: *EROI drop, Oil, Gas, Renewables, Net energy deficit.*

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CONTROVERSIES OF ENERGY STORING IN THE ENERGY TRANSITION

Vojin Grković

Abstract: The paper discusses the motives and purpose of energy storage in general and particularly primary, secondary and final energy. The energy system in the energy transition is considered using the energy matrix model. For the energy transition, two current concepts of secondary electrical energy storage are considered: the concept of secondary electrical energy storage as mechanical energy and the concept of the storage as chemical energy in the form of e-fuel. These two concepts are analyzed from the point of view of the density and the stored energy price. It is concluded that the competition between these two concepts is still going on and that neither of them has achieved an advantage in terms of adapting to the socio-technical regime of the energy transition. The competition of individual electrical batteries in terms of the price of stored energy is considered. It is estimated that, in this respect, sodium batteries have a significant advantage over lithium batteries. Finally, it is concluded that the competition will continue, on the one hand, between two concepts of secondary electrical energy storage and, on the other hand, between individual concepts of electric batteries.

Keywords: *Energy storage, Energy Transition, Batteries, E-Fuels.*

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DRYING THE HEMP FLOWER IN A CONDENSATION DRYER

Branka Radovanović, Jelena Janevski, Mića Vukić and Saša Pavlović

Abstract: The drying process of hemp flowers is crucial for preserving the quality of cannabinoids, terpenes, aromas, and other valuable compounds. In this study, the drying of hemp flowers using a condensation dryer, combined with a heat pump, is investigated. This type of dryer allows for significant energy savings by retaining both the latent and sensible heat within the chamber. Although the drying process is somewhat slower than in conventional dryers, the quality of the drying is exceptional. The dryer operates at slightly lower temperatures, up to 60°C, making it ideal for delicate products such as hemp flowers, herbs, and chopped fruits and vegetables. The drying process plays a key role in the retention of aroma and in the overall quality of the products. Key drying parameters, including air temperature, humidity, and the amount of condensate collected, are continuously monitored. Results will provide detailed hourly insights into these parameters, along with an analysis of the drying regime, offering recommendations for optimizing the process to preserve product quality.

Keywords: *Hemp flower, Condensation dryer, Drying parameters, Air temperature and humidity change, Condensate.*

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DIGITAL TWINS IN BIOGAS PRODUCTION: CHALLENGES, TECHNOLOGICAL POTENTIALS, AND KEY SENSOR PARAMETERS

Milena Mančić, Bojana Vukadinović, Milena Rajić, Marko Mančić and Miomir Raos

Abstract: Digital Twin technology is revolutionizing biogas production by enabling real-time monitoring, simulation, and optimization of plant operations. By integrating advanced sensors with data models, digital twins allow operators to simulate various operational scenarios, optimize key process parameters, and improve decision-making. This technology enhances methane yields, process control, and predictive maintenance, yet faces significant challenges, particularly related to sensor technology, data integration, and computational infrastructure. One major advantage of digital twins is their ability to optimize anaerobic digestion, which is sensitive to factors like temperature, pH, feedstock composition, and microbial dynamics. Digital twins allow continuous simulation and adjustment of these variables, enhancing efficiency and methane production. Additionally, they improve predictive maintenance by monitoring equipment health and forecasting potential failures, reducing downtime and maintenance costs. Sensor-related challenges, however, impede implementation. Accurate, real-time data is essential, but many biogas plants lack advanced sensor infrastructure. Harsh operating conditions, including high humidity and corrosive gases, degrade sensors, requiring costly, corrosion-resistant designs [3]. Variability in biological processes and feedstock composition also complicates modeling accuracy, and large data volumes demand robust IT infrastructure, which smaller facilities may lack. Key sensor parameters include temperature, pH, gas composition (CH_4, CO_2, H_2S), feedstock composition, volatile fatty acids (VFAs), and ammonia levels. These factors significantly impact microbial performance and biogas yield. Monitoring and optimizing these variables are critical for maximizing process efficiency. In conclusion, while digital twins offer significant potential for optimizing biogas production, challenges related to sensor reliability, data integration, and IT infrastructure must be addressed for successful implementation and long-term sustainability.

Keywords: *Digital Twins. Biogas, Sensor, Operational scenarios*

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UNLOCKING WATER-ENERGY-FOOD-ECOSYSTEMS NEXUS PLANNING UNDER EXTREME EVENTS: A HOLISTIC APPROACH ESTABLISHED IN THE NEXUSNET COST ACTION

Giannis Adamos

Abstract: The Water-Energy-Food (WEF) Nexus concept highlights the interactions among systems that contribute to the achievement of the UN Sustainable Development Goals (SDGs), focusing on No. 2 for food security, No. 6 for water and No. 7 for energy, and provides insights into the cross-sectoral implications of single-sector strategies. The existence of a Nexus that connects these resources has been acknowledged by the research communities, as well as the public management. Ecosystems, along with other dimensions, like climate, health, transportation, economy are also linked to WEF thus, an integrated approach is required to recognize potential synergies and trade-offs and secure the formulation of coherent policy recommendations. Acknowledging the severe impacts resulting from extreme events worldwide, NexusNet community set a new goal: to assess the Nexus implications of extreme events, by investigating shocks that are recognized by literature as natural hazards, interlink them to different dimensions of Nexus and apply the Nexus theory on drafting recommendations towards increasing national/regional/local resilience against such events. Flood, drought, wildfire, earthquake, tsunami, volcano, heatwaves, tornado, landslide and snowslide are initially indicated as the natural hazards to be investigated, along with other shocks, namely, pandemics, conflicts, migration flows, major athletic and cultural events (i.e. Olympic Games). Based on a structured and detailed literature review, an initial list of case studies will be established and then the most appropriate cases will be further analyzed, in order to determine interlinkages with different Nexus dimensions, including: water, energy, food, ecosystems, climate, soil, transportation, land uses, health, information and communication technologies, etc. The last step of this approach will focus on linking each interlinkage (impact) to a solution or recommendation proven to be successful for the mitigation of the impacts of extreme events.

Keywords: *WEFE, Natural hazards, Sustainability, Resilience, Holistic approach.*

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III.Renewable energy sources

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EXTENSION OF VLASINSKE HYDROPOWER SCHEME TO PUMPED STORAGE

Aleksandar Petković

Abstract: Vlasinske hydropower scheme is technically complex and spatially very distributed system, with four cascaded HPPs (Vrla 1-4). It had been built in two stages (mid 1950's and late 1970's). The second stage, as extension of the system, comprised development of additional facilities for collection of waters at high- and intermediate horizons (northern and southern watershed flank, respectively) and their conveying (dam and pumping station Lisina; channel network) towards the upper storage reservoir (lake of Vlasina) in order of hydropower utilization (second stage of HPPs derivation waterways and generating units) within the cascade. Additional extension of the system (the third stage), aiming to further enrich the water resources, could comprise development of necessary facilities (the lower storage reservoir and pumping stations Vrla 4-1 with appurtenant installations). Thus, pumping of the waters which are already utilized once within the cascade back into the upper storage reservoir (at low-price tariff) would allow for their seasonal redistribution and later-on utilization within the winter periods (at high-price tariff). Energy resources for pumping could be provided via long-term contracts with regional TPPs and NPPs operators. Within deregulated and commercialized electric power market environment, this could bring significant additional benefits. This paper briefly presents conception and main technical parameters of the extension of Vlasinske HPS.

Keywords: Hydropower, Pumped storage, Renewable energy sources, Vlasinske hydropower scheme.

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DEEP LEARNING SEMANTIC SEGMENTATION FOR MAPPING AGRICULTURAL WASTE SOURCES WITH THE GOAL OF VALORIZING ENERGY THROUGH BIOGAS PRODUCTION FROM AGRICULTURAL WASTE - VINEYARD CASE STUDY

Emina Petrović, Ana Momčilović, Dragana Dimitrijević Jovanović, Gordana Stefanović, Miloš Simonović, Maša Milošević and Vlastimir Nikolić

Abstract: Because there is a trend of increasing waste and decreasing resources, significant efforts are being made to identify innovative ways of using various types of waste as potential energy and material resources. Agricultural activities generate a large amount of agricultural waste, which, if not properly treated, can cause a variety of problems with negative environmental consequences. Converting AW into biogas is an excellent way to use it, but commercialization of this process requires a good understanding of potential resources, first of all, the types and quantities of generated waste. As a result, this paper suggests a deep learning-based image segmentation method for detecting potential agricultural waste sources in remote sensing images. The performance of the FC Network for semantic dataset segmentation with the objective of recognizing the vineyard as a source of AW for biogas production has been examined.

Keywords: *Semantic Segmentation, Agricultural Waste, Remote Sensing, Semantic Labeling, Vineyard.*

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RAW MATERIALS FOR BIODIESEL PRODUCTION - POSSIBILITIES AND CHARACTERISTICS

Boban Nikolić, Saša Marković, Nikola Petrović, Dragan Marinković and Vesna Jovanović

Abstract: Interest in using biodiesel as a fuel for diesel engines is typically increasing due to energy crises, rising crude oil prices, uncertain forecasts of actual fossil fuel reserves, and stricter environmental requirements aimed at preserving the environment. The use of biodiesel (and other alternative fuels) has increased in particular due to regulatory requirements regarding the minimum total share of alternative energy sources. The biodiesel raw material base is quite wide. It mainly depends on the region, climate, land composition and quality, local and traditional practices, as well as the applied technological processes. Theoretically, any organic matter whose processing can produce oil is potentially a biodiesel raw material. Practically, it depends on the oil content of the crops, yields, required cultivation land quality, production technology as well as the characteristics and impact of the obtained biodiesel on engine operating parameters, including exhaust emissions. Different crops can be used to obtain biodiesel, most often: oil palms, soybean, rapeseed, sunflower, algae, Jatropha, corn, Pongamia pinnata, Pennycress, peanuts, even mustard, hemp, Mahua, flax, cotton, castor, coconut, etc. The paper presents the characteristics and potentials of some raw plant crops for biodiesel production as well as the observed impact on the environment.

Keywords: *Alternative fuel, Biodiesel raw material, Oil content, Yield.*

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EXPERIMENTAL AND THEORETIC STUDY OF THE IMPACT OF REAL ATMOSPHERIC CONDITIONS ON PHOTOVOLTAIC MODULE TEMPERATURE

Danijela Kardaš Ančić, Mirko Komatina and Petar Gvero

Abstract: Solar radiation that reaches the surface of the photovoltaic (PV) module is partly transformed into electricity. The most of radiation is transformed into heat. The temperature of the photovoltaic module increases which causes a decrease in their electrical efficiency particularly at temperature above 25 °C. The accurate knowledge of the photovoltaic module temperature is essential for the correct prediction of the PV energy production. In this study is presented an overview of different empirical models for estimation of PV module temperature using measured weather data. In order to analyze the influence of wind velocity on the temperature of PV module, two groups of mathematical models were analyzed. The first group does not include the influence of wind velocity, while the second group takes into account wind velocity influence on PV module temperature. It is shown that empirical models can be used for estimation of PV module temperature taking into account specificities of geographical location and its climate. The obtained results were compared with the measured data of the temperature of the PV module at the experimental setup. The experimental installation was designed, constructed and built to enable measurement of all relevant parameters in real time. The results show that meteorological parameters such as air temperature, solar radiation and wind velocity define and have significant influence on PV module temperature and therefore on PV energy production.

Keywords: *Photovoltaic module temperature, Theoretical models, Experimental study, Meteorological data.*

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ASSESSMENT OF FLOATING SOLAR PANELS POTENTIAL FOR ELECTRICITY GENERATION IN THE ADRIATIC SEA

Danka Kostadinović, Milić Erić and Zoran Marković

Abstract: Solar energy helps achieve several Sustainable Development Goals that have been proposed by the United Nations. Offshore solar energy deployment has not gained satisfactory attention when it comes to the Adriatic Sea. In this paper, the energy production, reduction of carbon dioxide emissions, and carbon credit of offshore solar power plant are estimated. The best location for a solar power plant in the Croatian part of the Adriatic Sea was selected considering solar potential, distance from shipping routes, proximity of existing onshore power grid, and visibility impact. The conceptual design of an offshore solar power plant was proposed. The obtained theoretical results show that offshore solar plant could annually produce 785 kWh of energy while avoiding 162 tons of carbon dioxide emissions. The floating solar panels could annualy earn a carbon credit of 10,342 €. The findings of this research could serve policymakers for the creation of a future solar power generation policy and future pilot experimental investigations in Croatia.

Keywords: *CO_2 emissions, Floating PV, Solar power plant, SDG, Solar energy.*

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APPLICATIONS AND CHALLENGES OF DIGITAL TWINS OF FLOATING WIND TURBINES

Maria-Styliani Daraki, Beatrice Mina, Muhnad Almasoudi, Barbara Charalambidi, Marko Mančić, Junlin Heng and Charalampos Baniotopoulos

Abstract: A digital twin is a virtual model of a physical asset, like a wind turbine, synchronized with real-time data to provide insights into its performance, condition, and behavior. This technology has applications in environmental perception, condition assessment, predictive maintenance, anomaly detection, and optimizing the operational parameters of floating offshore wind turbines. This paper reviews the current state of research and practical applications of digital twins in this field. It explores the concept, focusing on the challenges posed by climate, system dynamics, and structural issues in wind turbines. Case studies include topics such as Fatigue Limit State, pitch blade control, drivetrain performance, power output, and structural strain. Technical challenges in implementing digital twins include issues related to data collection, transfer, communication, and standardization, as well as the robustness of models in accurately simulating physical behaviors. Solutions can be found through AI, IoT, advanced simulation tools, and improved monitoring techniques. Non-technical challenges, typical for emerging technologies, are mainly tied to human factors. However, the benefits and financial advantages of digital twin technology are expected to promote its widespread adoption in industrial applications.

