

BOOK OF ABSTRACTS

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TOWARDS COST-OPTIMAL DESIGN OF BOREHOLE THERMAL ENERGY STORAGE SYSTEMS INTEGRATED WITH DISTRICT HEATING

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Borehole thermal energy storage enables seasonal utilization of surplus district heating by shifting summer excess heat to winter demand. However, high investment cost and operational complexity have limited its large-scale deployment. To address these challenges, a system-level simulation framework was developed to represent integrated borehole operation under realistic closed-loop conditions, capturing auxiliary heat demand, heat pump performance, and overall energy flows. To allow iterative design exploration with reduced computational effort, a surrogate approach combining physics-based modeling and XGBoost machine learning method was implemented for accelerated estimation of borehole thermal response. The framework was applied to investigate the techno-economic implications of borehole sizing, evaluating auxiliary heat reduction, energy input requirements, heat export potential, and the total system cost. The results revealed clear trade-offs between investment and operational savings, highlighting the need for coordinated design and operation strategies in progressing towards cost-optimal borehole storage deployment.

DEGRADATION MECHANISMS OF TE-DOPED GAAS/ PEROVSKITE TANDEM SOLAR CELLS UNDER ACCELERATED CLIMATE CHAMBER TESTING

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Te-doped GaAs/perovskite tandem solar cells are a frontier technology. While Perovskite/Silicon tandems dominate commercial headlines, the GaAs/Perovskite combination fills the research gap in applications like aerospace, drones, and solar-on-car, due to its superior power-to-weight ratio. Using Tellurium (Te) as an n-type dopant in the GaAs base or tunnel junction allows for higher carrier concentrations and lower contact resistance compared to Si doping. While GaAs is a mature technology, integrating it with perovskite configuration is still largely in the research phase. Most papers focus on power conversion efficiency evaluation. Long-term reliability data is very limited and covers 500 to 1,000 hours. In this study, a methodology for aging test under thermal cycling in climate chamber is proposed, which makes sense, because the thermal expansion coefficients of GaAs and Perovskites differ significantly. Specific defects at the materials boundary are explored, such as layer/substrate integrity, ions migration under thermal stress and fill factor deviations.

This study is funded by the Bulgarian National Science Fund, grant KP06-H87/4.

ENERGY STORAGE FOR LOAD BALANCING IN NUCLEAR POWER PLANTS

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We have to do with different concepts of the role of Nuclear Power in individual countries. Examples include Germany, where nuclear energy has been phased out, France, where nuclear energy plays a key role. and Poland. Today, Poland's Energy Policy and the National Energy and Climate Plan emphasize the construction of new nuclear power units. This is happening amidst the intensive development of intermittent renewable sources. Already today we can observe periods of excess production capacity to meet the needs of energy. This is accompanied by the growing curtailment of renewable energy resources operation. The remedy is the construction of energy storage facilities and the use of various technologies for managing excess renewable energy. Examples of nuclear power plant plants cooperating with energy storage systems will be presented.

New proposal was presented during conference presentations and in the papers prepared for publication. This studies evaluates the feasibility of integrating steam accumulator-based thermal energy storage into the nuclear power plant secondary circuit to enable intraday grid stabilization, addressing renewable energy source intermittency. TES would be charged with steam produced in steam generator (SG), accounting for the pressure losses in the SG-to-TES and TES-to-turbine connecting pipelines.

As demonstrated, estimated round-trip efficiency of the presented solution will be lower than for typical lithium battery storage with comparable capacity, but visibly less expensive. Using the April 2025 Iberian Peninsula blackout as a case study, another analysis demonstrates that TES allows the reactor to avoid shutdown and xenon poisoning by diverting excess steam during the outage. Simulation results in this case indicate that the coupled TES-NPP system enables the plant to remain in hot standby and reconnect to the grid as early as 80 minutes after collapse – over 10 times faster than in the actual blackout scenario. More details will be provided for the presented examples.

LIFE CYCLE ASSESSMENT ANALYSIS USING RENEWABLE ENERGY IN THE PRODUCTION OF POLYMER FROM POLYSTYRENE WASTE

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Life Cycle Assessment (LCA) is a method that enables an in-depth analysis of various categories of potential environmental impacts of new products, taking into account energy. In the context of sustainable development, it can significantly help minimize a product's environmental footprint. Analyzing potential environmental risks using LCA also allows for comparing production processes that utilize alternative energy sources with those relying on traditional fuels such as hard coal or lignite. Currently, efforts are being made to reduce the extraction of mineral resources and to reuse and recycle waste. The aim of the study was to assess the environmental impact of a polymer produced from polystyrene waste, with particular emphasis on energy consumption and the associated emissions from production. The results of the environmental impact study of the new polymer—a sodium salt of a polystyrene sulfonate derivative obtained from polymer waste—indicate that the resulting products constitute a new generation of polyelectrolytes that are effectively used in the treatment of industrial wastewater. A comparative analysis of emissions associated with the energy used in the production process—from traditional fuels versus photovoltaic panels—is one of the main environmental impact factors analyzed. Despite minor differences in the degree of environmental pollution, energy obtained from a renewable source such as photovoltaics is a desirable investment asset, not only for environmental reasons but also due to low production costs.

INTEGRATED ASSESSMENT OF THERMAL COMFORT, INDOOR AIR QUALITY AND ENERGY PERFORMANCE IN AN OFFICE ENVIRONMENT

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This study presents an integrated approach for assessing thermal comfort, indoor air quality, and energy performance in an office environment. A dynamic TRNSYS model is developed to simulate indoor air temperature, relative humidity, ventilation rates, thermal loads, and HVAC energy consumption. The model is coupled with a MATLAB-based CO₂ model to evaluate indoor pollutant concentration under different operating conditions. Experimental microclimatic measurements are used to calibrate and validate the model. After validation, temperature set-points and air change rates are varied to analyse their effects on comfort conditions, indoor air quality, and energy demand. The proposed methodology supports the identification of operating strategies able to improve indoor environmental quality while limiting energy consumption.

GEOHERMAL ENERGY UTILIZATION: AN OVERVIEW WITH EMPHASIS ON MODELLING CHALLENGES

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Geothermal energy is a sustainable and low-carbon resource with the potential to significantly support global decarbonization efforts. Despite its considerable technical potential, its contribution to the current global energy mix remains modest, approximately 0.34%, constrained by high upfront costs, resource uncertainties, and limited institutional support. Nevertheless, its ability to deliver continuous, dispatchable base-load power distinguishes it as a valuable complement to intermittent renewables such as wind and solar.

Global installed geothermal capacity has expanded from roughly 10.7 GWe in 2009 to over 16.9 GWe by 2024, with more than thirty countries actively exploiting hydrothermal resources. Advances in reservoir characterization, high-temperature drilling, and power-plant technologies—including flash and binary cycles—have improved efficiency and broadened applicability. Emerging approaches, such as Enhanced Geothermal Systems (EGS) and supercritical resource development, further extend the potential for geothermal deployment.

In many types of geothermal energy utilization, especially in those with the highest potential such as EGS, the investment costs, thus, the associated risks are high. This causes a hesitant attitude of decision makers in front of new investments. Such large-scale geothermal systems are not amenable for laboratory testing. Thus, mathematical modelling and numerical simulation, although afflicted with many uncertainties emerge as an additional, important signpost that can support decision making. Obviously, mathematical models can also effectively be used in further development of existing systems and units.

In the present talk, first an overview on geothermal energy and its utilization for heat and power will be provided. In the second part, challenges for the mathematical modelling and numerical simulation in certain systems will be addressed and discussed on the basis of selected cases.

NUMERICAL MODELING OF A CONSTANT-FORCE SUSPENSION

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The safe and trouble-free operation of major energy pipelines depends on the proper functioning of all supports. If they do not function correctly, stress can build up at critical points. This can result in pipeline deformation and the occurrence of undesirable reverse slopes. The scope of work includes a review of the literature and technologies for fixed-support hangers, focusing on market solutions. A key stage is the development of numerical models of thermal and strength processes. Using Autodesk Inventor and ANSYS software, a Finite Element Method (FEM) analysis was conducted. This allowed the identification of areas under the highest stresses and deformations, accounting for dynamic loads and thermal expansion. The simulation results serve as the basis for further analyses aimed at optimising the geometry and selecting construction materials.

UPROSZCZONY MODEL POZIOMEGO PŁASZCZOWO-RUROWEGO MAGAZYNU ENERGII TERMICZNEJ Z MATERIAŁEM FAZOWO-ZMIENNYM

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Spośród metod magazynowania energii termicznej w ostatnich latach coraz większa uwaga skupiana jest na magazynach wykorzystujących materiały fazowo-zmienne (ang. Phase Change Materials, PCM), w których magazynowanie energii realizowane jest poprzez topnienie materiału roboczego. Jednak dominująca rola konwekcji naturalnej w procesie wymiany ciepła w ciekłym PCM znacząco utrudnia analizowanie takich magazynów. Aby rozwiązać ten problem zaproponowano uproszczony model poziomego płaszczo-rurowego magazynu energii termicznej z PCM, który uwzględnia wpływ konwekcji naturalnej na proces przemiany fazowej. Model został opracowany na podstawie 75 analiz CFD, przeprowadzonych dla trzech PCM i różnych parametrów eksploatacyjnych magazynu. Walidacja modeli CFD została przeprowadzona na podstawie wyników eksperymentu. Rozbieżności między zaproponowanym modelem uproszczonym, a CFD nie przekraczają 11%, przy czasie obliczeń rzędu 1 s.