Keywords: *Digital twins, Fatigue, Floating offshore wind turbine, Wind energy.*

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DEVELOPING RENEWABLE ENERGY SOURCES: ENHANCING ENERGY GOVERNANCE FOR A SUSTAINABLE FUTURE

Reyhaneh Loni and Saša Pavlović

Abstract: This paper explores the integration of renewable energy sources (RES) into contemporary energy governance frameworks to enhance sustainability, security, and equity in energy systems. As global energy demands continue to rise and environmental concerns become increasingly pressing, RES such as solar, wind, hydro, and biomass offer transformative solutions to mitigate climate change and reduce reliance on fossil fuels. The study examines case studies from various regions implementing innovative governance models that facilitate the adoption of RES. It highlights key strategies, including policy reforms, stakeholder engagement, and technological advancements, that promote efficiency and transparency in energy management. Additionally, the paper discusses the challenges faced, such as regulatory barriers and the need for cross-sector collaboration. By proposing a holistic approach to governance that incorporates decentralized energy systems and community participation, this research underscores the potential of RES to not only address energy needs but also empower local communities and promote socio-economic resilience. The findings advocate for a shift in energy governance paradigms that prioritizes sustainability and inclusivity, thereby paving the way for a more sustainable energy future.

Keywords: *Renewable energy sources (RES), Energy governance, Sustainability, Policy reforms, Decentralized energy systems.*

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DEVELOPING SOLAR CAVITY RECEIVERS TO IMPROVE ENERGY GOVERNANCE

Reyhaneh Loni, Saša Pavlović, Branka Radovanović, Mirjana Laković and Jelena Janevski

Abstract: This paper explores the development of solar cavity receivers as a pivotal technology in enhancing energy governance. Solar cavity receivers, which harness concentrated solar power (CSP) to achieve high thermal efficiencies, present a promising solution to the challenges of sustainable energy production. By integrating advanced materials and innovative design principles, this research aims to optimize the performance of solar cavity receivers, thereby increasing their viability for large-scale energy applications. The study examines the implications of improved energy governance through the adoption of solar cavity receivers, focusing on their potential to reduce reliance on fossil fuels, lower greenhouse gas emissions, and promote energy equity. Furthermore, the paper discusses policy frameworks and governance strategies necessary to facilitate the widespread implementation of this technology. Ultimately, the findings underscore the importance of solar cavity receivers in the transition towards a more sustainable and resilient energy future.

Keywords: *Solar Cavity Receivers, Concentrated Solar Power (CSP), Energy Governance, Sustainable Energy Production, Policy Frameworks.*

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ENHANCEMENT OF PV PANEL'S POWER USING CLOSED BACK SIDE COOLING SYSTEM

Stefan Djordjević, Marko Krstic, Lana Pantić, Ivana Radonjić, Marko Mančić, Veljko Begović, Sača Gocić and Branka Radovanović

Abstract: Transition to alternative energy sources such as wind, solar, geothermal, and biomass can significantly contribute to reducing negative environmental impact of conventional energy sources. Solar energy stands out as a clean and inexhaustible resource. The efficiency of PV panels is especially influenced by the temperature of the PV cells and the intensity of sunlight. Higher temperatures of PV cells reduce electrical power output, degrade performance, and impact the lifetime of PV panels. The aim of the experiment was to determine the change in output power of the PV panel, which was cooled from the back side using a closed system, in which about 20 l of water circulated with a constant mass flow of 70 l/h. The cooling process lasted from 10.15 a.m. to 1.29 p.m.. After 15 minutes from the beginning of cooling, the difference in power between the cooled and uncooled panel was 16.76 W, which represents a 33.9% increase in power. At solar noon, the increase in power of 32.6%, was achieved. The maximum effect of cooling was recorded at 1:29 p.m., corresponding to a 41.75% increase in power. It can be stated that cooling the PV panels from the back side is a very effective method to reduce panel's temperature and increase efficiency.

Keywords: *PV panel, Back side cooling, Power enhancement, Electrical efficiency.*

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IV.Environmental protection and decarbonization

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IMPACT OF GREEN ROOF ON PARTICULATE MATTER CONCENTRATION

Danka Kostadinović, Marina Jovanović and Vukman Bakić

Abstract: Air pollution is one of the most serious impacts of rapid industrialization and urbanization. Belgrade the capital and larger city of Serbia is often the most polluted city in the world. It is recognized that plants can have a positive influence on air quality. In that context, this paper investigates the impact of extensive green roof on ambient PM1, PM2.5, and PM10 concentrations. During summer, PM concentrations in ambient air were measured above the green roof and reference roof of a school building located in the urban environment. The backward trajectory of air mass from the HYSPLIT model was used to access the particle's emission source. The results show that green roof significantly contributes to reducing PM concentrations in ambient air. The larger impact was observed for PM1 particles, which are the most dangerous for human health. The high correlation coefficients for the ratio of PM2.5/PM10 concentrations were found above both roofs, indicating fine particulate dominance. The Air Quality Index shows that PM2.5 is the main pollutant. The findings of this paper can help the large-scale adoption of green roofs in Serbia.

Keywords: *Air pollution, Air quality, Green roof, PM, Particulate Matter.*

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EXAMINING PAHS PRESENCE IN NOVI SAD'S AMBIENT AIR: SOURCES AND ASSESSMENT

Maja Brborić, Branka Nakomčić Smaragdakis, Damir Šljivac, Saša Pavlović and Evangelos Bellos

Abstract: Air pollution poses a significant global health risk, with severe consequences for respiratory and cardiovascular diseases, particularly among vulnerable populations facing heightened exposure. The respiratory system is particularly susceptible to pollutants, resulting in various adverse health effects. Ambient air monitoring for benzo(a)pyrene (B(a)P) was conducted at four sites in Novi Sad throughout 2020, representing diverse environmental conditions. Sampling and analytical methods adhered to standardized protocols. B(a)P concentrations exceeded prescribed limits at most sites, with combustion processes and traffic emissions identified as primary pollution sources. Principal component analysis highlighted the dominance of combustion-related pollution, particularly during winter. Hierarchical cluster analysis revealed distinct pollution patterns across sites, with areas less burdened by traffic and combustion showing lower B(a)P levels. The study underscores the urgent need to mitigate local pollution sources, especially combustion and traffic emissions, to safeguard public health. The findings provide crucial baseline data for future monitoring efforts and highlight the importance of addressing air pollution for sustainable development and climate change mitigation.

Keywords: *PAHs, Benzo(a)pyrene, Air pollution, Sources identifications, Assessment.*

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IMPROVING FLOW HOMOGENEITY IN THE CHAMBERS OF THE ELECTROSTATIC PRECIPITATOR OF A 350 MW UNIT AND REDUCTION OF PARTICULATE MATTER EMISSIONS BY MODIFYING THE TURNING AND DAMPING ELEMENTS

Milić D. Erić, Zoran Marković, Predrag Stefanović Aleksandar Milićević and Ivan Lazović

Abstract: In order to protect nature, legal regulations on environmental protection are becoming ever stricter. The increasing development of exhaust gas cleaning technologies has led to quick solutions and ever shorter deadlines for the reconstruction and modernization of electrostatic precipitators. This has led to problems in the operation of electrostatic precipitators over a long period of time after reconstruction and to a lower efficiency of the plants. This paper presents the optimization of flue gas flow in the electrostatic precipitator chambers of the 350 MW unit after reconstruction. During the overhaul of the thermal power plant, the distribution of air velocities in the cross-section of the chambers was investigated and the results were used to validate the numerical model. A new conceptual solution was proposed based on the results of several numerical simulations of the flue gas velocity distribution for different configurations of turning and damping elements. The partuculate matter concentration was reduced from over 70 mg/Nm^3 to a value below 35 mg/Nm^3 after the modification and modernization.

Keywords: *Elestrostatic precipitor chamber, Distribution of velocities, Chamber cross-section of, Homogeneity of the flow field.*

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AQUAPONIC SYSTEM IN THE CULTIVATION OF MICROGREENS AND SPROUTS: A REVIEW

Spasoje Belošević, Stefan Marjanović, Jovana Marković, Ana Todorović, Steva Lević, Ana Salević-Jelić, Marko Stanković, Zoran Marković and Viktor Nedović

Abstract: Aquaponics is a novel system for the simultaneous cultivation of plants and fish, developed in response to the uncontrolled use of chemical fertilizers in plant production and the waste generated by aquaculture. In this closed-loop system, ammonia-rich fish waste is converted into nutrients by nitrifying bacteria, serving as fertilizer for plants, while the plants help purify water for the fish by removing waste products and excess nutrients. Through waste reduction and maximized resource efficiency, aquaponics exemplifies the circular economy in agriculture and food production. Microgreens and sprouts are young seedlings that only need a few weeks to grow in different substrates and systems. They are appreciated for their appearance, flavor, and higher concentrations of bioactive compounds compared to mature plants. Their short growing time and low nutrient requirements make them ideal for cultivation in all modern agricultural practises, including aquaponics. This review focuses on the application of aquaponics for cultivating microgreens and sprouts. So far, only one study has investigated the cultivation of microgreens in aquaponics, compared to more extensive research on hydroponics and sprouts. Growing arugula microgreens in an aquaponics system with goldfish positively impacted microgreens' growth rates, while sprout production exhibited higher levels of vitamin C, protein, and soluble sugars, as well as improved germination rates, weight, and height. Lettuce and rocket were successfully grown using trout wastewater as a nutrient source, enhancing yield and quality while promoting water efficiency and fertilizer savings compared to conventional production. The main limitation of the aquaponics system for growing small plants such as microgreens, sprouts, and baby leaves is the potential microbial contamination from the recirculating nutrient water. Overall, the aquaponics system is an emerging technology for growing microgreens with reduced use of natural resources while positively influencing growth parameters and phytochemical content.

Keywords: *Aquaponics, Circular economy, Microgreens, Plant and fish cultivation, Sprouts.*
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CULTIVATION TECHNOLOGY AND FEED UTILIZATION BY COMMON CARP (CYPRINUS CARPIO) USING DIFFERENT PROTEIN SOURCES

Stefan Marjanović, Marko Stanković, Spasoje Belošević, Vukosav Golubović, Aleksandra Dobričić, Dalibor Vukojević, Jelena Vranković and Zoran Marković

Abstract: The global demand for healthier foods is constantly increasing, especially for foods rich in amino acids and fatty acids, which have a reliable positive effect on human health. Fish is one of the ideal foods with a high content of essential amino acids and omega-3/6 fatty acids and therefore enjoys the attention of consumers. In response to the market demand for fish protein, the aquaculture sector is tasked with producing more fish to meet this demand, with fishmeal being used as the main source of protein in fish feed. However, fishmeal is produced from a small stock of wild fish, which affects the price of fishmeal. Given this limitation for aquafeed in aquaculture, new protein sources that can partially or completely replace fishmeal need to be found to ensure sustainable production in aquaculture. The aim of this study was to investigate how the complete replacement of fishmeal (FM) with earthworms (EM), mealworms (WM), and zooplankton (ZM) in the diet of common carp affects feed conversion when they are reared in a flow-through tank. The study was conducted at the Fish Nutrition Laboratory of the Faculty of Agriculture, University of Belgrade. Based on the data collected during the experiment, feed efficiency ratio (FER), daily feeding rate (DFR), and protein intake ratio (PI) were calculated. The highest value of the parameter FER was obtained in fish-fed with WM, followed by ZM and EM, while the lowest value of this parameter was achieved in fish-fed with FM. The fish fed with WM showed the lowest DFR values, while the highest value of this parameter was obtained in the control group. The highest protein consumption was observed in fish fed with WM. The results of feed conversion by common carp, suggest that earthworms, mealworms, and zooplankton could be a potential substitute for fishmeal in carp diets if feed conversion is good and would ensure more economical production in aquaculture.

Keywords: *Daily feeding rate, Earthworm, Feed efficiency ratio, Mealworm, Tank system technology.*

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POTENTIAL OF INSECTS AS A PROTEIN SOURCE IN COMMERCIAL FISH FEED PRODUCTION

Stefan Marjanović, Spasoje Belošević, Marko Stanković, Jelena Vranković and Zoran Marković

Abstract: In recent years, edible insects have been used as an alternative source of protein in commercial fish diets. The intensive development of aquaculture requires not only economic profitability, but also an increase in quantity and an improvement in feed quality. Compared to other animals, fish need more proteins in their feed, which mainly come from ingredients such as fishmeal and soybean meal. Soybean meal is one of the most commonly used vegetable protein sources. However, the presence of antinutritive factors (tannins, saponins) limits the intake of large quantities as they can damage the intestinal mucosa and impair the absorption of nutrients as well as the growth of the fish. The idea of using insects as a source of protein is becoming increasingly popular. From a nutritional point of view, insects are a natural fish feed, so they can be a very valuable component in the production of commercial feed. The nutritional value of insects is much more favourable than the nutritional value of plants, as they contain more proteins, essential amino acids, vitamins and minerals. Organising mass production and using insects as a source of protein in fish feed would have a positive economic impact on production. They are also easy to grow and have minimal negative impact on the environment. They can be bred on plant waste, have a high food utilisation and grow and reproduce quickly. Insects also have lower greenhouse gas emissions and require less water to grow. Tenebrio molitor is often used to convert organic waste into proteins. Insects can also be used to convert plastic waste into proteins. In this context, insects have great potential compared to other protein sources used in fish nutrition and directly reduce production costs.