LOW HEAD HYDRO-UNIT BASED ON KAPLAN TURBINE WITH PERMANENT MAGNET SYNCHRONOUS GENERATOR WORKING AT VARIABLE SPEED – PERFORMANCE OPTIMIZATION USING NEURAL NETWORK MODELS

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Low-head, run-of-the-river small hydropower plants, due to their low construction costs and high potential for location in Europe, remain an attractive renewable source of electricity. This article presents comprehensive research on a hydropower unit based on the model Kaplan turbine and a low-speed synchronous generator with permanent magnets. The use of a power electronic converter allows for rotational speed regulation, significantly increasing the control capabilities of the Kaplan turbine allowing it to operate with greater efficiency. The article presents a performance analysis of individual components and their impact on the hydropower unit's efficiency characteristics. The identification of mathematical models of hydropower unit components by approximation based on a limited number of measurements, using neural network analysis, is proposed. Results of CFD simulations and laboratory tests of a 4 kW model hydropower unit are presented. The analysis demonstrated a significant influence of the generator and converter efficiency maps on the hydropower unit's performance and optimal operating point.

BADANIA EKSPERYMENTALNE DOTYCZĄCE OKREŚLENIA SPRAWNOŚCI CIEPLNEJ ZMODYFIKOWANEGO MINIATUROWEGO SILNIKA TURBOODRZUTOWEGO

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Wykorzystanie obecnie na dużą skalę bezzałogowych statków powietrznych stanowi wyzwanie dla różnych typów układów napędowych. Z uwagi na niewielki obszar roboczy i wysokie temperatury analiza pracy dla małych modeli silników jest utrudniona. Istnieje więc duża potrzeba badania tych maszyn, w szczególności na polu eksperymentalnym. W pracy została przedstawiona analiza parametrów pracy takich jak temperatura przed i za komorą spalania, masowe natężenie przepływu powietrza i paliwa. Modernizacja silnika umożliwiła pomiar temperatury w różnych miejscach i na różnych głębokościach za komorą spalania. Na ich podstawie został wyznaczony punkt pracy silnika GTM 400 MOD zasilanego naftą JET A-1. Z przeprowadzonej analizy wynika, że dla prędkości 40000 obr/min osiągnięta jest maksymalna sprawność cieplna, równa 78%. Najniższa sprawność, wynosząca 68%, wystąpiła dla prędkości 80000 obr/min. Komora spalania pracuje wydajniej w zakresie małych i średnich prędkości, gdzie sprawność przekracza 72%.

ANALIZA ENERGETYCZNA ZINTEGROWANEGO SYSTEMU HYBRYDOWEGO PRODUKCJI WODORU Z ODPADÓW PLASTIKOWYCH (PET) I BIOMASY

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Celem pracy jest analiza energetyczna zintegrowanego systemu hybrydowego umożliwiającego produkcję wodoru z odpadów plastikowych (PET) i biomasy. System składa się z reaktora elektrochemicznego i reaktora zgazowania biomasy. Reaktor elektrochemiczny zasilają odpady PET, dwutlenek węgla i energia elektryczna z OZE. Reaktor ten produkuje mieszaninę CO i H₂ oraz cenny produkt chemiczny (kwas glikolowy). Wspomniana mieszanina gazowa miesza się z gazem syntezowym otrzymanym ze zgazowania biomasy. Otrzymany po zmieszaniu syngaz poddawany jest konwersji wodno-gazowej (WGS), co zwiększa uzysk wodoru. Następnie za pomocą układu membranowego następuje rozdzielanie H₂ i CO₂. Zoptymalizowano moce reaktorów, tak aby cały zintegrowany system nie emitował CO₂. Zdefiniowano i przedstawiono wartości wskaźników uzysku produktów. Wykonano analizy sprawności energetycznej całego układu zintegrowanego. Wyniki wskazują na wysoki potencjał integracji procesów produkcji wodoru i zagospodarowania odpadów.

BEZKONTAKTOWE POMIARY DRGAŃ OSIOWYCH WIRUJĄCYCH ŁOPATEK

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Praca przedstawia eksperymentalne badanie drgań w maszynach wirujących z wykorzystaniem innowacyjnego stanowiska pomiarowego. System wykorzystuje efekt Dopplera dla promienia laserowego w zakresie podczerwieni, umożliwiając bezkontaktowy pomiar drgań w dowolnie wybranym punkcie z bardzo wysoką dokładnością, co można uważać za technologię referencyjną. Skonstruowano urządzenie bazujące na układzie odchylenia optycznego wiązki lasera, które synchronizuje ruch punktu pomiarowego z badanym, wirującym obiektem. Rozwiązanie to pozwala na precyzyjne obrazowanie ruchu dowolnego punktu wirującej łopaty wirnika, w szczególności zjawiska flutter. System może być użyteczny przy projektowaniu, eksploatacji i diagnostyce maszyn wirnikowych, szczególnie w przypadku trudno uchwytnych problemów wibracyjnych wywołujących różnorodne i zmienne w czasie symptomy. W pracy omówiono konstrukcję układu pomiarowego w aspektach mechanicznym, sprzętowym, elektronicznym i programowym, a także przedstawiono możliwe scenariusze jego wykorzystania. Ponadto omówiono zalety i potencjalne ograniczenia zaproponowanego systemu, uwzględniając jego współpracę z innymi czujnikami poziomu drgań.

IMPACT OF FUEL BURNUP AND ACCIDENT TOLERANT FUEL CONCEPTS ON THERMAL SAFETY MARGINS DURING FLEXIBLE OPERATION OF PWRs

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Increasing penetration of renewable energy sources requires flexible operation of nuclear power plants, while modern pressurized water reactors (PWRs) operate with extended fuel cycles and higher burnup to improve performance. Accident Tolerant Fuel (ATF) concepts further modify fuel rod thermal behavior and safety margins. This work presents a numerical analysis of the combined impact of fuel burnup, load-following operation, and selected ATF properties on thermal safety margins in a representative PWR fuel assembly. A computational model integrating burnup-dependent fuel thermal conductivity with thermal-hydraulic calculations is developed. Fuel centerline temperature, cladding surface temperature, and margin to critical heat flux are evaluated. Conventional UO_2/Zr configurations are compared with ATF variants. Results show that although ATF may improve selected parameters, high burnup combined with frequent power transients can reduce local thermal margins. The approach supports safety-oriented assessment of extended fuel cycles and flexible PWR operation in low-carbon energy systems.

ENERGY AND ECONOMIC ASSESSMENT OF A WATER-SOURCE HEAT PUMP SYSTEM IN A HOLIDAY RESORT IN TURKEY

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The rapidly growing population is driving an increase in energy demand. Although this demand is currently met largely by fossil fuels, more efficient and environmentally friendly alternative energy production technologies, such as heat pumps, are being developed to reduce their negative impact on environmental sustainability. Heat pumps are highly energy-efficient systems that utilize low-temperature energy found in the air, water, and soil in nature to provide heating and cooling. System performance is directly linked to the type of source used and the heat energy. This study examines the application of a water-source heat pump system that utilizes wastewater discharged from the geothermal pools of a thermal resort in Afyonkarahisar, Turkey, as its source. In addition to examining the performance of the water-source heat pump, an economic analysis was also conducted as part of the study. The initial investment costs, operating expenses, and payback periods of the heat pump and other alternative systems were calculated and compared, taking into account the hotel's needs.

ASSESSMENT OF THERMAL FLEXIBILITY POTENTIAL IN A MULTIPURPOSE BUILDING IN NORWAY

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Weather dependency of renewable resources and electricity price volatility are posing challenges for providing sustainable and affordable heating to buildings. Thermal energy flexibility may contribute to utilize renewable resources more effectively. In this study, thermal flexibility available in the space heating system and building thermal mass was assessed for a building located in Asker, Norway. Space heating consisted of floor heating (FH) and air handling units (AHU) for a multipurpose building. By using detail building measurements, a building simulation model in IDA-ICE was calibrated with coefficient of variation of the root mean square error (CV(RMSE)), normalized mean bias error (NMBE), and coefficient of determination (R^2) of $< 30\%$, $< 10\%$, and > 0.9 respectively to further analysis of the flexibility potentials. Flexibility potential was investigated by implementing two measures: sizes of the FH and coordinated control strategies for the FH and AHU. Results showed that the oversized FH could help to decrease the peak load by 0.33 W/m^2 and to move the heat demand of 1.94 Wh/m^2 in a day. Oversized floor heating had an average of 2 K higher system return temperature than the one without oversizing. Coordinated control strategies between FH and AHU were implemented using P and PI controllers, which resulted in a decrease in the peak load for 0.86 W/m^2 and 1.93 W/m^2 , and a move in heat demand of 4.01 Wh/m^2 and 6.13 Wh/m^2 , respectively. This showed that the coordinated control strategy as a cost-effective measure outperformed the oversizing. Further work will focus on the system return temperature decrease to further enhance the energy flexibility and the heat pump performance.

EXPERIMENTAL INVESTIGATION OF CONDENSATION OF R513A IN MINICHANNELS

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In response to increasing demands for energy efficiency and reduced environmental impact of refrigeration systems, significant development has been observed in technologies based on two-phase flows and miniaturized heat exchangers. Phase change processes enable high heat transfer coefficients, while minichannels increase the specific heat transfer area and reduce device size. The selection of a suitable refrigerant is also crucial. R513A, characterized by low global warming potential and properties similar to R134a, is a promising alternative. This paper presents experimental results on the heat transfer coefficient during condensation of R513A in minichannels with diameters of 1.1–3.2 mm. The influence of channel diameter and flow parameters was analyzed, and dominant heat transfer mechanisms were identified. A new correlation for predicting the heat transfer coefficient is proposed for the design of compact heat exchangers.

ON THE INFLUENCE OF CONSTRUCTION AND SUPPLY PARAMETERS ON HEAT OUTPUT OF CONVECTOR SITUATED IN THE FLOOR FOR DISTRICT HEATING APPLICATIONS

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Reducing the supply temperature of heating medium in existing buildings supplied by district heating requires the use of highly efficient heat emitters. This paper presents the results of extensive laboratory research on the optimization of trench (canal-floor) heaters, analyzing the following elements: the type of grille covering the trench heater, the design of the heat exchanger with natural and forced convection, the position of the heat exchanger in the bath, and the type of bath in which the heat exchanger is placed. The research was conducted in a climatic chamber and included a total of 32 design variants of convector heaters. Based on the research, it was observed that the trench heater achieves higher power when placed in a high bath, against an external wall. The grille covering the trench heater has a significant impact on the power achieved. An extended version of this material will provide measurable comparative results and a discussion of the obtained results in the context of the use of these trench heaters in buildings supplied by low-temperature district heating.

THE POSSIBILITY OF IMPLEMENTING SMART HOUSING ESTATES IN POLISH CONDITIONS

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The paper analyzes the possibilities of creating smart housing estates in Poland. The smartness of such estates primarily means the efficient use of energy with respect to environment and engaging the local community in energy and environmental efforts. Such efforts involve utilization of local energy resources, renewables, and efficient methods of energy generation and consumption. In Poland, the most recommended method for implementing such initiatives is to use photovoltaic systems to generate electricity and heat pumps to meet heating needs. Energy savings are achieved when energy generated by residents' own PV system is used on-site. The share of energy generated by the system and consumed on-site in relation to the total energy generated by the system is called the self-consumption index. The higher this index, the more efficient the entire energy system is. Studies were conducted on the feasibility of operating such combined systems in various configurations in hypothetical housing estates. Results shown that relatively simple solutions can increase the index from 20% to 45%, without electricity storage facilities.

THE USE OF ARTIFICIAL INTELLIGENCE FOR PREDICTING TEMPERATURE DISTRIBUTION ON THE FINS OF AN AIR-TO-WATER HEAT EXCHANGER

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The aim of the study was to predict the temperature at 54 nodes located on the fins of a water-to-air heat exchanger. To accomplish this task, machine learning methods were applied, with particular emphasis on artificial neural networks. The study examined two training algorithms, Bayesian Regularization (BR) and Levenberg–Marquardt (LM), as well as two neural network architectures: Cascade Forward and Feed Forward Backpropagation (FFBP). In total, 20 predictive models were developed and analyzed.

The input data included the temperature at the fin base, the air-side heat transfer coefficient, and synthetic data describing the structure of the analyzed system. These data comprised temperature values at individual nodes and information on the connections between them. The primary criterion for evaluating forecast quality was the MAPE index, which was approximately 1%. In addition, Theil's coefficient was calculated and used to assess forecast quality, identify areas of potential prediction errors, and indicate model components and training process elements requiring further optimization.

The conducted analysis made it possible to compare the effectiveness of the applied algorithms and neural network architectures, as well as to evaluate the potential for further improvement in forecast quality. The obtained results confirm that artificial neural networks can be an effective tool for predicting temperature distribution on the surface of heat exchanger fins.

OPORY PRZEPŁYWU W QUASI-IDEALNYM PŁASZCZOWO-RUROWYM WYMIENNIKU CIEPŁA Z PRZEGRODAMI SEGMENTOWYMI

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Wymienniki ciepła płaszczowo-rurowe (STHEX) są najczęściej stosowanymi urządzeniami do przekazywania energii cieplnej w wielu dziedzinach techniki. Wynika to z możliwości stosowania tego typu wymienników w bardzo szerokim zakresie ciśnień i temperatur. Stąd od niemal stu lat prowadzone są prace nad rozwojem metod obliczania zarówno współczynników przenikania ciepła, jak i spadków ciśnienia. Dokładniejsze metody obliczeniowe mają kluczowe znaczenie ze względu na oszczędność energii i materiałów używanych do budowy wymienników ciepła, a także na koszty ich eksploatacji.

We współczesnych STHEX standardowym rozwiązaniem jest stosowanie przegród, których zadaniem jest intensyfikacja wymiany ciepła przez zwiększenie turbulencji przepływu i eliminację stref martwych, a także podparcie rur, np. w celu uniknięcia szkodliwych drgań. Jednak stosowanie przegród wiąże się ze wzrostem oporów przepływu, a w konsekwencji ze wzrostem mocy pompowania. Dlatego konieczne są metody pozwalające na precyzyjne wyznaczanie zarówno współczynników przejmowania ciepła, jak i oporów przepływu.

Współczesne metody obliczania oporów przepływu w STHEX opierają się na modelu Tinkera, który zaproponował podział przepływu po stronie płaszcza na: strumień poprzeczny do pęku rurek, strumień przeciekowy wynikający z luzów pomiędzy otworem w przegrodzie a rurkami, strumień opływający pęk rur w przestrzeni pomiędzy pękiem rurek a płaszczem oraz strumień przeciekowy wynikający z luzów pomiędzy przegrodą a płaszczem.

W idealnym STHEX nie ma przecieków płynu pomiędzy przegrodą a rurkami, przecieków między przegrodą a płaszczem, a pęk rurek wypełnia cały płaszcz. W quasi-idealnym STHEX zakłada się brak przecieków płynu pomiędzy przegrodą a rurkami i przecieków między przegrodą a płaszczem, co zwiększa opory przepływu. Występuje natomiast przestrzeń pomiędzy pękiem rurek a płaszczem, przez którą część płynu omija pęk rurek, co powoduje znaczące obniżenie oporu przepływu.

W pracy przedstawiono wyniki obliczeń spadków ciśnienia po stronie płaszcza dla quasi-idealnego STHEX o średnicy wewnętrznej płaszcza 200 mm i długości czynnej rurek 518 mm. Liczba miedzianych rurek (12/10 mm), w układzie przestawionym, o podziałce 1.5 wynosiła 85. Liczba przegród segmentowych o strzałce wycięcia 25% wynosiła 9, przy odstępnie 48 mm. Średnia temperatura wody gorącej płynącej w płaszczu wynosiła 69°C, a strumień masy zmieniał się w zakresie 1-6 kg/s. W szczególności testowano wpływ średnicy obwiedni pęku rurek oraz taśm uszczelniających na spadek ciśnienia. W obliczeniach zastosowano rozszerzoną metodę Bell-Delaware oraz metodę VDI (Gaddisa-Gnielinskiego). Otrzymane wyniki porównano z obliczeniami wykonanymi w programie Aspen EDR oraz z modelowaniem CFD przeprowadzonym przy użyciu procedury OpenFOAM.

KONDYCJONOWANIE BIOGAZU Z ZASTOSOWANIEM WĘGLA AKTYWNEGO – ANALIZA PIERWIASTKÓW CHEMICZNYCH ODPADU I JEGO REGENERACJA

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Biogaz przed energetycznym wykorzystaniem jest poddawany kondycjonowaniu w celu zapewnienia niezawodności pracy silnika gazowego w zespole kogeneracyjnym i wysokiej sprawności wytwarzania energii. Celem pracy było wykonanie badań dwóch rodzajów zużytego, formowanego węgla aktywnego z instalacji kondycjonowania biogazu z wykorzystaniem skaningowego mikroskopu elektronowego (SEM) wraz z analizą pierwiastków chemicznych (EDS). Wykonane badania węgla z oczyszczania biogazu składowiskowego, wykazały największe procentowe udziały masowe dla siarki (67,7%), wapnia (7,83%), sodu (4,37%) i krzemu (2,13%). Natomiast dla węgla aktywnego z oczyszczania biogazu w oczyszczalni ścieków, procentowe udziały masowe były zróżnicowane i stanowiły, dla siarki (26,41%), wapnia (16,3%), żelaza (6,38%) i krzemu (4,47%). Pozostałe pierwiastki to glin, tlen, sód, węgiel i magnez. Różna zawartość poszczególnych zanieczyszczeń, wynika głównie ze zmiennego składu biogazu oraz rodzaju instalacji kondycjonowania. Wyniki badań potwierdziły wysoką skuteczność adsorpcyjną węgla aktywnego do usuwania zanieczyszczeń z biogazu w tym związków siarki i krzemu oraz możliwość jego termicznej regeneracji w ujęciu gospodarki o obiegu zamkniętym.