Keywords: *Antinutritional factors, Saponins, Tannins, Tenebrio molitor.*

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INDICATING THE CONTRIBUTION OF A COUNTRY'S CARBON-DIOXIDE EMISSIONS TO GLOBAL EMISSIONS AND ENVIRONMENTAL JUSTICE

Vojin Grković

Abstract: The paper discusses the problem of objectively comparing different countries in terms of their carbon dioxide emissions, in the light of climate and environmental justice. Two traditional and three nontraditional indicators are included. The indicators were applied to a selected group of thirteen countries that includes part of the BRICS countries and the G7 countries. The ratio of the share of carbon dioxide emissions of a country in the global emission and the share of its population in the global population makes a basis for comparison different countries. For defining just relation among the countries regarding carbon dioxide emissions, it is necessary to identify the sinks of carbon dioxide and to include them into the definitions of the emission's indicators. The paper also reviews the possibilities of further improvements in the definition of appropriate indicators for an objective comparison of different countries in terms of their carbon dioxide emissions. Based on the performed analyses in the paper are discussed energy transition and environmental justice.

Keywords: *Environmental justice, Climate justice, Carbon dioxide emission indicators.*

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OPTIMISATION OF ELECTROSTATIC PRECIPITATORS IN PULVERISED LIGNITE-FIRED THERMAL POWER STATIONS

Zoran Marković, Milić Erić, Aleksandar Milićević, Ivan Lazović, Predrag Stefanović and Ilija Stevanović

Abstract: The energy transition while maintaining energy security and environmental protection is recognised by the Republic of Serbia and Joint Stock Company Elektroprivreda Srbije (EPS) as a priority in the implementation of the Green Agenda. Starting from 2004, around 97 million euros was invested into reconstruction and modernisation of the plate-wire electrostatic precipitators (ESP) of the 15 thermal power plant (TPP) units in the EPS system. The aim was to reduce particulate matter emissions from each unit below the limit value of 50 mg/Nm^3. This resulted in a reduction of more than 90% in particulate matter emissions from 66,626 tonnes in 2003 to 6,344 tonnes in 2022. Over the past ten years, however, periodic measurements of particulate emissions have revealed a decline in the efficiency of many ESP systems, usually due to a deterioration in coal quality. The plate-wire ESP achieves maximum dust removal efficiency by simultaneously generating the maximum spark voltage over a homogeneous velocity field of the flue gas between the plates. The consortium consisting of the Vinča Institute of Nuclear Sciences and the Nikola Tesla Electrotechnical Institute successfully diagnoses these new working conditions of the ESP based on the results of periodic measurements of particulate emissions, the results of measurements of flue gas velocity distribution in the ESP channels and chambers and the results of measurements of various electrical parameters of the ESP. Detailed analyses and numerical simulations are used to identify the existing limitations of ESP properties and to investigate suitable measures to improve ESP efficiency. This paper presents the results of the testing and optimisation of the ESP of six thermal power units in the EPS system, which was carried out from 2020 onwards. The implementation of the measures proposed by the consortium, both the reconstruction of the mechanical turning and damping elements of the ESP and the installation of the proposed new power control elements, was carried out as part of the annual overhaul of these units. The effectiveness of the measures applied is demonstrated by the fact that the particulate emissions of each optimised ESP were reduced from over 60 mg/Nm^3 to around 30 mg/Nm^3.

Keywords: *Energy, Optimisation, Thermal power.*
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TOWARDS ZERO ENERGY IN THE FOOD PROCESSING INDUSTRY

Marko Mančić, Milan Đorđević, Milena Rajić, Milena Mančić and Bojana Vukadinović

Abstract: Zero energy and waste in fruit processing is essential for reducing environmental impact and maximizing resource efficiency. Over the past 20 years, Serbia has seen an increase to over 30 operational biogas plants. The presented research is a case study of a fruit processing company in Serbia which processes 8,000 t of fruit annually, consuming 2,049 MWh of electricity and 3,936 MWh of heat. The company generates several waste streams: 400 t of fruit pits, 200 t of organic waste from processing (peels, seeds, pulp), 50 t of waste from pipelines of the hot processing facility by pigging, and 30 tons of sludge from wastewater treatment. In total, 280 tons of organic waste are available annually for either biogas or pellet production as part of a biorefinery approach. A biogas biorefinery CHP system with an installed capacity of 100 kW is recommended based on the waste streams. This system can produce 200 MWh of electricity and 500 MWh of heat annually, covering 10% of the company's electricity consumption and 13% of its heat needs. Pellet production from the 280 tons of waste can generate 740 MWh of heat annually based on the calculated boiler efficiency according to the measured emissions, covering 19% of the company's heat demand. A pelletizing system with a capacity of 100-150 kW is recommended. The ROI for pellet production is less than 1 year due to its simplicity and immediate impact on heat savings. Pellet combustion would emit arround 1,000 kg of CO_2 per MWh, whereas biogas, with its methane capture, could lower emissions to around 200 kg of CO_2 per MWh. With Serbia starting to implement the EU Emission Trading System (ETS), the ROI of the biogas CHP system, would drop to 1.5 to 3 years by cost of annual carbon savings based on the current ETS rate. This biorefinery approach of combining biogas or pellet production with the existing biomass system could significantly reduce external energy dependance and move the company closer to zero waste and zero energy, while enhancing energy efficiency and sustainability.

Keywords: *Zero energy, Zero waste, Fruit processing, Energy efficiency.*

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URBAN RESILIENCE PLANNING TO CLIMATE CHANGE THROUGH INNOVATIVE NEXUS APPROACH

Serena Caucci, Giannis Adamos, Tamara Rađenović, Dejan Vasović and Snežana Živković

Abstract: Addressing the need for enhanced urban resilience planning is pressing in response to the escalating impacts of climate change in many regions of the world, particularly in the wider Western Balkans region and Mediterranean areas. Rapid urbanization, and water extremes, coupled with unsustainable land use practices, exacerbate the vulnerability of cities to climate-related hazards such as heatwaves, floods, and wildfires. Recognizing the urgency of this challenge, this study adopts an innovative Nexus Approach to support the transition of municipalities and institutional policy frameworks into a solid system for resilient urban planning. By leveraging the strengths of GIS-based models and engaging multiple stakeholders in co-creation processes, the Nexus approach aims to develop robust strategies for enhancing urban and peri-urban resilience. Drawing on the principles of the Water-Energy-Food-Ecosystem (WEFE) Nexus, the study employs a multifaceted approach to address the complex challenges of urban resilience planning and integrates urban water management, energy systems, green infrastructure, and peri-urban agriculture into holistic planning frameworks. Through stakeholder engagement and capacity-building initiatives, it aims to co-create innovative solutions tailored to the specific needs of different regions. These endeavors are directed towards empowering decision-makers and communities to develop and implement effective strategies for climate resilience.

Keywords: *Urban Resilience Planning, WEFE Nexus Approach, Climate Change.*

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V.Innovative technologies and plants in energy science

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OPTIMAL SYSTEM FOR COLLECTING LANDFILL GAS - LANDFILL MEGLENCI, REPUBLIC OF NORTH MACEDONIA

Blagoj Dimovski, Vangelce Mitrevski, Vladimir Mijakovski and Cvete Dimitrieska

Abstract: The energy strategy of Republic of North Macedonia until 2040, in addition to the use of classic renewable energy sources and high criteria for environmental protection, also foresees the use of landfill gas that is produced in the open landfills on its territory. In addition to the large number of wild illegal landfills, the only legal landfill in North Macedonia is landfill Drisla near Skopje. In the Meglenci regional landfill near REK Bitola, which is planned to serve the southwestern part of RSM, the efficient collection of landfill gas, which would be used as energy, is of great importance. This paper presents an analysis based on results obtained from theoretical and experimental research, with the aim of choosing the optimal system for the collection and conversion of gas in the Meglenci landfill. In doing so, the latest relevant data on the quantity and quality of the organic fraction from the waste, the conditions in the landfill, climatic factors and other input data were used in order to obtain data on the yield of landfill gas. Technologies that are available and applicable for the specific landfill have been studied, based on the data obtained from the mathematical model and the techno-economic analysis. The "collection" of greenhouse gases, such as landfill gas, is a legal obligation within the framework of environmental protection, but the possibility of using it as an energy source contributes to the energy system at the local level.

Keywords: *Landfill gas, Experimental methods, Waste to energy systems, Optimal solution.*

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PADDY DRYING IN MIXED-FLOW TOWER-TYPE DRYER

Filip Mojsovski and Vladimir Mijakovski

Abstract: The purpose of this paper is to present the relevant data for paddy drying in mixed-flow dryer, obtained with conducted research on high-capacity dryer. An examination was carried out to reach the correct drying condition in industrial rough rice dryer. The attention was concentrated on main dryer element, the horizontal drying module. One drying module is composed of one or two drying rooms and one tempering section. By field tests, the heat flow amount and continuity were observed and evaluated in multi-thermal zoned drying process. The dryer is composed of five modules with double drying room and one tempering section, one module of three drying rooms without tempering section and four drying rooms in package as cooling section. Two thermal-zones drying system was exploited, with inlet air temperatures up to 44 oC, and with inlet air temperatures up to 40 oC. In the cooling section the air temperature was dictated by the grain outlet temperature up to 36 oC. Intermittent paddy tempering of up to two hours was accepted.

Keywords: *Mixed-flow dryer, Intermittent process, Paddy.*

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DETERMINING THE RELIABILITY FUNCTION OF THE THERMAL POWER SYSTEM IN THE POWER PLANT "NIKOLA TESLA, BLOCK B2"

Ivan Popović, Milan Đorđević, Jasmina Skerlić, Vladan Jovanović and Snežana Kirine

Abstract: In the modern world, where a uninterrupted energy supply is required for proper functioning, thermal energy systems are key components of the infrastructure. Considering the complexity of these systems, it is essential to develop procedures that enable specific determination of the reliability function of thermal energy systems. Analysis of the reliability of the thermal energy system is crucial for maintaining the stability and efficiency of the system. In this paper, by applying the mathematical theory of reliability to the exploitation research data and using simple and complex two-parameter Weibull distribution, the theoretical reliability functions of the thermal power plant Nikola Tesla, Block B2 were determined. A significant advantage of such a study is the possibility of an early and thorough understanding of the logic and mechanisms of risky behavior in the system, as well as a more precise assessment of its functioning throughout the future exploitation.

Keywords: *Thermal power system, Reliability, Weibull distribution.*

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EXPERIMENTAL INVESTIGATION ON THE EFFECT OF WATER BASED NANOFLUIDS USED AS HTF IN A PCM BASED THERMAL ENERGY STORAGE SYSTEM INTEGRATED WITH CONSTANT HEAT SOURCE - DOMESTIC APPLICATIONS

Krishna Reddy Kondakrindi, Meenakshi Reddy Reddigari, Madhava Reddy K and Venkata Mohan Reddy

Abstract: The present work focus on the thermal performance of a packed bed combined with sensible and latent heat storage unit integrated with constant heat source. A cylindrical insulated storage tank in the Thermal Energy Storage (TES) unit is filled with spherical capsules separately which contains phase change material (PCM) as paraffin wax and stearic acid. The PCM usage has the benefits that it can be used as a thermal management tool and it reduces the cost and size of the system as it offers higher isothermal behavior and thermal storage capacity. The thermal conductivity of heat transfer fluid (HTF) can be enhanced by using nanoparticles mixed in water. Nanofluids are the more efficient fluids for the applications of heat-transfer. The water based nanofluids are used to transfer heat between the solar collector and storage tank which is a sensible heat storage material. The HTF materials are varied and Experimental trials have been conducted separately. Experimentation was carried out First by considering only water as HTF and is extended by adding water with one of the Nanomaterials-i.e.Al2O3 and MgO, each in 3 HTF volume % as 0.2, 0.5 & 0.8. The study was transpired by varying the flow rates of nanofluids as 2, 4 and 6 l/min. The novelty of this work is to envisage the enhancement of heat transfer and to study the effects on the melting time of the PCMs of these fluids which were carried out. The performance parameters like charging time, instantaneous stored heat, cumulative stored heat and system efficiency were studied for the different HTFs and for the PCMs-paraffin and stearic acid. The batch wise process experiments for Discharging were carried out to recover the heat stored, and the results are presented.

Keywords: *Thermal energy storage system (TESS), Phase change material (PCM), Paraffin wax, Stearic acid, Nanoparticles, Nanofluids, Charging, Discharging.*

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ENERGY EFFICIENCY OF THE PASSIVE SYSTEM FOR EXTRACTION OF LANDFILL GAS AT THE LANDFILL OF NISH

Ljubica Stojković, Ivan Mihajlović and Dragoslav Pavlović

Abstract: LANDFILL gas (LFG), which mainly includes methane, is a greenhouse gas collected by extraction systems, released into the air, or directly used to generate electricity. The paper measured the temperature of landfill gas (LFG) on biothorns, at the landfill in Nish, and investigated the possibility of utilizing the potential of landfill gas before its closure. Infrared thermographic method (IF) of radiation was used to test the QUANTITY of methane on the passive system. The paper concludes that heat and gases are released that cannot be further used for the production of electricity in thermal power plants. Analyzing the results, no thermal irregularities in the immediate environment were observed, and the conclusion is reached that the passive GASA degassing system has no impact on the environment.

Keywords: *Landfill gas, BioThorn, Gasification, Electricity.*

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POTENTIAL METHANE GENERATION CAPACITY ON THE LANDFILL GAS EXTRACTION SYSTEMS AT THE LANDFILL IN NIS

Dragoslav Pavlović, Ivan Mihajlović, Ljubica Stojković, Bojan Banković and Gradimir Cvetković

Abstract: Systems for the production of electricity require the previous collection of gas from the organic matter of municipal waste. Collection of landfill gas is done by a degassing system. In the case of the Niš landfill, this system was partially built by installing biothorns for the evacuation of landfill gas into the air. The paper presents the results of testing landfill gases, which include: determination of the volume fraction of methane (CH 4), carbon dioxide (CO 2), hydrogen sulfide (H 2 S), carbon monoxide (CO) and hydrogen (H 2). Measurements were made at the control points at the exit from the biothorn, at the closed and rehabilitated fields S 2 and S 3 , simulated results at the control point of the pilot project of the active system, at the exit from the horizontal and vertical drain, at the active field S4, Niš landfill. Measurements were performed using the electrochemical method, with a GEM TM 2000 Plus gas analyzer, once a month. The LandGEM emission model was used to estimate the energy potential of methane. The paper concluded that the most energy-efficient method for waste disposal is the use of an active degassing system. Using an active landfill gas extraction system, a 1MW power plant can be built.