COMPARATIVE ANALYSIS OF EMISSIONS AND THERMAL PROPERTIES FROM COMBUSTION OF WOODY AND NON-WOODY BIOMASS PELLETS IN SMALL RESIDENTIAL HEATING UNITS

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Despite extensive research on woody biomass, systematic comparative assessments of woody, agricultural, and waste-derived pellets under identical operating conditions in small-scale automatic burners remain limited. This study provides a systematic and standardised comparison of seven woody and non-woody biomass pellets combusted in a 16 kW automatic residential burner. The investigated feedstocks included pine branches, wheat straw, alfalfa, coffee waste, sunflower husks, brewer's spent grain, and cotton waste. Comprehensive physicochemical characterization was conducted in accordance with relevant EN and ISO standards, including determination of moisture, ash, volatile matter, fixed carbon, and calorific value. Combustion experiments were performed under steady-state conditions with controlled excess air ratio, while flue gas composition (CO, CO₂, NO, NO₂, SO₂, C_xH_y) and particulate matter (PM) were continuously monitored and normalized to 10% O₂. The results demonstrated significant differences in both thermal behavior and emission profiles depending on biomass origin and composition. Woody biomass exhibited the lowest ash content and particulate emissions (<40 mg·m⁻³), ensuring stable combustion and high efficiency. Agricultural residues showed increased ash-related operational challenges and elevated CO and PM emissions, reaching up to 95 mg·m⁻³. Waste-derived biomass, particularly coffee waste and brewer's spent grain, achieved high fixed carbon fractions (>24%) and calorific values approaching 19 MJ kg⁻¹, resulting in combustion efficiencies up to 91.8% and competitive emission indices. A clear inverse correlation between CO and NO_x emissions ($r \approx -0.85$) confirmed the trade-off between oxidation completeness and nitrogen oxide formation. An optimal combustion temperature near 780°C was identified as a compromise minimizing CO while maintaining acceptable NO_x levels. The findings indicate that properly densified non-woody and waste biomass can achieve emission and efficiency parameters comparable to conventional wood pellets, provided that combustion conditions are appropriately optimized. The study contributes to the development of evidence-based strategies for fuel selection and emission control in small-scale biomass heating systems aligned with current environmental regulations.

LIFE CYCLE ASSESSMENT OF E-FUEL PRODUCTION FROM INTEGRATED SOLID OXIDE CO-ELECTROLYSIS AND FISCHER-TROPSCH SYNTHESIS

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The study presents a life cycle assessment (LCA) of e-fuel production based on integrated high-temperature co-electrolysis in solid oxide cells (SOEC) and Fischer–Tropsch (FT) synthesis. The analysis uses a cradle-to-gate system boundary, the ecoinvent 3.8 database, and the Environmental Footprint 3.0 method. The results indicate that the largest share of environmental impacts originates from the SOEC process due to high electricity consumption, the dominant source of GHG emissions. When electricity from non-renewable sources is used, the process provides no environmental benefits compared to fossil fuels, whereas renewable electricity significantly reduces CO₂ emissions and improves overall environmental performance. The choice of CO₂ source significantly influences the results. Using generic liquefied CO₂ datasets can overestimate environmental impacts, as they do not capture variability between CO₂ sources, highlighting the need for source-specific modelling. Overall, e-fuels are environmentally viable when low-carbon electricity and a suitable CO₂ source are used.

THE IMPACT OF CHANGES IN THE LEGAL REGULATIONS ON LOW-EMISSION EMITTERS ON CHANGES IN AIR QUALITY IN THE CENTER OF AN URBAN AGGLOMERATION

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An analysis was conducted of the impact of low-emission emissions from individual heat sources and road transport on air quality within the Cracow University of Technology (CUT), located in the center of this agglomeration. The data obtained from measurements and numerical analyses showed that the greatest impact on air pollutant concentrations is exerted by individual heat sources such as gas boilers, oil boilers, tiled stoves, and kitchen stoves located (accounting for an average of 33% of all sources) in the multi-family housing surrounding the KUT area. Pollutants emitted from the southwestern side of the KUT area (where as many as 47% of all individual sources are fueled by fossil fuels) are particularly significant due to prevailing wind directions, which cause pollutants to drift over the CUT area. Furthermore, the dense urban core contributes to the accumulation of pollutants in low-elevation zones. Despite the implementation of regulations and programs aimed at improving air quality in Cracow, a number of scattered sources of low-emission pollutants, especially around the Cracow agglomeration, remain that significantly impact pollutant concentrations, as the analysis results demonstrate.

NUMERICAL INVESTIGATION OF HEAT TRANSFER IN TRANSFORMER INSULATING LIQUIDS UNDER NATURAL CONVECTION CONDITIONS

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The paper presents a numerical analysis of heat transfer in electro-insulating liquids used in power transformers under natural convection. Mineral oil, synthetic ester, and natural ester were evaluated for cooling performance and suitability in modern power systems. A CFD model was developed in ANSYS Fluent to simulate heat dissipation from a heated surface immersed in the liquid under varying heat loads and orientations relative to gravity. The CFD analysis employed the finite volume method to solve the conservation equations of mass, momentum, and energy. An appropriate turbulence model and realistic boundary conditions were applied, while temperature-dependent thermophysical properties enabled accurate representation of coupled thermal-flow effects. Convergence was verified using residual criteria. Results reveal significant differences in heat dissipation efficiency between mineral oil and ester-based liquids, especially at higher heat fluxes, supporting the design of energy-efficient, reliable transformers and the adoption of biodegradable electro-insulating liquids.

NUMERICAL SIMULATION AND EXPERIMENTAL COMPARISON OF U-SHAPE DOUBLE PIPE HEAT EXCHANGER

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In this work, a computational tool based on a control volume formulation is developed and applied for the prediction of thermal and flow-behavior in a U-shaped double-pipe heat exchanger. The model formulates the equations that govern mass, momentum, and energy, an implicit step-by-step method is used to solve them allowing the prediction of temperature profiles and pressure drops throughout the flow domain. Heat transfer by Fourier law in the internal tube wall is solved. Experimental data from the literature are taken up, where cold and hot water streams are introduced into the heat exchanger in countercurrent and parallel arrangements, until they reach a steady state. The numerical results of this model are compared with the experimental data, obtaining good agreement in the u-shape heat exchanger. The computational tool presented in this work could help design engineers in the manufacture and experimentation of this type of heat exchanger.

CLOSED-LOOP GEOTHERMAL SYSTEMS: PARAMETRIC STUDY INCLUDING INTERMITTENT OPERATION

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Closed-loop geothermal wells are gaining traction as a sustainable option for heating and power generation due to their (i) low environmental impact, (ii) small land footprint, and (iii) high-capacity factors. Their thermal performance is strongly influenced by parameters such as properties of the sub-surface rock structures, temperature gradient, well geometry, insulation, and operational strategies, which include the inlet water mass flow rate and temperature, and intermittent loading conditions that are common in heating applications. This study presents a parametric analysis of the effect of the key control parameters for a closed-loop co-axial geothermal well, i.e. water flowing through an annular pipe and returning via an insulated central pipe. The effect of changes in key parameters, i.e. (i) load duration (6-month cycle), (ii) flow rate (1-10 kg/s), (iii) inlet fluid temperature (5-50°C), (iv) ground thermal conductivity (1-5 W/mK), and (vi) well depth (1-5 km) on both thermal and temperature outputs was assessed. The main aim was to evaluate their impact on heat extraction performance over a 30-year operational period.

INVESTIGATION OF HYBRID RENEWABLE ENERGY-BASED HYDROGEN PRODUCTION AND POWER SUPPLY FOR OFF-GRID SYSTEMS

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In this paper, an elaborated mathematical model is implemented for numerical investigations aimed at predicting electricity and hydrogen production in integrated off-grid energy systems for various specific geographic locations worldwide. New algorithms and optimization procedures were developed and used in dedicated calculation software written in Python. The results of simulation studies on the availability of electricity from renewable energy sources and hydrogen production capacity were further used to simulate possible scenarios of operating the integrated electrical energy production with heat or heat/cold generation for households. The phenomena of heat recovery from the electrolyser as well as fuel cell operation are also discussed.

The paper presents the results of simulation studies obtained using optimized prediction algorithms for various climatically diverse locations: Poland, Bulgaria, Malawi, and Gambia. The numerical investigations conducted for Poland, specifically the Krakow location, were experimentally verified using an installation for household electricity production. The experimental results are in very good agreement with the simulation results for the Krakow location. In the following part of the paper, the application of the developed numerical models to predict household electrical load profiles based on data from predicted electricity production is presented. The numerically determined electrical load profiles are analyzed alongside the experimentally determined profiles. The results of experimental studies on the energy efficiency of such a system are presented. The findings on the predicted lifespan and durability of electrochemical batteries and fuel cells in these systems are also discussed. The benefits regarding environmental impact are also addressed.

ENERGY REFURBISHMENT PLANNING OF SOCIAL HOUSING AT URBAN SCALE: COMPARATIVE ASSESSMENT OF TRNSYS, LADYBUG TOOLS AND A PYTHON-BASED DYNAMIC BEM FRAMEWORK

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The large-scale energy refurbishment of social housing represents a key challenge in the transition toward low-carbon cities, requiring reliable and scalable simulation tools capable of supporting retrofit planning. This study investigates the performance of three modelling approaches for the dynamic simulation of energy retrofit scenarios at urban scale: TRNSYS, Ladybug and Honeybee Tools, and a novel Python-based Building Energy Modelling (BEM) framework. The analysis is conducted on a real social housing complex located in Anguillara Sabazia (Italy), considering baseline conditions and three retrofit scenarios: envelope insulation, HVAC system replacement with centralized heat pumps, and a combined intervention.

Beyond the evaluation of retrofit impacts, the primary objective of the study is to assess the capability of different tools to simulate HVAC system upgrades, highlighting differences in modelling approaches, input requirements, and output reliability. Results show that detailed dynamic tools (TRNSYS and Ladybug Tools) provide consistent trends in energy demand and consumption, although differences arise due to modelling assumptions and system representation.

Deviations between Ladybug Tools and TRNSYS, range from negligible values for lateral buildings (0–1.4%) to more pronounced differences for the central buildings, up to approximately 11.1% in the combined retrofit scenario.

Ladybug Tools demonstrates strong potential as an open-source alternative, offering flexibility, parametric modelling capabilities, and integration with advanced simulation engines, while reducing barriers associated with proprietary software.

The proposed Python-based framework introduces a novel trade-off between accuracy and scalability. By leveraging automated input generation based on limited building information (geometry, construction period, use type, and climate zone), it significantly reduces the input burden compared to traditional tools, while maintaining acceptable accuracy in predicting heating and cooling demands.

The comparative analysis highlights that envelope retrofits primarily affect energy demand, while HVAC system upgrades mainly influence final energy consumption and primary energy, emphasizing the importance of integrated modelling approaches. The study demonstrates that simplified Python-based frameworks can effectively support urban-scale retrofit planning, offering a scalable and computationally efficient alternative to high-resolution simulation tools, while maintaining sufficient reliability for decision-making processes.

FROM CALIBRATED ENERGY MODEL TO DIGITAL TWIN: AN INTEGRATED FRAMEWORK FOR ENERGY ASSESSMENT, RETROFIT OPTIMIZATION AND OPERATION MANAGEMENT OF RESIDENTIAL BUILDINGS

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The increasing availability of monitored data and advanced simulation tools is fostering the transition from static building energy models toward dynamic digital twin frameworks for building performance management. This study presents an integrated approach for the development of a digital twin of a residential building, combining experimental measurements, Building Energy Modeling (BEM), and cloud-based data integration.

A three-story multi-family building located in a Mediterranean climatic zone was selected as a case study. A comprehensive monitoring campaign was conducted to collect indoor air temperature, surface temperature, and relative humidity data. A detailed energy model was developed in EnergyPlus and calibrated against measured data to ensure reliable representation of the building's thermal behavior.

The calibrated model was used to perform an energy diagnosis and to evaluate retrofit scenarios, including the adoption of a heat pump-based HVAC system with fan coils and envelope improvements. The calibrated model outputs were implemented within a digital twin environment using Autodesk Tandem. The platform enables the structured integration of simulated and measured data, supporting a semantic representation of building components, systems, and performance indicators.

Unlike conventional approaches, the proposed framework transforms the calibrated energy model into a dynamic and updatable digital twin, capable of continuously comparing simulated and real operating conditions. This enables advanced functionalities such as real-time monitoring of indoor environmental quality, detection of performance deviations, and support for data-driven decision-making.

Furthermore, the integration within a digital twin platform lays the foundation for future implementation of automated control strategies aimed at maintaining thermal comfort conditions while minimizing energy consumption. The results demonstrate how digital twin technologies can bridge the gap between energy simulation and building operation, enhancing the effectiveness of retrofit strategies and enabling continuous performance optimization.

KONCEPCJA STANOWISKA BADAWCZEGO DO ANALIZY PARAMETRÓW PRACY I WPŁYWU URZĄDZEŃ ZDECENTRALIZOWANEJ WENTYLACJI FASADOWEJ NA KLIMAT WEWNĘTRZNY POMIESZCZEŃ

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Celem artykułu jest przedstawienie koncepcji stanowiska badawczego przeznaczonego do kompleksowej analizy pracy urządzeń decentralizowanej wentylacji fasadowej oraz ich oddziaływania na środowisko wewnętrzne. Na stanowisku planuje się badanie parametrów przepływowych, temperaturowych, ciśnieniowych oraz energetycznych w warunkach pracy cyklicznej nawiew-wywiew. Szczególną uwagę poświęcono możliwości rejestracji szybkich zmian temperatury związanych ze zmianą kierunku przepływu powietrza, co stanowi istotny aspekt pracy tego typu urządzeń. Stanowisko umożliwi prowadzenie badań różnych trybów pracy, konfiguracji czasów cyklu oraz rozwiązań konstrukcyjnych i materiałowych elementów odzysku ciepła. Przewidziano również analizę wpływu pracy urządzeń na parametry powietrza wewnętrznego i warunki klimatyczne w otoczeniu przegrody. Modułarna koncepcja stanowiska pozwala na testowanie różnych wariantów wymienników, w tym rozwiązań z zastosowaniem materiałów zmiennofazowych.

EXPERIMENTAL STUDY AND CONJUGATE CFD OF HEAT TRANSFER IN AN ANNULAR MINICHANNEL

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This work presents an experimental investigation supported by conjugate heat-transfer CFD simulations of refrigerant flow in a 1.2 mm deep annular minichannel. The test section was electrically heated using an internally mounted, axially aligned heater, and the imposed heat flux was determined from the measured electrical power. The bulk fluid temperature and pressure were monitored at the inlet and outlet, together with the mass flow rate, while the heater wall temperature was recorded at selected locations using thermocouples under steady-state conditions. A conjugate heat-transfer model was developed in Simcenter STAR-CCM+ to reproduce the geometry and operating conditions of the experiment. The numerical setup accounted for heat conduction in the solid domain and convective heat transfer in the fluid domain, with refined near-wall resolution in the annular gap. The numerical results were assessed by comparison with experimental data, including the measured outlet fluid temperature and pressure at the channel inlet. In addition, the consistency of the energy balance was checked by comparing the electrical power input with the enthalpy change of the fluid between the inlet and outlet. The study also examined the influence of selected modelling assumptions on the obtained results, providing guidance for more reliable CFD predictions of heat transfer in annular minichannels.

WYSOKO-TURBULENTNE STRUGI SYNTETYCZNE W URZĄDZENIU DO CHŁODZENIA PRZEMYSŁOWYCH OPRAW OŚWIETLENIOWYCH LED

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Technologia oświetleniowa LED jest szeroko wykorzystywana w różnych gałęziach gospodarki, począwszy od oświetlenia domów poprzez oświetlenie dróg, hal przemysłowych aż po motoryzację. Charakteryzuje się ona wysoką sprawnością generacji promieniowania widzialnego oraz długim okresem eksploatacji źródeł światła, co stanowi motywację do stopniowego zastępowania innych rodzajów oświetlenia tą właśnie technologią. Aby oświetlenie LED mogło długo i bezawaryjnie działać, musi współpracować z dobrej jakości źródłem zasilania oraz wydajnym systemem chłodzenia. Branża oświetleniowa LED wykorzystuje diody LED o coraz większej mocy w coraz mniejszych oprawach oświetleniowych, skutkiem czego jest wymóg stosowania wysokowydajnych urządzeń chłodzących. Celem niniejszej pracy jest prezentacja innowacyjnego systemu chłodzenia lampy LED wykorzystującego konwekcję wymuszoną powietrza realizowaną przez wysoko-turbulentne strugi syntetyczne. Zostanie zaprezentowana skuteczność chłodzenia lampy LED o mocy 512 W w warunkach nieizotermicznych.

EXPERIMENTAL INVESTIGATION OF FLOW STRUCTURES AROUND DIFFERENT BUILDING MODELS BY USING PIV

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Urbanization has increased rapidly, and tall buildings with complex architectural forms have become fundamental elements of modern cities. In the design of these structures, environmental effects are as important as aesthetic appearance. Since wind loads directly affect both the structure and its occupants, building aerodynamics has become an important interdisciplinary field that provides the necessary data for designing structures that are both safe and comfortable. In this study, the flow structures around three different building models were experimentally investigated using the Particle Image Velocimetry (PIV) technique: a roofless model rotated by 45° with dimensions of 5 cm × 5 cm × 5 cm, a roofed model with a 30° roof slope and dimensions of 5 cm × 5 cm × 5 cm, and a roofed model with a 30° roof slope and dimensions of 5 cm × 10 cm × 5 cm. As a result of the experimental measurements, instantaneous velocity fields were obtained, and by taking their time average, mean velocity fields $\langle V \rangle$, streamlines $\langle \psi \rangle$, vortex contour maps, and dimensionless vorticity contours $\langle \omega \rangle$ were plotted.