Keywords: *Methane, Gas extraction systems, Gasification, Electricity.*

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EFFECT OF PROPERTIES OF WORKING FLUIDS ON THE EFFICIENCY OF A LOW-TEMPERATURE ORGANIC RANKINE CYCLE

Marija Živković, Aleksandar Mijatović, Dejan Ivezić and Boban Pavlović

Abstract: Decarbonization of all segments of energy systems, both on the supply and demand side, is one of the main goals of the energy transition. Electricity supply in the future will largely rely on generation from intermittent energy sources: wind and solar. Locally available, non-utilized alternative low-temperature energy sources as hydro-geothermal wells, and abounded oil and gas wells, have the potential to provide continual energy production over the year. Electricity generation from these energy sources is carried out with working fluids with low evaporation temperatures. Commonly used fluids are categorized into several groups based on their chemical composition, which determines their thermophysical properties. In this paper the effect of chemical composition of six fluids from three groups on thermophysical properties was analyzed. The effect of fluids' properties on the efficiency of ORC is analyzed for the case of a typical range of temperatures of hydro-geothermal and abounded oil and gas wells in Serbia, which may be used as heat sources for electricity generation.

Keywords: *Properties, Working fluids, Efficiency, ORC, Low temperature.*

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DEVELOPING SOLAR THERMAL POWER PLANT TO IMPROVE ENERGY GOVERNANCE

Reyhaneh Loni and Saša Pavlović

Abstract: This paper explores the development of solar thermal power plants as a viable solution to enhance energy governance in the context of sustainable energy systems. With the increasing global demand for clean and renewable energy sources, solar thermal technology has emerged as a promising alternative that can significantly contribute to reducing greenhouse gas emissions while ensuring energy security. The paper outlines the potential benefits of solar thermal power plants, including their ability to provide base load power, their scalability, and their compatibility with existing energy infrastructure. Additionally, it examines the critical role of effective energy governance in facilitating the successful implementation and operation of solar thermal projects. This includes the establishment of clear regulatory frameworks, stakeholder engagement, and the promotion of public-private partnerships. The paper presented best practices and key challenges encountered in the development of solar thermal power plants, emphasizing the importance of integrated planning and comprehensive policy approaches. Ultimately, this research aims to contribute to the discourse on energy governance by providing insights into how solar thermal power can be leveraged to foster sustainable energy transitions and enhance energy governance frameworks.

Keywords: *Solar thermal power, Energy governance, Renewable energy, Greenhouse gas emissions, Sustainable energy systems.*

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APPLICATION OF COLD PRESSING PROCESS TO DEVELOP POTENTIAL FUNCTIONAL AND SENSORY ACCEPTABLE RED BEET MICROGREENS-APPLE BEVERAGE: TOTAL PHENOLIC CONTENT AND ANTIOXIDANT PROPERTIES

Spasoje Belošević, Danijel Milinčić, Ana Salević-Jelić, Steva Lević, Jovana Marković, Stefan Marjanović, Verica Đorđević, Mirjana Pešić and Viktor Nedović

Abstract: Cold-pressed juices are consumed worldwide due to their beneficial effects on human health, which are related to phytochemical content. Wheatgrass sprout juice is the most popular cold-pressed juice consumed in its raw state and used to treat chronic diseases. Microgreens resemble sprouts and have a higher content of bioactive substances compared to mature plants. Recently studies have investigated the use of microgreens in some food technology processes such as cold-pressing. Moreover, cold-pressed red beet microgreens juice has a high content of phenolic compounds and betalains and good antioxidant properties. However, the specific taste of microgreen juices such as grassy, astringent and earthy taste is not generally accepted by consumers. Therefore, there is a need to obtain a sensorially acceptable healthy juice with a high content of health-promoting compounds. The aim of this study was to develop a cold-pressed red beet microgreen-apple juice and to evaluate the total phenolic content and antioxidant activity. The red beet microgreen and apple were cut and pressed in a cold-press juicer and then mixed in a ratio of 51% to 49%, respectively. The total phenolic content (TPC) and antioxidant activity were determined using the Folin-Ciocalteu's reagent and the assay based on radical cation scavenging (ABTS•+), respectively. The sensory test was evaluated with a 9-level hedonic scale. The developed red beet microgreen-apple juice showed a high TPC and a good ability to scavenge ABTS●+ radical cations. In terms of sensory evaluation by consumers, the newly developed juice showed good overall acceptance. In conclusion, red beet microgreens-apple juice has a high content of health-promoting compounds and good antioxidant activity, so it can be considered as potential functional beverage, but future research is needed, including additional in vitro studies.

Keywords: *Cold-pressing, Red beet microgreens-apple juice, Bioactive compounds content, Antioxidant activity.*
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NATURAL DRAUGHT COOLING TOWER OPERATION DURING WINTER

Vladimir Mijakovski, Monika Lutovska, Filip Mojsovski and Mile Spirovski

Abstract: Operation of natural draught cooling towers and its ability to cool water is solely dependent on ambient air parameters (temperature and humidity). During winter period, at low temperatures of external air, circulation of air through the natural draught cooling tower causes greater cooling of the water and appearance of ice on places where air enters into the tower. In such case, with proper operation of the system cooling tower – pump station, and by reducing water's cooling range, temperature of the cold water ought to be maintained at sufficiently high temperature level in order to avoid freezing of the water in the tower and appearance of ice at air entering surfaces.

Keywords: *Natural draught, Cooling tower, Winter.*

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POTENTIAL OF EVAPORATIVE COOLING IN THE CLIMATE OF SERBIA

Milan Đorđević, Marko Mančić, Milena Mančić and Mirjana Miletić

Abstract: Evaluating the evaporative cooling potential first depends on gaining a detailed and accurate understanding of the local climate. In this study, the potential of evaporative cooling was estimated based on the bioclimatic analysis and psychrometric chart using Climate Consultant software. Bioclimatic charts were developed for 22 locations within a different climatic conditions in Serbia in order to quantify the potential of evaporative air cooling strategies for different regions. Bioclimatic charts are generated by plotting Typical Meteorological Year weather data set on the psychrometric chart along with ranges defined with human thermal comfort models. The software tool demonstrates the effectiveness of Direct and Two-stage Evaporative Cooling for defined comfort model. The percentage reduction in the total cooling hours with these systems varies from 16.1 to 94.9% at the locations considered. The study also indicates that indirect systems with vapor-compression second stages can provide adequate comfort cooling with significant savings throughout the cooling season. The obtained results generally recommend the application of evaporative cooling technology in air conditioning in the climatic conditions of Serbia, especially in all types of cooling systems based on fresh air. This can have significant implications for engineers when choosing a combination of cooling strategies which are appropriate for the specific location.

Keywords: *Evaporative cooling, Thermal comfort, Climate Consultant.*

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ENERGY PERFORMANCE INVESTIGATION FOR RESIDENTIAL AIR SOURCE HEAT PUMP IN SUMMER CHANGE OVER REGIMES

Goran Vučković, Mirko Stojiljković, Marko Ignjatović and Branka Radovanović

Abstract: Heat pump technology occupies a leading position when it comes to preserving thermal comfort and sanitary water heating in the residential building sector. Simple installation, good prices and improved seasonal efficiency have brought the air source heat pumps to the leading position on the market. Heat pumps meet the needs of the residential sector through the following three purposes: space heating, space cooling and sanitary water heating. In this paper, an analysis of experimental research on the air source heat pump energy performance in real summer change over regimes, given that these are periods that significantly affect the reduction of seasonal efficiency. The transition regimes between the two modes of operation with the most pronounced changes were especially considered. That is the transition regimes characteristic of operation in the summer period, namely: the transition from the space cooling mode to the sanitary water heating mode, and vice versa. In the observed period, a total of 60 measurements were made with a resolution of 1 minute. In that period two changes in the operating mode were made, from the stationary space cooling mode (when the heat pump prepared water for the underfloor cooling at 17°C) to the sanitary water heating mode (when the heat pump prepared hot water in the tank at 43°C), as well as switching to the previous one, cooling mode. The results show that the heat pump in the observed period worked with average energy performance coefficient of 2.84, although in stationary modes of space cooling and sanitary water heating it worked, respectively, with performance values of 3.45 and 3.56.

Keywords: *Heat pump, Building sector, Efficiency*

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VI. Energy efficiency in industry, civil engineering, communal systems, and traffic

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RATIONAL USE OF ENERGY AND WASTE HEAT AT COMPRESSOR PLANTS IN THE WOOD PROCESSING INDUSTRY OF SERBIA

Aleksandar Dedić, Dušan Bajić, Srđan Svrzić, Matilda Lazić and Duško Salemović

Abstract: Obtaining pressurized air represents a significant expenditure of energy for every branch of industry, and today it is simply unthinkable to exist industrial plants without the production, distribution and use of pressurized air. This is particularly representative in the wood processing industry where it has been shown that there is a low awareness of the savings that can be made with the produced air under pressure, starting from its proper use to the use of waste heat through recovery. Bearing the above in mind, research was carried out in companies of the wood industry in Serbia in order to analyze the economics of obtaining and adequate use of pressurized air. Also, solutions were suggested for the recovery of waste heat in screw and reciprocating compressor plants, which are most present in the wood processing industry, as shown by the survey. The conclusions were drawn in the form of guidelines for the rational use of pressurized air, which can bring significant savings in energy consumption and increase efficiency and productivity in work.

Keywords: *Compressors, Energy Savings, Heat Recovery, Wood Industry.*

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ANALYTICAL ASSESSMENT OF COOLING DEGREE-DAYS FOR ESTIMATING ENERGY CONSUMPTION IN BUILDING SECTOR DURING COOLING SEASON IN BELGRADE

Branislav Petrovic and Milan Gojak

Abstract: Although the degree-day method for heating is classified as a single-parameter method, as it only accounts for daily changes in outdoor air temperature to estimate the heating demand of a building due to climatic influences, it has proven to be highly reliable over decades of practice and is now widely regarded as a standard method for determining heating requirements. However, due to evident climate changes and rising outdoor air temperatures, treating the heating degree days as a prescribed constant value for the specified location, leads to significantly inaccurate results, as demonstrated in this paper through an analysis of data from the Republic Hydrometeorological Service. Meanwhile, the use of the cooling degree days method to determine cooling demand has proven to be highly unreliable. This is because the method does not account for solar radiation, which, during the summer months, is as significant a factor as outdoor air temperature. To address this issue, while preserving the core concept of the method the heat load to be removed from a cooled space is proportional to the difference between the average daily outdoor air temperature and the base indoor temperature, a considerably lower base indoor temperature can be used in place of the internal design (reference) temperature. This paper presents the corrected method, along with international experiences and best practices, and includes data from the Republic Hydrometeorological Service. Additionally, cooling degree days for Belgrade have been calculated and presented, providing more accurate and reliable cooling demand forecasts.

Keywords: *Cooling degree-days, Avarage daily outside temperature, Annual energy consumption, Climate change.*

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SYSTEMATIC APPROACH FOR IMPLEMENTING ENERGY EFFICIENCY MEASURES IN INDUSTRIAL STEAM BOILER PLANT

Elena Stefanoska, Sevde Stavreva and Igor Andreevski

Abstract: To achieve optimal performance in industrial steam boiler plants, it is necessary to reduce energy consumption per unit of product. By conducting a systematic assessment of the performance of steam boiler plants and assessing the potential for improving energy efficiency, it is possible to approach the correct selection and implementation of appropriate measures and technical solutions, which can result in significant energy savings, improvement of production quality, reducing production costs and mitigating negative environmental impacts. The subject of consideration in this paper is a steam boiler plant in the industrial sector, where the main purpose is, with comprehensive systematic approach of the current situation, to consider the possibilities for effective implementation of measures and to analyse the achieved effects that contribute to the efficiency and sustainability of the overall system.

Keywords: *Energy efficiency, Energy performance, Energy savings, Industrial sector, Steam boiler plants.*

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THERMOTECHNICAL INSTALLATIONS FOR A SPECIAL HOSPITAL (GYNECOLOGY AND SURGERY) WITH A PHARMACY, FLOORS P0+P+2, ON C.P.N. 394/34 CM NIS-CELE KULA, STREET VIZANTIJSKI BULEVAR IN NIS

Jasmina Mitić Stojanović, Ivan Ristić and Mirjana Laković

Abstract: An energy efficiency report was prepared for the subject building, by which the energy class of the object "B" was determined. For the preparation of the Project for the building permit (PBP) of thermotechnical installations for the object in question, the location conditions, the foundations of the architectural and construction project, geodetic survey, Elaboration of energy efficiency, technical regulations and standards were used. The project provided the following systems: heating, ventilation, air conditioning and central preparation of hot sanitary water. The main sour for optimal operation of the heat pump, a buffer, storage tank is provided of heat energy is the water-water heat pump, and the backup source of energy is an electric boiler. Air conditioning chambers are used for air conditioning systems, while separate hygienic air conditioning chambers are used for "clean areas". An air VRV heat pump consisting of 2 modular units was chosen as the energy source for the air conditioning chambers. The ventilation of sanitary rooms is provided by a separate system. Underfloor heating is provided, except in those areas where it is not needed. Filter ceilings, perforated diffusers for air injection are provided for "clean spaces", and grills are provided for air extraction. For other spaces (waiting rooms, pharmacy, doctor's offices, patient rooms...) for cooling/heating, cooling beams are provided. Offices, patient rooms and doctor's rooms are equipped with wall (IN WALL) recuperators for individual ventilation, with a recovery rate of over 90%. The primary DHW heating on the water heater exchanger is carried out over the heating circuit to the heat pump, and on the second exchanger an electric boiler with complete equipment is connected as an independent heating circuit.