ONLINE ESTIMATION OF THERMAL STRESSES IN CYLINDRICAL OBJECTS WITH HOLES

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The main goal of this study was to develop a fast and computationally effective method for estimating thermal stresses in thick-walled cylindrical objects with holes. In the essence, the method is based on the concept of translating the inverse heat conduction problem into a simple heat flux control task. As a result, the approach assumes the use of a virtual controller driving a direct heat conduction (DHCP) model based on the error between the measured local temperature and the estimated one from the DHCP model. The calculated output is in the form of nodal temperatures and heat flux at the boundary. The obtained temperature field distribution is then employed in the thermal stress computing step. Using an exemplary cylindrical object with temperature dependent material properties and the developed procedure, the authors present the simulation results as time histories of the nodal temperatures and stress levels. Moreover, the accuracy of the developed nodal model was verified against the results obtained with ANSYS Transient Thermal finite-element model.

ANALIZA PRACY GENERATORA TERMoeLEKTRYCZNEGO W ZMIENNYCH WARUNKACH CIEPLNYCH I ELEKTRYCZNYCH

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Badanie miało na celu analizę wydajności generatora TEG zbudowanego z pięciu modułów termoelektrycznych w zależności od temperatury źródła ciepła oraz konfiguracji elektrycznej. Pomiar przeprowadzono na stanowisku ze stalową płytą stanowiącą źródło ciepła i wodnym układem chłodzącym. Testy dynamiczne wykazały, że konfiguracja szeregową generuje najwyższą moc maksymalną, osiągając 9.43 W przy nagraniu źródła do 850°C. Wynik ten był lepszy od 7.19 W uzyskanych dla układu równoległego. Różnica wynika z sumowania napięć w połączeniu szeregowym. Podczas prób dynamicznych zaobserwowano spadek mocy w czasie z powodu szybkiego stygnięcia stalowej płyty. Najważniejszych wniosków dostarczyły pomiary w stanie ustalonym, gdzie przy stałej temperaturze 210°C na generatorze układ szeregowy wygenerował aż 19.29 W. Dowodzi to, że dla maksymalizacji wydajności generatora TEG o wiele ważniejszy od chwilowej wysokiej temperatury jest stabilny i ciągły strumień ciepła dostarczany do niego.

COST-EFFECTIVE TRANSIENT ANALYSIS OF COMPACT PLATE-FIN HEAT EXCHANGERS UNDER VARIABLE AIRFLOW CONDITIONS WITH A STEADY-STATE AIR-SIDE APPROACH

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Compact heat exchangers (PFHE) are widely used components in industrial installations, households, and the automotive industry. Their size and design features—such as flow arrangement, flow resistance affecting heat transfer area, finning, and construction material, are selected based on the maximum thermal load that must be removed from the higher-temperature system. Additionally, installation constraints and the type of working fluids used are important factors. The ϵ -NTU method is commonly applied for their design. An important limitation is that this method is typically used for steady-state operation of the heat exchanger. In practice, however, such devices are often subjected to time-varying operating conditions. Different thermal inertia on both sides of the exchanger affects the heat transfer rate, its effectiveness, and the time required to reach steady operation. This study presents an analysis of the impact of a step change in the velocity of air flowing through an automotive radiator on its performance parameters and thermal inertia. The research is based on CFD flow and heat transfer analysis of a representative segment of a car radiator, as well as transient numerical analysis using a steady-state model on the air side. The novelty of this work lies in a cost-effective methodology for transient heat exchanger calculations, enabling fast and efficient simulations.

ECONOMIC IMPACT OF RETROFIT SOLUTIONS APPLIED TO A TRIGENERATION PLANT CONNECTED TO A DHC NETWORK IN COMPLIANCE WITH THE TRANSPOSITION OF THE EU DIRECTIVES

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This work presents the results of a technical and economical analysis pursued to investigate an upgrading of a Trigeneration District Heating and Cooling (DHC) plant located in the City of Trento (Northen Italy) actually fed with methane. This was necessary to comply with the requirements introduced by the Directive (EU) 2023/1791 which establishes, from 2028 onwards, a minimum share of 5% of heat produced from renewable or waste heat resources to achieve the qualification of Efficient DHC, with progressively stricter thresholds in the following years. A comprehensive analysis of all the components of the plant has been preliminary carried out based on exercise data of the year 2024. Several scenarios, integrating different renewables technologies, are implemented. Among the investigate solutions, the installation of geothermal heat pumps, open or closed circuit, to preheat the DHC return flow before feeding the CHP, has emerged as the most effective. The economic feasibility is strongly dependent from the operating time of the CHP unit. The proposed approach can serve as a procedural framework to be applied to similar plants to comply with the EU directives currently in force.

EXPERIMENTAL INVESTIGATIONS OF THE AIR-ATOMIZED SPRAY COOLING PROCESS WITH THE ADDITION OF SURFACTANTS ON OXIDIZED SURFACES

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The paper presents the results of research on the effect of surfactant additions (polyvinylpyrrolidone (PVP) polymer and ethyl alcohol) to water on heat transfer in the process of atomized spray cooling of oxidized metal surfaces.

The scope of work included experimental studies involving temperature measurement inside sensors made of Inconel 600 alloy and AISI 304 steel, cooled from an initial temperature of 700°C and covered with a layer of scale. Based on the experimental results, numerical calculations were performed to identify the heat flux on the cooled surfaces using the inverse problem for the heat conduction equation. A detailed characterization of the cooled surfaces was performed, including roughness measurement and morphological analysis of the scale layer, contact angle measurement, and thermal conductivity tests of the cooled materials. The conducted analysis provided an evaluation of the effectiveness of cooling fluids used during spray cooling of oxidized surfaces and the parameters influencing the obtained result.

NUMERICAL INVESTIGATION AND MODEL TUNING OF A COMBINED LARGE-SCALE HEAT AND ELECTRICITY STORAGE

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An increasing share of renewable energy in power and heat supply requires large-scale energy storage capacities (>> MWh). The Thermal Pumped Piston Storage (TPPS) is a novel dual-storage concept that combines geotechnical gravitational energy storage for balancing daily-to-weekly power fluctuations with a hot-water system for bridging seasonal heat demand, integrated in a single configuration. TPPS shows high potential at a large scale, yet demonstrators are not available. Therefore, numerical models were developed to investigate storage behavior and evaluate its potential using real Central European grid energy data.

Two complementary models are developed. A computationally efficient 1D model based on the energy transport equation enables multi-year parameter studies and annual grid-level simulations, but provides limited thermo-fluid dynamic resolution. In contrast, an axisymmetric 2D model resolves detailed thermo-fluid interactions within the system. It serves as a surrogate for a full-scale demonstrator and provides a basis for validating and refining the 1D model.

This contribution presents key findings from 2D simulations that guide the systematic tuning of the reduced 1D model. The results demonstrate that natural convection within the water body, radial heat transfer to the surroundings, and heat transfer to the solid piston are non-negligible and must be incorporated into simplified modeling approaches. Furthermore, flow-induced mixing significantly affects thermal stratification, storage state, and exergetic quality. Leading to deviations in predicted storage behavior.

Based on these insights, the 1D model is extended to incorporate simplified free-convection modelling, radial heat transport from the seal gap region into the surrounding soil and the piston, and convective inlet mixing. The refined 1D model enables reliable annual simulations of large-scale TPPS at minimal computational cost, providing a foundation for future grid-integration and energy system studies.

PACKED BED FLOW MODELLING

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Packed Bed Reactors (PBRs) are a critical technology for large-scale Thermal Energy Storage (TES) due to their high heat transfer surface area and structural simplicity. This analysis theoretically evaluates the thermodynamic and fluid-mechanical performance of PBRs when utilized for sensible and latent heat storage. Central to this study is the mathematical modelling of the thermocline—the steep temperature gradient between hot and cold zones—which determines the storage efficiency and usable capacity of the system.

LIFE CYCLE ASSESSMENT OF ELECTRICITY MIX IN POLAND

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Monthly Polish electricity mixes (Nov 2024 to Oct 2025) were modeled per 1 kWh in openLCA using EF v3.1 inventories. Fossil generation dominated (66.6%), led by hard coal (about 52.0%) and natural gas (12.9%), low-carbon sources were 32.9% (wind 15.6%, PV 11.9%). Normalization and weighting revealed air pollution indicators as the primary hotspots, rising from November to April. Contribution analysis identified hard coal and lignite as the key drivers of acidification and particulate matter. Robustness was tested by one-at-a-time sensitivity (+/- 20% for hard coal, Lignite, and PV) and uncertainty propagation using central sensitivity ratios with first-order error propagation. Coal shares-controlled climate change and air pollution results, while higher PV increased the relevance of minerals and metals use and freshwater ecotoxicity. Operative mitigation requires coal phase-down with stronger SO₂ and NO_x controls and cleaner, further circular PV supply chains.