Keywords: *Energy efficiency, Heating, Ventilation, Air conditioning.*

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PROPOSAL OF NEW BUILDING 4E IMPROVEMENT

Darko Ristanović and Maja Todorović

Abstract: Based on numerous analyzes, expertise and energy audits of buildings in the last decade, as well as on the basis of data published by the line ministries responsible for the field of construction and energy sectors, it is evident that the gross final energy consumption in the Building sector in Republic of Serbia is growing. The new and amended EU directives, as well as the legislative framework, imply, in addition to reducing the primary energy used in buildings, the implementation of efficient technical systems that include renewable energy sources (RES), have a minimized impact on the environment (Zero Emission Buildings), as well as positive economic indicators. For these reasons, especially when it comes to newly designed buildings, it is necessary to implement improvements in terms of the 4Es: Energy, Efficiency, Ecology and Economy. The paper gives a proposal of bulding 4E improvement, based on the analisys of different energy sources and technical systems in a newly designed residential building located in Belgrade. Four scenarios with different energy sources, as well as internal installations in the building, which include a heating system and domestic hot water preparation, were analyzed. Energy source types, which are compared are as follows: district heating system that generates heat from fossil fuels, biomass, natural gas and air to water heat pumps, with the calculation of primary energy, CO2 emission and the exploitation cost for each scenario. The results obtained after the conducted analysis indicate the optimal solution.

Keywords: *Building energy class, Energy source type, Primary energy, Buildings technical systems, CO2 emisssion, Operating energy cost.*

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AIR-CONDITIONING CONTROL STRATEGIES FOR AN AMPHITHEATER FOR DIFFERENT SCENARIOS

Jovan Matić, Nataša Nord, Maja Todorović and Milan Ristanović

Abstract: This thesis focuses on the ventilation control strategies employed in Amphitheater A at the Faculty of Mechanical Engineering, University of Belgrade, and examines their alignment with the Passive House Standard. The Passive House Standard is renowned for its stringent requirements regarding energy efficiency, airtightness, and thermal comfort, making it an ideal framework for achieving high-performance buildings. Given the amphitheater's high occupancy level of up to 500 people and variable usage patterns, designing an efficient ventilation system becomes crucial for maintaining both optimal indoor air quality and energy consumption. The study explores the implementation of Constant Air Volume (CAV) and Variable Air Volume (VAV) systems, with ventilation controlled by different strategies, including CO_2 concentration, air temperature, and a combined CO_2 and air temperature control approach. Each of these strategies was simulated using the IDA ICE software to evaluate their effectiveness in ensuring thermal comfort and indoor air quality, as well as minimizing energy consumption. The results of the simulations reveal significant differences in the performance of the CAV and VAV systems. The VAV system, particularly when controlled by air temperature. The demand-controlled ventilation (DCV) feature of the VAV system allowed for precise adjustments to ventilation rates based on real-time occupancy and environmental conditions, reducing unnecessary energy usage during low-occupancy periods. On the other hand, the CAV system, while maintaining a constant airflow, resulted in higher energy consumption due to its inability to adjust ventilation rates dynamically. Overall, this thesis provides valuable insights into the feasibility and benefits of adopting Passive House principles in the design of ventilation systems for large spaces, contributing to the broader efforts in sustainable building design and operation.

Keywords: *Ventilation Control, Passive House Standard, Constant Air Volume (CAV), Variable Air Volume (VAV), Energy Efficiency*

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APPLICATION OF REINFORCED LEARNING IN INTELLIGENT BUILDINGS

Matija Žuža, Milan Ristanović, Žarko Ćojbašić and Luka Filipović

Abstract: This paper aims to present the fundamental mathematical framework necessary for understanding reinforcement learning (RL) and provides an overview of RL algorithms, focusing on their application in Heating, Ventilation, and Air Conditioning (HVAC) systems. Specifically, the paper addresses the use of RL in Building Energy Management Systems (BEMS) to tackle the issue of high CO2 emissions resulting from HVAC operation, with RL proposed as a potential solution for reducing emissions by enhancing energy efficiency while maintaining occupant comfort. Additionally, the paper highlights the key advantages and limitations of RL when applied in intelligent buildings. The review bridges theoretical concepts and findings from the literature to identify appropriate algorithms for various problems and highlight research gaps. Furthermore, the future research direction of meta-RL is discussed, which trains agents on diverse tasks, offering strong generalization capabilities, making RL algorithms more adaptable to real-world conditions.

Keywords: *Reinforced learning, Control algorithms, Intelligent buildings.*

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USAGE EFFECT OF THE SELECTIVE ABSORPTION FACADE INSTEAD AN INSULATION LAYER AND INFLUENCE ON ENERGY PERFORMANCE OF THE FAMILY HOUSE

Nebojša Lukić, Đorđe Radisavljević, Aleksandar Nešović, Novak Nikolić and Novak Popović

Abstract: In this paper the usage influence of the selective absorption facade instead an insulation layer on heating energy consumption of the family house is simulated. Using EnergyPlus software on the model of existing family house the defined influence has been analyzed. On selected exterior walls (especially southern) the insulation layers were removed and replaced with the selective absorption facade. This procedure resulted in the increased radiation gains as well as increased convection losses. Sixteen simulation scenarios were carried out. Results of these simulations were shown that a lack of insulation layer on southern facade can be compensated by application of the selective absorption surface.

Keywords: *Energy consumption, Selective façade, Residential house.*

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IMPACT ASSESSMENT OF ENERGY FACILITIES ON GEOECOLOGY

Vahe Davtyan

Abstract: The article is devoted to the problems of the impact of energy facilities on geoecology. The main criteria for the impact of the operation of energy facilities on the environment are identified. Separate sectors of the energy sector (nuclear, thermal, hydro- and alternative energy) are singled out for a separate determination of the level of influence of different energy facilities on the geoecological situation. The main geoecological problems of energy development of Armenia are considered. A geoecological assessment of the key energy facilities in Armenia is given.

Keywords: *Geoecology, Energy, Facilities, Assessment, Pollution, Ecosystem.*

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OPTIMIZING ENERGY CONSUMPTION IN SCHOOL BUILDINGS: IMPLEMENTING A HEATING CONTROL SCHEDULE BASED ON SCHOOL WORKDAYS

Vladan Jovanović, Dušan Ranđelović, Marko Ignjatović, Mirko Stojiljković and Dragana Dimitrijević Jovanović

Abstract: Energy overconsumption in the building sector is a critical global issue, particularly in educational buildings, where heating systems often operate inefficiently. This study focuses on optimizing the heating energy consumption of a primary school in Niš, Serbia, connected to a district heating network. Analyzing the school's current energy usage, we identified an annual demand of 160 kWh/m^2 substantially higher than necessary and reflective of poor heating management practices. Two energy simulations were performed to address this: one reflecting the current heating schedule and one using an optimized heating control system that adapts to the school's occupancy patterns and external weather conditions. This intelligent heating schedule reduced unnecessary heating during non-operational hours while maintaining thermal comfort during school activities. The results indicate that implementing this schedule can significantly reduce energy consumption, with potential savings of up to 30% annually. This lowers operational costs for the school and allows the district heating plant to distribute energy more efficiently, reducing overall fuel consumption. Additionally, this study highlights the environmental benefits of reducing carbon emissions associated with energy production. The research emphasizes the importance of integrating smart energy management systems in public buildings, offering a scalable solution that can contribute to sustainability targets in the education sector and beyond.

Keywords: *Energy Optimization, District Heating Control, School Buildings, Sustainability in Education.*

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SMART TIME TEMPERATURE ECOLABELS (TTE) AS CATALYSTS FOR REDUCING FOOD WASTE: ENHANCING RESOURCE EFFICIENCY WITHIN THE WEFE NEXUS FRAMEWORK

Vladimir Kitanovski, Monika Lutovska, Zoran Trifunov, Sani Demiri and Olga Popovska

Abstract: Over the past decade, food waste and food loss have emerged as significant challenges globally, driven by inefficiencies across the food chain and consumer habits. According to Eurostat in 2023, food waste was approximately 58 million tons in the EU, and around 54% of this comes in the household link of the food chain. The main objective of this paper was to contribute in raising awareness among consumers to eliminate the abuse of food intake, its proper storage, and thus reducing food waste. To address this, the implementation of smart time-temperature ecolabels offers a promising solution. These labels monitor the freshness of food products, providing real-time data that can prevent spoilage and reduce waste at critical points in the supply chain. We build medium scenario with 10% acceptance rate in total until 2030, and by lifecycle assessment (LCA), we identify the key performance indicators (KPI's) that are interdependent in the Water-Energy-Food-Ecosystem (WEFE) framework, so the impact can be quantified. This model assesses the reduction in resource use, demonstrating how smart labeling can contribute to a more sustainable food system. The resulting data can guide policy decisions and promote practices that align with environmental preservation goals across the region.

Keywords: *Lifecycle assessment, Environmental degradation, Food intake, Consumption practices, Cold supply chain.*

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CHANGE IN QUALITY OF THE KOLUBARA LIGNITE USED FOR OPERATION OF THERMAL POWER PLANTS "NIKOLA TESLA" A AND B

Nikola Živković, Vukman Bakić, Dejan Cvetinović, Sanja Vujnović and Marina Jovanović

Abstract: The paper presents experimental investigation, calculations and analysis in order to determine quality of the Kolubara Basin lignite used for the operation of the Thermal Power Plant (TPP) "Nikola Tesla". Investigated lignite samples presented in this work, and their mutual comparison, dated from 2012, 2015, 2017 and 2018 years. The results for the samples dated from 2012 year are taken from our previous work. Experimental researches were used in order to determine the emission factor of lignites, including ultimate, proximity analysis and determination of lower heating value for samples for “as received”, “as determined” and “dry” basis. Based on the obtained experimental results, correlated dependences of the emission factor of lignites for the specified years were established, and comparison have been made. From 2020 year, the Republic of Serbia imports Indonesian coal, mixing it with Kolubara basin lignite and use the mixture for operation of TPP (Thermal Power Plant) "Nikola Tesla". A comparison has been made of Kolubara lignite from past years, with a mixture of Indonesian coal and Kolubara lignite, from 2023 year. As shown in our previous works, and in this work, quality change for lignite during time, has been noticed.

Keywords: *Laboratory analysis, Ultimate analysis, Proximate analysis, Carbon emission factor, Kolubara lignite, Coal from Indonesia.*

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VII.Automatics and control of processes, equipment, and plants, FEMA

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ON THE GLOBAL FEATURE IMPORTANCE FOR INTERPRETABLE AND TRUSTWORTHY HEAT DEMAND FORECASTING

Milan Zdravković

Abstract: The paper introduces the ante-hoc Explainable AI methodology to assess the global feature importance of the Machine Learning models used for heat demand forecasting in intelligent control of District Heating Systems, with motivation to facilitate their interpretability and trustworthiness, hence addressing the challenges related to adherence to communal standards, customer satisfaction and liability risks. Methodology includes use of four different approaches, namely intrinsic interpretability of Gradient Boosting method and selected post-hoc methods, namely Partial Dependence, Accumulated Local Effects and SHAP. None of the selected methods assume feature permutation or perturbations which can introduce bias due to introduction of random unrealistic values of data instances. Discussion of results is provided, including the assessment of complementarities where applicable, with specific interpretations in context of the district heating processes.

Keywords: *District Heating System, Heat Demand Forecasting, Machine Learning, Artificial Intelligence, Explainable AI.*

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PREDICTING HEAT DEMAND OF RESIDENTIAL BUILDINGS WITH LAG AND TIME VARIABLES

Mirko Stojiljković, Marko Ignjatović, Goran Vučković and Vladan Jovanović

Abstract: Building heat demand depends on various parameters: properties of the materials, geometry, climate conditions, occupancy patterns, usage habits, etc. Short-term forecasts of the heat demand can be based on different subsets of these parameters, depending on the application and available data. Recently, black-box models that apply machine learning methods became widely used to predict the heat demand. This paper is a part of a broader research effort and investigates the time-series prediction properties of a simple model based on the Random Forest regression that uses only lag and time-related variables as inputs. The time resolution is one hour. The lag variables are the heat demand one hour before, 24 hours before, and 25 hours before the time of prediction. The time-related variables are the hour of day, day of week, and month. The model has the coefficient of determination of over 0.99, root-mean-square error 38.2 kWh, and mean absolute error 19.1 kWh. The most important predictor is the 24-hours lag. Large errors occur mainly early in the morning and late in the evening, when the heat demand changes have high values.

Keywords: *Building simulation, Multi-story apartment building, Random forest, Time-series forecasting.*

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OPERATIONAL OPTIMIZATION OF HEATING SYSTEMS WITH AIR-SOURCE HEAT PUMPS AND THERMAL STORAGE BASED ON REALISTIC ELECTRICITY TARIFFS

Mirko Stojiljković, Goran Vučković and Marko Ignjatović

Abstract: Heat pumps are among the crucial technologies for increasing renewable energy utilization in the building sector. One of the main factors for adopting heat pumps is their economic attractiveness, which depends on several factors. Air-source heat pumps are especially challenging in this regard because their performances relate significantly to the outdoor conditions. Optimization of operation regimes can lead to lower running costs of heating systems with heat pumps and thermal storage. However, most research efforts in this area are based on relatively simple pricing rules. This paper presents an attempt to perform operation optimization of a heating systems based on a realistic electricity pricing policy, applicable to the households in Serbia. The approach uses the results of detailed building simulations and existing rules for charging electricity as the inputs. It applies mixed integer linear programming to obtain the operation regimes that minimize the cost of electricity over one year. The paper shows the comparison of the obtained results to the results drawn from simplified electricity pricing rules. Finally, it discusses the importance, applicability, and limitations of the presented approach.