EXPERIMENTAL STUDY ON AIR-STAGING COMBUSTION PROCESS OF H₂/NG FUELS IN DIFFUSION FLAMES

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In light of accelerating climate change and increasingly stringent European Union regulations, reducing CO₂ emissions in the industrial sector has become one of the key challenges facing enterprises. Particular attention should be given to energy-intensive industries that generate substantial amounts of greenhouse gases, including the steel and non-ferrous metals sectors. One promising pathway for emission reduction is the electrification of industrial processes through the use of electricity generated from renewable energy sources or, alternatively, the adoption of low- or zero-carbon fuels such as hydrogen or ammonia. Hydrogen is especially promising from a climate perspective, as its combustion does not produce CO₂. Moreover, it can be produced from surplus renewable electricity via electrolysis, which may also contribute to the stabilization of the national energy system. This study presents research on the co-combustion of hydrogen and natural gas in an industrial diffusion burner. Experimental investigations were carried out for different volumetric shares of hydrogen in the fuel mixture, namely 46% and 59% vol., corresponding to hydrogen contributions of 20% and 30% to the thermal input, respectively. The experimental campaign included measurements of toxic emissions and total heat flux density over a wide range of excess air coefficients, from 1.05 to 1.3. Preliminary results showed that combustion of a fuel mixture containing 59% vol. H₂ and 31% natural gas increased NO emissions from 56 to 77 ppm and from 68 to 90 ppm at 1% and 3% oxygen content in the flue gas, respectively. No significant effect of hydrogen addition on total heat flux density or carbon oxide emissions was observed.

To mitigate the adverse effect of hydrogen on NO formation, the burner was modified to enable staged air supply, with the combustion air divided into primary air (PA) and secondary air (SA). The greatest reduction in NO emissions, reaching 55%, was obtained for a PA/SA ratio of 50/50 at a hydrogen content of 46% vol. and low oxygen concentration in the flue gas. For a hydrogen share of 59% vol., the NO reduction remained substantial at 50%. The results further indicate that increasing the oxygen concentration in the combustion chamber reduces the effectiveness of air staging in limiting NO emissions.

TEMPERATURE MEASUREMENT WITH A NEW THERMOMETER IN A MASSIVE CASING UNDER VARIABLE FLOW CONDITIONS USING THE INVERSE METHOD

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In this paper, an inverse marching method has been used to measure the transient temperature of a fluid using thermometers in a solid casing. The method is based on measuring the temperature in the axis of a cylinder that is part of the thermometer housing, in which a small-diameter hole has been drilled to insert a thermocouple. The method is based on the control volume method. By marching from the control volume at the axis towards the edge of the case, the temperature of its outer surface is determined. Based on the energy balance for the control volume at the edge of the housing and the heat transfer coefficient determined from Nusselt number correlations in the literature, the fluid temperature is determined. The method was verified on a laboratory bench, where thermometers of different diameters were tested. The bench consists of a long, straight duct through which air heated in an electric heater flows. Both the airflow velocity and the heater power can be adjusted. The shape and length of the duct allow for hydraulically developed airflow. The air temperature was determined using the inverse method presented and then compared with the temperature measured at the same time using a thin sheathed thermocouple.

BIOWĘGLE Z ODPADÓW AGRO-PRZEMYSŁOWYCH I ROLNICZYCH PRZEMYWANE KWASEM I AKTYWOWANE CHEMICZNIE DO WYCHWYTYWANIA CO₂

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W pracy oceniono wpływ przemywania kwasem (HCl) oraz aktywacji KOH na właściwości biowęgla otrzymanych z fusów kawowych, łusek cebuli oraz obornika drobiowego w kontekście wychwytywania CO₂. Usuwanie składników mineralnych metodą płukania HCl znacząco poprawiło rozwój struktury porowatej oraz zwiększyło powierzchnię właściwą, szczególnie w biowęglach o wysokiej zawartości popiołu. Najwyższą pojemność adsorpcyjną CO₂ (111,0 cm³/g przy 20°C i 100 kPa) uzyskano dla biowęgla z łusek cebuli po aktywacji KOH. Wyniki potwierdzają, że skuteczność poprawy zdolności sorpcyjnych jest silnie uzależniona od rodzaju surowca oraz jego składu mineralnego. Podkreśla to konieczność stosowania spersonalizowanych strategii modyfikacji zamiast uniwersalnych protokołów aktywacji.

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AMMONIA INHIBITION ON THE METHANOGENESIS OF METHANOBACTERIUM SUBTERRANEUM, METHANOMASSILIICOCCUS LUMINYENSIS, METHANOSARCINA BARKERI, AND METHANOTHRIX PELAGICA

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Ammonia inhibition is a key constraint in anaerobic digestion (AD). Physiological responses of pure methanogenic archaea to total ammonia nitrogen (TAN) were evaluated using specific methanogenic activity (SMA) assays, including acetoclastic (SAMA) and hydrogenotrophic (SHMA) tests. Four pure cultures (*Methanobacterium subterraneum*, *Methanomassiliicoccus luminyensis*, *Methanosarcina barkeri*, and *Methanotrix pelagica*) showed distinct TAN tolerance. *M. barkeri* maintained methane production up to 3 g N/L, whereas *M. pelagica* was strongly inhibited above 2 g N/L. Hydrogenotrophic methanogens were more robust, with *M. subterraneum* sustaining activity up to 5 g N/L, while *M. luminyensis* exhibited moderate sensitivity. This study represents the first experimental application of the SHMA test, providing novel mechanistic insights into ammonia-induced inhibition at the strain level. The integration of SMA assays, qPCR-based abundance analysis, and inhibition modeling revealed distinct tolerance thresholds and inhibition kinetics across methanogenic lineages.

EXPERIMENTAL DETERMINATION OF BOUNDARY CONDITIONS DURING HEATING OF A CRANKSHAFT FRAGMENT USING THE SOLUTION OF THE INVERSE HEAT CONDUCTION PROBLEM

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Crankshaft journals are gas nitrided to improve their mechanical properties. Controlling the layers produced during nitriding is a problem, especially for complex geometries such as crankshafts. An experiment was conducted to heat a fragment of a crankshaft. The temperature was measured at several points inside the element. Unknown boundary conditions on the surface of the journal were determined by solving inverse heat conduction problems.

ANALYSIS OF THE EMISSION PATTERNS AND CHARACTERISTICS OF CRACKED AMMONIA TURBULENT SWIRL FLAMES

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Ammonia has gained recognition as a promising renewable energy carrier, particularly for power generation and achieving net-zero emissions. Previously, its utilisation was constrained to laboratory scales due to the high NO_x emissions and flame instability associated with its use. The Amburn project has demonstrated the possibility of large-scale application. This study undertakes a numerical analysis of Cardiff University's novel burner, focusing on swirl flame characteristics and emissions, and examines the flame structure alongside interactions between chemical processes, flow hydrodynamics and local flame shaping. The ammonia with a 20% cracking ratio was utilised across an equivalence ratio range from 0.7 to 1.1. Numerical simulations were conducted within a 3D domain employing RSM turbulence models, utilising the EDC for species transport followed by the PaSR model with a dynamic mixing. Mechanisms by Stagni et al. and Alnasif and Nagy were applied to assess outlet emissions, flame properties, and compare cracked ammonia with a premixed 70/30 NH₃/H₂ blend. The simulation results demonstrated strong alignment with experimental data, revealing a notable reduction in NO emissions and a shift in the flame stability window. These outcomes are attributable to local flame shaping and the specific properties of cracked ammonia.

ADVANCES IN FLOW BOILING IN SMALL TO MICROSCALE HEAT EXCHANGERS FOR COOLING ELECTRONICS

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Highly efficient and reliable electronic devices are a key factor in further electrification as part of the greater adoption of renewable energy sources and drive to a net-zero carbon economy. The rapid advances in performance and miniaturization of these electronic devices resulted in huge heat fluxes that need to be dissipated effectively, while maintaining low and uniform system temperatures. Traditional air-cooled heat sinks have reached their limits, and the research community has now focused on single-phase and flow boiling in heat sinks, applied directly to the heat dissipating device. These systems can achieve high heat transfer rates, low and uniform substrate temperature (component to be cooled), low power consumption, high thermal performance and use eco-friendly and dielectric refrigerants. Applications include the possible dissipation of high heat fluxes in modern central processing units, graphics processing units, memory cards, data storage devices, insulated gate bipolar transistors, switch-mode power supplies and use in systems such as fast charging vehicle stations and data centres, fuels cells and photovoltaics. Three different geometries were investigated, namely: a simple microgap (single wide channel), rectangular multi-channels and a heat sink having micro-pin fins in a staggered arrangement. Fundamental issues that need to be considered in the drive towards a wider adoption of these heat sinks include the definition of micro scales, the prevailing flow regimes, the effect of system pressure, mass and heat flux, channel aspect ratio and length and surface characteristics on the resulting heat transfer rates, critical heat flux (CHF) and pressure drop. A high-speed, high-resolution camera was used to record the flow regimes. The microgap provided benchmark results with lower maximum heat transfer rates and lower pressure drop. Both the micro-channels and the micro pin-fin heat sinks provided better heat transfer results, with the latter showing superior performance. A large data bank for flow boiling in micro-channels was used to design new well-validated heat transfer and pressure drop correlations suitable for the design of thermal management systems. The CHF in these systems was compared with existing correlations and again design recommendations were made for safe operational limits. The pressure drop and heat transfer results obtained with the micro-pin fin heat sink were compared with correlations and final recommendations, including modifications for the heat transfer correlations, were made for system design.