Keywords: *Heat pump, Mixed integer linear programming, Operational optimization, Residential building.*

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PROBLEMS OF LEAD SCREW ACCURACY MADE BY TURNING

Oleh Onysko, Volodymyr Kopei and Vitalii Panchuk

Abstract: The accuracy of closing and opening of taps, and accordingly the efficiency of energy saving, largely depends on the accuracy of the lead screw. Lead screws are mostly made using lathes. The accuracy of the thread of the lead screw is primarily the accuracy of the thread profile. Basically, the shape and profile of the screw must meet the standards of the trapezoidal thread and, accordingly, with the Archimedean form. However, based on the real conditions of the turning process, the shape of the thread will have a convoluted character, which functionally depends on the accuracy of the setting of the needle relative to the part. Taking this approach into account, it is possible to effectively apply the calculation algorithm, which provides for the maximum possible accuracy of the actual production of a lead screw with a trapezoidal or triangular profile.

Keywords: *Turning process, Manufacturing of machine, Thread accuracy.*

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MACHINE LEARNING FOR ROOF TYPE DETECTION AND CLASSIFICATION REVIEW

Dragana Dimitrijević Jovanović , Emina Petrović, Dušan Ranđelović and Vladan Jovanović

Abstract: Fast, precise, and intelligent acquisition of building information plays an important role in mapping, urban planning, digital city, climate change monitoring, and geographic information engineering. One of the most important parts of a building envelope is the roof. In urban areas, roofs make up a large percentage of the impervious surface in cities. Depending on the type of the building, orientation, climate condition, and aesthetics variety of roof types could be identified. Nevertheless, in most studies flat, gable, and hip, as the most fundamental roof types, were selected for research. In recent years, researchers have tried to use various methods to achieve automatic rooftop detection from aerial images. This review paper presents findings from different research conditions and approaches exploring the use of machine learning for roof type detection and classification. The support vector machine (SVM), a classical machine learning approach, the convolutional neural network (CNN), a deep learning approach, and the one-shot learning (OSL) approach were investigated.

Keywords: *Machine learning, Roof, automatic, Detection, Classification.*

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VIII.Flow, heat and mass transfer, combustion

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THEORETICAL THERMODYNAMIC ANALYSIS OF THE ORGANIC RANKINE CYCLE

Evangelos Bellos, Saša Pavlović, Mića Vukić, Branka Nakomčić-Smaragdakis and Mirjana Laković

Abstract: The present work is a theoretical investigation of the organic Rankine cycle (ORC). A simplified cycle is studied aiming to determine the ORC thermodynamic efficiency in an analytical and simplistic way. Reasonable assumptions have been made and the methodology is based on an analysis of the cycle depiction in the temperature – specific entropy diagram. An analytical solution for the ORC efficiency was developed using the low cycle temperature, the high cycle temperature, the superheating degree, the liquid and vapor-specific heat capacities and the fluid latent heat at the high-temperature level. The reported mean deviation of the suggested analytical model compared to the detailed thermodynamic one was found at 5.03% which is an acceptable value. Moreover, analytical approximations for the efficiency with regression models were created for three different working fluids names n-pentane, toluene and R600. The present approach can be extended to extra working fluids and operating conditions and the present work consists of the first step for the establishment of this methodology.

Keywords: *Theoretical cycle, Thermodynamic cycle, Organic Rankine Cycle, Thermal efficiency, Power cycle.*

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AVERAGED AXISYMMETRIC FLOW SURFACES IN HYDRAULIC TURBOMACHINES

Jasmina Bogdanović Jovanović, Živojin Stamenković, Jelena Petrović and Miloš Kocić

Abstract: Hydraulic turbomachines represent a group of turbomachines that operate with incompressible fluid, mostly water. They have a huge application in different hydraulic systems, such as water supply, irrigation, in cooling systems, hydraulic transport, as part of technological procedures in the industry etc. The optimal design of the hydraulic turbomachine is crucial for its optimal operation, i.e. work with maximum efficiency. In the process of turbomachine designing one of the basic assumptions is that fluid flow passing the impeller is axisymmetric, and on that bases the elementary stages of the impeller are determined. This paper presents the procedure for determining the averaged axisymmetric flow surfaces based on the results obtained using numerical simulations of flow in the impeller. Numerical simulations are used to verify and correct results of flow velocity in impeller domain, enabling the correction of the impeller geometry in accordance with the obtained results of the numerical analysis. According to the obtained results, the correction of specific works of elementary stages can be calculated in order to compare with the assumption made in the previous iteration.

Keywords: *Hydraulic turbomachines, Averaged flow surface, Numerical simulations.*

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LIGNITE COMBUSTION IN THERMAL POWER PLANT KOLUBARA A AS A SOURCE OF MERCURY POLLUTION

Jovana Buha-Marković, Ana Marinkovi, Jasmina Savić, Milić Erić, Zoran Marković, Aleksandar Milićević and Mihajlo Gigov

Abstract: Coal combustion is a major contributor to environmental pollution, releasing various harmful pollutants, including mercury, which poses significant risks to soil and water quality through atmospheric deposition. For this reason, many countries have established regulatory limits on mercury emissions from coal combustion, requiring the use of advanced pollution control technologies to capture and effectively reduce mercury emission. In this study, the mercury content in coal, coal ash samples and flue gas from the Kolubara A thermal power plant is analyzed. The results show that the mercury concentration in coal was 0.73 mg/kg, whereas the concentrations in fly ash and bottom ash were 0.02 mg/kg and 0.03 mg/kg, respectively. The mercury concentrations in coal and coal byproducts were in accordance with existing literature. In addition, the overall mercury content in flue gas was 38.73 μg/Nm^3, falling within the permissible emission limit for thermal waste treatment in Serbia. The calculated mercury emission factor was below the upper limit specified in the Air Pollutant Emission Inventory Guideline of the European Monitoring and Evaluation of Air Pollutants (EMEP/EEA). These findings provide useful data for long-term environmental monitoring and regulation of mercury emission from coal combustion in Serbia.

Keywords: *Coal, Coal ash, Mercury, Emission, Direct mercury analyzer.*

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ANALYSIS THE IMPACT OF COAL MIXING ON BOILER CHARACTERISTICS

Lidija Joleska Bureska

Abstract: Due of the depletion of the mines that were basis for the design and construction of the Thermal Power Plants in Macedonia, the necessary quantities of coal have to be supplied from other mines. The issue is further complicated by the fact that the current mines are providing coal with higher mineral matter content and lower calorific values towards the end of their operation, resulting in a lower quality compared to the originally intended specifications. Utilizing such coal in boilers has a number of disadvantages, such as lower efficiency, limited power, higher load on the fuel supply and preparation system, as well as slag and ash removal systems, an increased frequency of failures, and so on. To increase the quality of coal the existing one should be mixed with coal of a higher quality. This paper analyzes the selection of coal for blending, coal characteristics, and boiler operation with a few types of coal. Through analyzing calculation results, ash composition, and fusion temperatures, it is evident that the choice of coal for mixing should not solely focus on increasing calorific value but should consider a broader range of characteristics for a comprehensive analysis.

Keywords: *Coal, Mixing, Boiler, Ash, Slagging etc.*

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EFFECT OF WALL HEAT FLUX ON FLOW AND HEAT TRANSFER CHARACTERISTICS IN COILED CORRUGATED PIPES

Milan Đorđević, Marko Mančić, Velimir Stefanović and Mića Vukić

Abstract: The objective of this paper was to study the influence of high-intensity asymmetric heat flux at the wall on pressure drop and heat transfer in the Archimedean spiral coil made of transversely corrugated tube that was exposed to radiant heating and is supposed to represent heat absorber of parabolic dish solar concentrator. The working fluids were water and a mixture of propylene glycol and water (90% and 10% by volume, respectively). An increase in the heat flux density at the pipe wall affects the increase in the pressure drop and peripherally averaged Nu number in the considered geometry in all flow regimes. The effect is most noticeable in the laminar region and monotonically decreases with increasing Reynolds number and curvature ratio. The intensification of heat transfer is less compared to the increase in pressure drop with increasing heat load at the wall. Quantitative comparison of the obtained data with results in the literature is lacking due to significant differences between the considered geometries and experimental conditions.

Keywords: *Corrugated spiral coil, Heat flux density, Pressure drop, Heat transfer.*

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RESULTS OF THE TEMPERATURE VARIATION IN EXPERIMENTAL RESEARCH OF THE KOLUBARA LIGNITE DRYING PROCESS IN FLUDIZED BED

Milić D. Erić , Zoran Marković, Danka Kostadinović, Aleksandar Milićević, Rastko Jovanović, Ivan Lazović and Mihajlo Gigov

Abstract: Of all the fossil fuels in the world, the largest coal reserves are the most evenly distributed, and their mass exploitation ensures a stable and relatively low price on the international market, but coal contributes significantly to total greenhouse gas emissions. Reducing carbon dioxide emissions by increasing the energy efficiency of converting fossil fuels, especially coal, into electricity is known as Clean Coal Technologies. Particular attention is paid to low-grade coals with high moisture content, including lignite, which has significant reserves worldwide. Against this background, intensive efforts are being carried out to increase the energy efficiency of electricity generation from low-grade coal with high moisture content in the thermal plant by developing and introducing the process of pre-drying using the thermal energy available in the thermal plant. The drying process was investigated under fluidized bed conditions in an experimental apparatus designed and constructed for this test. Experimental investigations were carried out for two different fluidization velocities and three different air temperatures measured at the front of the sample. The results obtained show that the drying rate of the sample increases with increasing temperature, while the drying time of the sample decreases.

Keywords: *Convective drying, Temperature, Lignite, Moisture, Fluidized bed.*

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HEAT TRANSFER EFFECTS ON THE EMHD FLOW OF TERNARY HIBRID NANOLUID IN THE CHANNEL WITH POROUS MEDIUM

Milica Nikodijević Đorđević, Jelena Petrović, Miloš Kocic and Živojin Stamenković

Abstract: EMHD flow and heat transfer of a ternary hybrid nanofluid is considered in this paper. The base fluid is water with three types of nanoparticles suspended in it. Fluid flows in a horizontal channel with walls on different temperatures and its filled with porous medium. A homogeneous magnetic field acts perpendicular to the walls of the channel and a homogeneous electric field acts perpendicular to the direction of the magnetic field. The problem is considered in the induction-free approximation. The nanofluid velocity and temperature distributions, shear stresses and Nusselt numbers on the channel walls were determined. Some of the obtained results are presented graphically and tabularly.

Keywords: *EMHD, Ternary hybrid nanofluid, Porous medium, Heat transport, Horizontal channel.*

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MIXED CONVECTIVE EMHD FLOW OF A TERNARY HYBRID NANOFLUID IN A VERTICAL CHANNEL WITH POROUS MEDIUM

Jelena Petrović, Milica Nikodijević Đorđević, Miloš Kocić, Jasmina Bogdanović Jovanović and Živojin Stamenković

Abstract: This paper considers the mixed convective EMHD flow of a ternary hybrid nanofluid in a vertical channel. There is a homogeneous porous medium in the channel whose walls are on different temperatures. A homogeneous magnetic field acts perpendicular to the channel walls and a homogeneous electric field acts perpendicular to the direction of the fluid flow. The base fluid is blood and nanoparticles of three types of materials are suspended in it. The induced magnetic field is neglected. Velocity and temperature distributions were analytically determined and presented in the form of graphs. The shear stresses and Nusselt numbers on the channel walls are calculated and tabulated.

Keywords: EMHD, Ternary hybrid nanofluid, Vertical channel, Porous medium, Nusselt number.

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OPTIMIZING FLUE GAS RECIRCULATION FOR ENHANCED EFFICIENCY IN BIOMASS-FIRED BOILERS: A COMPREHENSIVE STUDY

Nenad Tomić, Jovica Podunavac, Mladen Tomić, Aleksandar Anđelković, Miroslav Kljajić and Predrag Živković

Abstract As sustainable energy practices become more popular, biomass-fired boilers are becoming a choice over traditional fossil fuel models due to their eco-friendly nature. Despite their environmental advantages, biomass boilers still emit pollutants like particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and carbon monoxide (CO), posing environmental concerns. To mitigate these emissions, modern biomass-fired boilers often incorporate Flue Gas Recirculation (FGR). This research focuses on a 14 MW biomass-fired boiler operating with a 20% FGR rate, examining three scenarios: two with varying FGR levels and one without FGR. The analysis reveals a connection between emission reduction via FGR and boiler efficiency maintenance. Additionally, it suggests optimizing FGR levels to boost boiler efficiency. The study presents a comprehensive approach to effectively implement FGR in biomass-fired boilers while ensuring acceptable efficiency levels. NO_X emissions were analyzed using combustion simulation software and the Zeldovich method to estimate thermal NO_X production.

Keywords: *Gas Mixture, Real Gases, Temperature-Dependent, Viscosity.*

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DETERMINING GAS AND GAS MIXTURE VISCOSITY ACROSS WIDE TEMPERATURE RANGES: REFINEMENTS AND PREDICTIVE MODELS

Jovica Podunavac, Nenad Tomić, Mladen Tomić, Aleksandar Anđelković, Miroslav Kljajić and Predrag Živković

Abstract This study delves into refining the ideal gas viscosity equation by introducing amendments that account for temperature variations and critical temperature ratios across diverse ideal gases. The investigation involves comparing the adjusted formula with empirical data obtained from various gases under extreme conditions, including ultra-critical temperatures and near-critical points like for water and carbon dioxide. The primary objective is to enhance the equation's accuracy and applicability. The research proposes novel modifications integrating a temperature-dependent dumping coefficient and a redefined temperature exponent. These adjustments aim to capture gas behavior across a wider spectrum of temperatures, pressures, and gas compositions. Building upon foundational works in gas dynamics and molecular theory, this study bridges the gap between theoretical formulations and empirical observations. To validate these modifications, empirical data from gases under diverse conditions, including ultra-critical temperatures and mixtures, were utilized. Notably, the study's focus extends to analyzing gases under extreme conditions, highlighting the formula's improved predictive capability, and assessing its performance against complex gas mixtures using software-generated data. The findings reveal that these proposed adjustments significantly enhance the equation's alignment with real-world observations. Specifically, the analysis showcases improved predictive accuracy, especially in extreme gas conditions, and promising results when evaluating complex gas mixtures. These modifications offer a more comprehensive framework for estimating viscosity across a broad range of gas types and conditions, thereby enhancing the predictive power of the ideal gas viscosity equation.

Keywords: *Gas Mixture, Real Gases, Temperature-Dependent, Viscosity.*

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T-JUNCTION AND TRANSFER OF TRANSIENT MODES IN HYDRAULIC SYSTEMS

Valentino Stojkovski, Marija Lazarevikj and Zoran Markov

Abstract: A T-junction of a hydraulic system is the point where hydraulic parameters (which are defined by variable pressure and discharge) join or separate. The transmission of the hydraulic conditions distributed by the T-junction connection are numerically analysed in different conditions which provide insight into the distribution – transfer of hydraulic parameters through the T-junction.Numerical calculations were performed for defining the transient modes and the interaction between the hydraulic parameters in the case of a T-junction with the application of the AFT Impulse software package. The software was chosen as suitable based on previous experience with good alignment between numerical calculations and field measurements.The results from the numerical prediction of the occurrences for different conditions in the T-junction construction showed the influence of simultaneity (interaction and dissipation) of the fluid flow parameters, time delay or parallel flow and counter-flow in the transient modes, which contribute to the technical opinion on the phenomena occurring in a T-junction.

Keywords: *Transient Modes, Interference, Dissipation, Fluid flow parameters.*

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A MODEL OF TWO-PHASE FLOW IN PNEUMATIC TRANSPORT OF POWDER MATERIAL

Saša Milanović, Veljko Begović, Miloš Jovanović, Boban Nikolić, Živan Spasić and Petar Miljković

Abstract: The paper presents a numerical simulation of two-phase turbulent flow in straight horizontal channels with a square cross-section, with the dimensions of 200x200 mm and the length of $80D_h$. The flow of solid particles of quartz, flour and ash using air was chosen for the two-phase flow simulation. During the modelling of the flow, the transported particles were observed as spherical. The turbulence was modelled using a full Reynolds stress model, while the complete model was used to examine turbulent stresses and turbulent temperature fluxes. The same initial flow conditions and a single uniform grid were employed in all numerical experiments. The fineness of the numerical grid was tested during the simulation, and the paper shows the results of the numerical grid of the highest resolution beyond which the fineness did not affect the obtained results. The paper also presents the change in the velocity of the transported material by air in the cross-section and along the channel.

Keywords: *Computer Simulation, Pneumatic Transport, Solid Particles, Channel, Two Phase Flow.*

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INFLUENCE OF FLUE GAS RECIRCULATION ON NITROGEN OXIDES EMISSION DURING NATURAL GAS COMBUSTION

Luka Marinović and Dejan Mitrović

Abstract: Environmental protection is one of the crucial requirements that are placed on designers of boilers and other combustion devices. Nowadays, with the increased consumption of gaseous fuels, the emission of nitrogen oxides has become big problem. This paper deals with the impact of recirculation of combustion products on the reduction of nitrogen oxide emissions. In the first part of the paper, mechanisms of NO_x formation and the factors that affect it are reviewed. After that, a simplified analysis of the flue gases recirculation was performed. The presented methodology can be very useful for quick emission calculations to engineers, either in the process of design or plant maintenance.

Keywords: *Nitrogen oxides, Zeldovich mechanism, Flue gases recirculation, Combustion.*

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WATER VAPOR CONDENSATION FROM COMBUSTION PRODUCTS AND ITS USAGE POSSIBILITIES

Luka Marinović, Dejan Mitrović, Mirjana Laković and Marko Ignjatović

Abstract: Moisture condensation from combustion products must appear in the fuel gasses stream of every boiler plant, in some period of operation. Discharging this condensate into environment leads to additional heat loss. Although this amount of heat compared to the total capacity of boiler house is not significant, it is not negligible. At the beginning, this paper deals with causes and sources of water vapor in the combustion products. Then possibilities of usage of formed condensate in the district heating system for improving energy efficiency and decreasing carbon dioxide emission on an example of system in District heating plant "Krivi Vir" in Niš, is presented. After that, some vital factors which have influence on efficiency of considered system are pointed, as well as possibilities for application.

Keywords: *Carbon dioxide emission reduction, District heating system, Fuel saving, Water vapor Condensation from combustion products.*

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IX. Mathematical modeling and numerical simulation

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ADVANCED MODELING AND SIMULATION OF SOLAR CELLS AND PV MODULES BY USING PVSYST AND MATLAB

Aleksandar Pantić, Neda Branković, Adriana Petković and Sanja Aleksić

Abstract: This paper presents advanced modeling and simulation of solar cells and photovoltaic (PV) modules using PVSyst and Matlab, with a focus on the Republic of Serbia's renewable energy potential. The study employs PVSyst for system-level simulations and long-term performance analysis, while Matlab is used for detailed component-level modeling. Meteorological data from various regions in Serbia, especially those with high solar irradiance, are integrated into the models to assess the impact of local conditions on PV system performance. Results indicate that southern Serbia, with higher average solar radiation, offers significantly greater energy yield potential than northern regions. Additionally, the study highlights how temperature fluctuations in Serbia's continental climate affect PV efficiency, underlining the importance of temperature management in system design. The combined approach of PVSyst and Matlab provides a comprehensive analysis that informs optimized design strategies for solar energy deployment in Serbia, addressing both residential and large-scale installations.

Keywords: *Solar, Renewable Energy, Serbia, Photovoltaic, Matlab, PVSyst, Performance Analysis, Energy Yield.*

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NUMERICAL MODELING AND ANALYSES OF HYDRO-ELECTRO-MECHANICAL TRANSIENT PROCESSES OF HPP BISTRICA FOR THE STATE AFTER REFURBISHMENT AND UPRATING

Aleksandar Petković and Jovan Ilić

Abstract: HPP Bistrica is a peak-load, 2 × 55 MW turbine output derivation-scheme HPP. It was commissioned in 1961. Nowdays, after more than 60 years of exploitation it is envisaged to undergo refurbishment. The refurbishment comprises, inter alia, complete replacement of generating units, with increase of installed discharge and uprating of power capacity. Therefore, it is necessary to undertake due investigation of HPP behavior in transient regimes, analyze hydro-electro-mechanical processes so to determine adequate protective measures (of structural- or regime- nature). In the existing state, the HPP's protective measures comprise a surge tank and synchronous pressure relief valves at both turbines. The paper presents main findings of the analyses, discussion of the results and selection of protective measures.

Keywords: *Hydropower plants, Hydro-electro-mechanical transient processes, Renewable energy sources, HPP Bistrica.*

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WALL VARIABLES FOR DIFFERENT EFFECTIVE THERMAL CONDUCTIVITIES OF THE FURNACE WATERWALLS ASH DEPOSITS

Nenad Crnomarković, Srđan Belošević, Ivan Tomanović, Aleksandar Milićević, Andrijana Stojanović and Dragan Tucaković

Abstract: During the operation of the pulverized coal-fired furnaces, the ash deposits are formed on the waterwalls. Ash deposits increase the temperature of the deposit surface, which implies bigger heat loss due to emission of the radiation, and decrease the surface emissivity of the deposit, and smaller absorbed heat flux from the flame radiation. The most important thermo-physical property of the ash deposits is its effective thermal conductivity. It affects the values of the wall variables: wall heat flux, wall temperature, and wall emissivity. The objective of this investigation is to find difference between wall variables for different functional types of the effective thermal conductivity of the ash deposits on temperature was examined in the paper. Three curves were formed on the basis of the available data in literature. The results showed that type of the curve did not influence the mean values of the wall variables. The curves influenced the distribution of the wall variables little. The maximal value of the mean relative difference was less than 2.0%. The investigation showed that the type of the curve determined the ash deposit thickness with which the numerical simulation was conducted. In other words, the relation between the deposit thickness and total exchanged heat in the furnace could indicate the real values of the effective thermal conductivity.

Keywords: *Numerical simulation, Waterwall, Ash deposit, Effective conductivity, Wall variables, Deposit thickness, Heat transfer.*

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INFLUENCE OF BUILDING SHAPE ON WIND FLOW: CFD SIMULATIONS

Danka Kostadinović and Ivan Lazović

Abstract: Buildings significantly affect the wind flow pattern over an urban area, leading to regions with an accelerated wind flow. The change in wind flow influences pollutant dispersion, urban microclimate, formation of fog and haze, urban heat island, comfort of pedestrians, and wind-created noise. It is important to include the simulation of wind flow around buildings in the early architectural design stage. The paper investigates the effect of different shapes of buildings on the wind flow pattern using Computational Fluid Dynamics (CFD) simulation. Results have been represented through pressure, velocity, and turbulence kinetic energy contours for five different cases. The ANSYS software was employed to solve the flow governing equations. The standard k-ε turbulent model was used for turbulence modeling while the Semi-Implicit Method for Pressure Linked Equation (SIMPLE) algorithm was applied as a solver for governing equations. This study clearly illustrates that different building shapes generate different wind flow patterns.

Keywords: *ANSYS, Building, CFD, Turbulence, Velocity, Wind.*

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MEASUREMENT ELEMENTS AND SCADA SYSTEM OPERATION IN THE REMOTE HEATING SYSTEM OF THE FACULTY OF MECHANICAL ENGINEERING

Dejan Mitrović, Marko Ignjatović, Dušan Stojiljković, and Rajko Turudija

Abstract: The enormous amounts of energy consumed today for the production of thermal energy intended for households, on the one hand, and the reserves of all types of fuels available worldwide, on the other hand, require that a more rational consumption should be implemented among all consumers. One of the many enhancements to heating systems that aims to improve overall efficiency is the concentration of thermal energy output for a greater number of users, which produces a far better result. This has led to the implementation of a centralized supply of thermal energy for multiple buildings and facilities, residential blocks, and entire urban areas. This method of producing and transmitting thermal energy for heating purposes is called district heating. The thermal energy, produced centrally, is transferred via pipelines to substations, and then through heat exchangers and secondary networks to end-users. Due to the fact that energy consumption constitutes a significant part of the budgets of individual and collective users and requires compliance with the European Union directives on increasing efficiency in all spheres of energy transformation, there is a need for optimized production and consumption of thermal energy. Optimization involves adequate supervision of relevant parameters of the heating process, including production (boiler room), distribution (pipelines), transfer (substations), and consumption (end-user). Supervision entails the ability to command and monitor the operation and parameters of the process. To achieve this goal, the supervisory system must collect and display important process data to detect possible problems or causes of inefficiency in the process itself, thereby alerting the operator. The main goal of the supervisory system is to enable the operator to control and command a highly automated process. Therefore, supervision involves a series of tasks aimed at controlling the process and monitoring its parameters. The Supervisory Control and Data Acquisition (SCADA) system has wide application in district heating systems for monitoring, control, and data acquisition.

Keywords: *SCADA system, Remote heating system, Measurement element.*

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MATERIAL SELECTION OF WAVE ENERGY TURBINE BLADE BY USING MCDM SOLVER

Dušan Petković and Miloš Madić

Abstract: Selection of materials is a complex and multi-criteria decision making problem, which requires a lot of knowledge and experience. Selection process is influenced by few factors such as thermal, mechanical, electrical, chemical, physical and technological properties as well as their price and availability. This paper considers material selection problems of wave energy extraction turbine blade by using MCDM approach. Due to help decision makers in solving this complex task, a decision support system named MCDM Solver. MCDM Solver was used in decision-making process to rank materials for the turbine blade with respect to several criteria. Based on the results the best ranked materials are Carbon fiber reinforced polymer, titanium alloys and Glass fiber reinforced polymer.

Keywords: *Material selection, Wave energy extraction turbine blade, Multi-criteria decision making, MCDM Solver, Decision support system.*

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IN-DEPTH EXAMINATION OF WATER JET FORMATIONS AND PATTERNS AT DAM OUTLETS: COMPARATIVE INVESTIGATION EMPLOYING CFD SIMULATIONS AND ON-SITE DRONE FOOTAGE

Filip Stojkovski, Robert Broz, Sašo Belšak and Valentino Stojkovski

Abstract: This scientific paper presents a comprehensive study on the Computational Fluid Dynamics (CFD) modeling of water jet formations at dam bottom outlets, with a focus in the comparative analysis of CFD results against actual drone footage captured on-site. The research commences with the development of a detailed CFD models, encompassing the geometric and hydraulic characteristics of the dam bottom outlet structure. Special attention is given to incorporating boundary conditions and numerical schemes that accurately simulate the water jet formation process. Computational simulations are conducted for a range of operational scenarios i.e. bottom outlet gate openings. To validate the CFD results and prove their applicability, a field campaign is carried out, involving the use of camera equipped drone and one stationary camera, to capture real-time footage of water jet formations at dam bottom outlet. The drone footage provides invaluable visual data that allows a direct comparison between the CFD predictions and actual on-site observations. The comparative analysis involves a quantitative assessment of key parameters, such as jet velocities, trajectories, flow patterns etc. Discrepancies between the CFD predictions and real-world observations are analyzed to identify potential areas for model refinement and future improvement. The results of this research contribute to a better understanding of the hydraulic behavior of dam bottom outlets. By leveraging advanced CFD modeling and real-world drone footage, this study provides a holistic approach to studying water jet formations at dam outlets, bridging the gap between numerical simulations and empirical observations in a complex hydraulic environment.

Keywords: *Computational Fluid Dynamics (CFD), Water Jet Formations, Comparative Analysis, Dam Bottom Outlet, Hydraulic Modeling, Volume of Fluid (VOF), Multiphase Flow.*

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TEMPERATURE UNIFORMITY AND EQUIALIZATION OF A MEASUREMENT PIPE LINE DESIGNED WITH CFD ANALYSIS

Filip Stojkovski, Valentino Stojkovski and Gjorgji Karaliev

Abstract: Due to the need for expanding the measurement system for the delivery of thermal energy (based on the flow rate) and due to the inability of the existing measurement line to provide the required flow rate consistently, an extension of the measurement line has been implemented by installing a parallel pipeline to ensure flow rate and hydraulic relaxation. A calorimeter, measuring flow rate and temperature, has been installed on the additional parallel line, serving as the basis for the delivery of thermal energy. The issue of unambiguous definition within the measurement system for the delivery of thermal energy has revealed an imbalance in aligning the supply water with the distribution according to measurement lines for delivery and defining the thermal calorific value towards the distributive part of the system. The system providing metered distribution of water from the station, in terms of flow rate and heat, showed a disproportion in temperature determination for the water measured through the two lines after the reconstruction. Given that the systemic product given to the consumer (named distribution) technologically depends on the additional mixed water, numerical simulations were conducted to predict the method of water mixing, aiming to achieve consistency across the measurement lines. In this case, the possibility of mixing is through the adjustment of two thermally loaded water flows. The analysis aims to achieve temperature stability across the measurement pipe lines. The analyzed states are defined using the CFD technique. The results of the numerical calculations showed that with the specified structural changes, thermal uniformity can be ensured within the system towards the measurement system.

Keywords: *Computational Fluid Dynamics (CFD), Temperature Uniformity, Water Mixing, System Design Upgrades. Thermal Energy.*

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INVESTIGATION OF PROCESSES IN THE "REFORMER-FUEL CELL" SYSTEM BY THE MATHEMATICAL MODELING METHOD

Iliya Iliev, Antonina Filimonova, Natalia Chichirova, Mirjana Laković, Egor Mayorov and Dmitriy Bazin

Abstract: This study involved the creation of a mathematical model and the research of the "reforming-fuel cell" system with the aim of obtaining optimal operating parameters for a solid oxide fuel cell. Based on the results of reforming system modeling in ASPEN PLUS simulation software, the exergy efficiency of the reformer was calculated. The results were used to determine the optimal parameters for the steam conversion process of hydrocarbon fuels. Also, in the ANSYS software package, the technical parameters of the fuel cell operation were calculated - the temperature of the fuel cell at the outlet of the anode, the current density at the outlet of the fuel cell, as well as the composition of the exhaust gases. As a result of the study, technological parameters were calculated, which allow us to draw a conclusion about the influence of gas composition on the output parameters of the fuel cell. For various molar compositions of synthesis gas, the efficiency of the fuel cell, the temperature at the anode outlet, and the current density were calculated. Based on the values of the exergetic efficiency of the reformer and the electrical efficiency of the fuel cell, the obtained calculations made it possible to conclude about the most optimal composition of the obtained synthesis gas.

Keywords: *Reformer, Modeling, System, Syntes-gas, Fuel.*

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THE HYDRAULIC ROLE OF ELBOWS IN RECTANGULAR DUCTS OF HVAC DISTRIBUTION SYSTEMS ANALYSED BY CFD

Marija Lazarevikj, Zoran Markov and Valentino Stojkovski

Abstract: Ducts with rectangular cross-section are widely used in HVAC (heating, ventilation and air conditioning) distribution systems applied to residential, commercial and industrial buildings where round elements can't be used. Usual practical problem is calculating the required pressure drop to drive the air flow for a given duct geometry at a certain flow rate, for which the total hydraulic losses should be obtained. Friction losses in ducts depend on their size (height to width ratio of rectangular section, length of channel etc), flow capacity and construction material, while minor losses are caused by changes in flow stream direction, expansions or contractions, fittings and valves. The installation of elbow in a channel can induce larger losses due to local flow separation and swirling secondary flow. This paper focuses on evaluation of hydraulic losses in cascade connected straight rectangular sections by three elbows with the application of Computational Fluid Dynamics (CFD). Viscous incompressible flow of air in the ducts was modelled and simulated. Rectangular ducts which have the same hydraulic diameter but differ according to the lengths of their straight sections were being analysed. The numerically obtained loss coefficients were compared with available theoretical data and show good agreement especially in a selected range of Reynolds number. The phenomena of flow separation and secondary flow in the elbow inlet and outlet region are studied for each case. A conclusion is drawn from the comparative analysis that the lengths of the straight sections between the elbows significantly influence the hydraulic resistance of the duct because of the contribution to the velocity profile uniformity. Moreover, during the separate analysis of the elbows, it is detected that the elbow position in the system is an influencing parameter on the elbow loss coefficient.

Keywords: *Rrectangular duct, Elbow, Hydraulic resistance coefficient, CFD.*

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MEASUREMENT OF WATER QUALITY PARAMETERS USING THE SPECTROPHOTOMETRY METHOD

Radmila Koleva, Darko Babunski, Emil Zaev, Atanasko Tuneski and Magdalena Koleva

Abstract: Having quality drinking water is a leading factor in maintaining public health, environment protection, and the promotion of sustainable development in industrial and agricultural needs. Measurement and analysis of chemical parameters in drinking water are crucial for ensuring the safety and quality of water for public health. This research was conducted using the spectrophotometry method including a UV-VIS DR 6000 HACH Lange spectrophotometer with a wavelength range of 190 to 1100 nm and a high-speed temperature thermostat HT 200 S. Chemical parameters that are measured in this research are chlorides, nitrates, nitrites, potassium, phosphates, and ammonium. All of them are measured on a different wavelength. Samples were taken from three measuring points, all of which are used as drinking water sources and irrigation in the nearby villages. One measuring point is a thermal spring and the other two springs from the foot of a mountain. The water from all three water sources is considerable drinking water. One sample is taken from Vardar River and its water is considered as non-drinking. The results of all measured parameters will be represented through a table and bar graphic chart.

Keywords: *Water quality parameters, Water quality analysis, Drinking water, Spectrophotometry, DR6000.*

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NUMERICAL STUDY ON THERMAL ENERGY STORAGE SYSTEM INTEGRATED FLAT PLATE SOLAR COLLECTORS IN BUILDINGS

Saša Pavlović, Evangelos Bellos, Velimir Stefanović, Mirjana Laković, Branka. Radovanović, Gradimir Cvetanović, Mića Vukić and Branka Nakomčić-Smaragdakis

Abstract: The use of renewable energy sources for electricity is one of the most promising techniques in order to face environmental problems and high CO2 emissions. However, the power production from photovoltaics and wind energy is not stable and this fact creates issues between the production profile and the demand profile. Therefore, an effective storage technique is needed, except for the idea of batteries. The objective of the present investigation is the investigation of a novel pumped thermal energy storage system. This system uses the volatile electricity from renewables in order to feed a heat pump that produces heating at a medium temperatures level (e.g. 150 °C) and stores it in a latent storage unit. The stored thermal energy can be used later in an organic Rankine cycle for power production when there is the proper demand. The novelty of this work is the incorporation of flat plate collectors for assisting the heat pump in order to increase the overall performance of the examined storage system. According to the results, the ambient source system leads to maximum power to power ratio of 38.5% and this value is lower than the respective values of the solar-assisted system. The maximum system efficiency was found for storage tank temperature at 220 °C and evaporator temperature at 30 °C, and in this case, the system energy efficiency is 19.1%, while the system exergy efficiency is 19.7%. For the typical case of (Tst = 150 °C and Tevap = 70 °C) the solar-assisted system presents a 61.1% power to power ratio which is 58.7% higher than the ambient source case.

Keywords: *Solar energy, Flat plate collector, Latent storage, Volatile electricity, Renewables.*

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THREE-DIMENSIONAL NUMERICAL INVESTIGATION OF FLUIDIZED BED GASIFICATION IN A PILOT PLANT GASIFIER: FLUID FLOW

Nikola Ćetenović, Dejan Cvetinović and Djordje Čantrak

Abstract: Fluidized bed combustion offers key advantages such as high efficiency, environmental friendliness, fuel flexibility, and load adaptability, making it suitable for various applications such as power generation, biomass gasification, and petrochemical processing. This study presents a numerical investigation of the gasification processes in a pilot-scale fluidized bed gasifier using a 3D computational model. The model simulates the complex turbulent multiphase flow within the real gasifier geometry of the pilot plant and focuses on the interactions between air and sand, as well as the temperature distribution. Initial numerical results show good agreement of fluid flow structure with experimental data. Future work will include combustion modeling, with the numerical results to be validated by experiments in the pilot plant. After model validation, the model will be used for similarity analysis to optimize the process parameters.

Keywords: *Fluidized bed, 3D Mathematical modeling, Multiphase flow, Turbulence, Gasifier.*

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DEVELOPMENT OF A MATHEMATICAL MODEL OF A DRUM STEAM BOILER BY USING THE AUTOMATIC CONTROL SYSTEM – SECOND STEP

Aleksandra Janković and Milica Ivanović

Abstract: Steam boiler or steam generator is widespread equipment for energy conversion in the industry for obtaining steam and later electricity. Processes in energy states are complex and require the application of automatic control theory, which basically relies on mathematical models of objects and processes given in the state space. This approach requires knowledge of both the static and dynamic properties of the processes taking place in the thermoelectric plant. The general approach to mathematical modeling consists in setting bilas equations as well as an appropriate number of supplementary equations which, together with the previous ones, give a closed system of equations to be solved. In this paper, the second step in the modeling of a steam boiler is presented, and for the specific case, a simulation of the mathematical model was performed on the basis of experimentally collected data.

Keywords: *Steam boiler, Mathematical model, Combustion dynamics, Automatic control.*

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LIFE CYCLE IMPACT ASSESSMENT - A REVIEW OF TOOLS FOR SUSTAINABLE ENERGY MANAGEMENT

Milena Rajić, Zorana Stanković and Peđa Milosavljević

Abstract: Life Cycle Assessment (LCA) has become an important tool for evaluating the environmental impacts of energy systems, in the context of sustainable energy management. This paper provides a review of LCA software tools, including OpenLCA, SimaPro, GaBi, Umberto, Brightway2, and OpenEco, with a focus on applications in renewable energy systems. The comparison of these tools in terms of their functionalities, data handling capacities, and impact assessment methodologies, provides the results of how suitable they are for different energy systems and industrial applications. Particular attention is given to the interpretation and reporting of LCA results, bearing in mind the challenges associated with uncertainty, sensitivity analysis, and trade-offs in energy systems. The paper also includes a discussion on how LCA tools contribute to environmental protection measures, energy efficiency improvements, and socio-economic considerations in energy policies. The implications for policymakers and industries are also given, with recommendations for improving LCA practices in future energy projects. This review offers practical data for stakeholders in order to optimize energy systems and provide a sustainable and low-carbon future.

Keywords: Life Cycle Assessment, Life Cycle Impact Assessment, Sustainable management, Energy management, Circular economy.

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TWO-STEP CLUSTER ANALYSIS FOR ENERGY PERFORMANCE INDICATORS COMPARISON

Žarko Rađenović and Milena Rajić

Abstract: Assessing energy performance indicators is important for understanding EU countries' progress toward achieving sustainability and climate goals, including reducing greenhouse gas emissions and increasing the share of renewable energy. This paper clusters EU member states based on six key energy indicators: primary energy consumption, energy productivity, and renewable energy in transport, electricity, and heating, using IBM SPSS 26.0 for two-step cluster analysis. Four distinct clusters were identified, revealing varying strengths and weaknesses. These insights provide important guidance for policymakers, enabling the development of targeted strategies for improving energy efficiency and sustainability across the EU.

Keywords: Energy performance indicators, Two-step cluster analysis, Energy management, Sustainability.

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THERMAL COMFORT MODELS FOR FUTURE TOURISM USING HEART RATE VARIABILITY

Miloš D. Milovančević

Abstract: Current thermal comfort technologies for future tourism, known for their high energy usage, often fall short by creating uniformly neutral conditions that lack efficiency. The key body areas crucial for tourist thermal comfort are the wrists, feet, and head. Thus, there's a pressing need for technologies that specifically target these areas to optimize thermal comfort. Changes in the thermal environment are observed to influence the heart rate variability (HRV) of individuals, indicating fluctuations in their physiological responses to thermal conditions. The primary objective of this study was to identify which HRV indicators significantly affect individual thermal comfort levels. Accurately assessing thermal comfort is essential for energy-efficient environments, yet predicting tourists' thermal comfort proves challenging due to the multitude of influencing factors.

Keywords: Future tourism, Thermal comfort, HRV, Regression, Neuro fuzzy JEL classification: Z31, Z38.

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IS THERE A CIRCULAR ECONOMY BUSINESS MODEL THAT CAN BE EASILY IMPLEMENTED?

Ana Kitić and Miloš Milovančević

Abstract: Strategic management, operations management, and technology management are just a few of the areas where the circular economy concept is gaining more and more attention. It requires that businesses create their business models around a new idea of sustainable development that reduces resource consumption and protects the environment. This includes the value network, interactions with supply chain partners, and value offerings to customers. Existing research, however, falls short of fully describing how businesses design their business models in accordance with the concepts of the circular economy. This paper presents an overview of the current business models of the circular economy.

Keywords: *Circular economy, Business model, Value, Environment, Strategic management.*

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