EXPERIMENTAL INVESTIGATION OF CO₂ CAPTURE FROM FERMENTATION USING POROUS ADSORBENTS

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CO₂ generated during yeast fermentation was captured and quantified in a laboratory-scale experimental setup. The gas stream released during fermentation was directed through a tubing system into graduated funnels, enabling volumetric measurement. Control experiments without adsorbents were conducted in parallel to establish reference production. Experimental runs incorporating weighed adsorbents included activated carbon and three zeolite materials (ZAP-4A, ZAP-5A, and ZAP-MFI). CO₂ capture performance was evaluated based on gas volume reduction, changes in air quality parameters, and adsorbent mass increase. All tested materials demonstrated effective CO₂ capture compared to the controls, with ZAP-MFI exhibiting the highest efficiency. Furthermore, desorption processes are also considered to assess the potential for adsorbent reuse. The results demonstrate effective capture of biogenic CO₂ from fermentation using porous materials and indicate the potential of low-cost adsorption strategies for emission mitigation.

LIFE CYCLE ASSESSMENT OF HYDROCHAR PRODUCTION FROM RAW AND FERMENTED HEMPSEED OIL POMACE VIA HYDROTHERMAL CARBONIZATION

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Hempseed oil pomace (HP), a byproduct of hemp oil production, was investigated as a feedstock for hydrochar production via laboratory-scale hydrothermal carbonization (HTC). Raw HP and HP pretreated by solid-state fermentation (SSF) with *Thermomyces lanuginosus* were processed under the same experimental conditions. A cradle-to-gate life cycle assessment (LCA) was performed using openLCA, the ecoinvent 3.8 database, and the EF 3.0 method. Hydrochar derived from fermented HP exhibited a slightly higher yield and higher heating value than that obtained from raw HP (29.2 vs. 28.7 MJ/kg). While HTC-related impacts were comparable, the inclusion of SSF significantly increased the overall environmental burden, primarily due to electricity-intensive sterilization and incubation steps, with electricity consumption accounting for over 95% of SSF-related impacts. The results emphasize the importance of energy efficiency when integrating biomass fermentation into HTC-based valorization pathways. Additionally, scale-up considerations for hydrochar production are discussed.

ASSESSING INTERFACE-INDUCED STRESS CONCENTRATION AND LOAD-PATH BIAS IN PITCH-BEARING FATIGUE TESTING (DIAMETER>5M): A STRUCTURAL-ANALYSIS APPROACH

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This study aims to elucidate, from a structural analysis perspective, how interface design features such as jigs, fastening configurations, and the load-transfer path from the test rig to a full-scale bearing affect test outcomes and damage patterns. A fatigue test was conducted on an ultra-large bearing testbed to assess the reliability and safety of a 10-MW wind turbine pitch bearing with a diameter exceeding 5 m. The test applied equivalent combined loading (axial, radial, and tilting moment) for a total duration of 520 h 30 min. Based on the test data and structural analysis, the root cause of anomalous behavior and potential damage zones was identified by considering both intrinsic bearing factors and interface-induced stress concentrations. The study establishes a monitoring framework for wind turbine bearings to improve condition monitoring and diagnosis and to support decisions on test suspension. Future work will optimize grease sampling and analysis intervals, define diagnostic thresholds, and develop a fault-diagnosis framework through multi-sensor data fusion of vibration and acoustic signals.

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BADANIE ZINTEGROWANEGO SYSTEMU OGRZEWANIA PŁASZCZYZNOWEGO W PRZEGRODACH PRZEZROCZYSTYCH

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W obliczu dekarbonatyzacji sektora budowlanego, kluczowym zagadnieniem badawczym pozostaje minimalizacja strat ciepła przez przegrody przezroczyste. Niniejsze opracowanie prezentuje wyniki badań okna trzyszybowego wypełnionego argonem z aktywnym układem grzewczym. Badania zostały przeprowadzone w komorze klimatycznej w kontrolowanych warunkach laboratoryjnych. Celem badań było określenie powierzchniowego rozkładu temperatury oraz ocenę wpływu ogrzewania płaszczyznowego na ograniczenie strat ciepła przez przegrodę przezroczystą. Wyniki badań wskazują, że zastosowanie technologii powierzchniowej maty grzewczej na przegrodzie przezroczystej pozwala na zarządzanie mikroklimatem wnętrza, stanowiąc alternatywę lub wsparcie dla tradycyjnych systemów grzewczych, szczególnie w obiektach o wysokim stopniu przeszklenia.

ENHANCING INDOOR THERMAL COMFORT THROUGH AUTONOMOUS PV-POWERED ACTIVE GLAZING SYSTEMS

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Maintaining thermal comfort near expansive glazing is a challenge in Net-Zero Energy Building design. The "cold-pane" effect induces localised discomfort through radiative cooling, despite stable ambient temperatures. This study evaluates an autonomous smart window featuring an active thermal barrier powered by integrated photovoltaics. Climatic chamber simulations at $-25\text{ }^{\circ}\text{C}$ demonstrate that the system elevates the internal surface temperature from $10.7\text{ }^{\circ}\text{C}$ to $17.1\text{ }^{\circ}\text{C}$. This intervention reduces the temperature differential between the glazing and indoor air to below 3 K, effectively eliminating radiant temperature asymmetry. Consequently, predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) indices are substantially improved. Empirical validation confirms that LiFePO_4 energy storage supports operational autonomy between 1.7 and 6.6 hours per diem. The results indicate that transitioning to active heat-exchange components is essential for NZEB infrastructure to prioritise occupant comfort alongside energy efficiency.

CFD INVESTIGATION OF CONDENSATION HEAT TRANSFER OF R32 AND R407C IN MICROCHANNELS

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Zeotropic mixtures, widely employed as refrigerants in refrigeration systems and heat pumps. Due to the temperature slip phenomenon caused by the variable phase change temperature, there are significant challenges in accurately simulating their condensation process. This study presents a computational fluid dynamics (CFD) analysis of the condensation process of refrigerant R32 (difluoromethane) and R407C, a zeotropic mixture composed of R32 (difluoromethane, 23% by mass), R125 (pentafluoroethane, 25% by mass), and R134a (1,1,1,2-tetrafluoroethane, 52% by mass), in microchannel geometries. The objective is to evaluate and compare the heat transfer performance and flow characteristics of both working fluids under varying operating conditions relevant to compact heat exchangers. A multiphase flow model incorporating phase change phenomena is employed, with appropriate turbulence and interfacial models to capture the dynamics of vapor-liquid interactions. The simulations consider the effects of mass flux, vapor quality, and channel hydraulic diameter on local and average heat transfer coefficients as well as pressure drop.

EKSPERYMENTALNE PORÓWNANIE WŁASNOŚCI UŻYTKOWYCH PALIW E10 I E100 W SILNIKU ZI

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We współczesnej motoryzacji jednym z istotnych problemów jest poszukiwanie paliw alternatywnych do tych opartych na produktach rafinacji ropy naftowej. Jednym z dostępnych powszechnie substytutów benzyn jest alkohol etylowy. Historycznie był on wykorzystywany zarówno jako samodzielne paliwo do silników o zapłonie iskrowym, jak też dodatek do benzyn. W porównaniu do stosowanych obecnie w Polsce paliw do silników ZI, alkohol etylowy cechuje się m.in. mniejszą wartością opałową, wyższą liczbą oktanową oraz wyższym ciepłem parowania. Celem niniejszej pracy jest doświadczalne zbadanie wpływu jednego z parametrów regulacyjnych- kąta wyprzedzenia zapłonu- na zużycie paliwa silnika zasilanego paliwem E100, w porównaniu do zasilania benzyną E10 o liczbie oktanowej 95. Otrzymane dane porównano do obliczeń wynikających z właściwości tych paliw, a efekt zamieszczono w postaci wartości względnej możliwej do uzyskania zmniejszonego zużycia paliwa E100.

MATLAB-BASED THERMO-HYDRAULIC ANALYSIS OF TiO₂ AND MgO NANOFLUIDS IN A MICROCHANNEL HEAT EXCHANGER FOR ELECTRONICS COOLING

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This study presents a MATLAB-based numerical methodology for assessing the thermal and hydraulic performance of a microchannel heat exchanger arranged in a parallel configuration, with a channel diameter of 2 mm. The system was supplied with nanofluids based on TiO₂ and MgO nanoparticles at concentrations ranging from 0.5 to 1.5 wt.%. Experimentally determined thermophysical properties of TiO₂:DI nanofluids were implemented into the model, while MgO:DI properties were estimated using classical mixture correlations. With increasing Reynolds number, the convective heat transfer coefficient increased and the base temperature of the heat exchanger decreased by approximately 30÷35% between the lowest and highest operating conditions. The heat transfer coefficient increased from 3200 to 5400 W/(m²K) with an average value of 4184 W/(m²K) for TiO₂:DI at 1.0 wt.%, which corresponds to a 2.5% improvement compared with water. The highest thermo-hydraulic performance improvement reached 8.7% compared with water.

CATALYTIC TORREFACTION OF BEECHWOOD FOR ENHANCED BIOFUEL PROPERTIES: INFLUENCE OF ZEOLITE AND BENTONITE ON SOLID FUEL QUALITY AND GAS COMPOSITION

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This study examines the catalytic torrefaction of beechwood chips utilizing zeolite and bentonite to improve solid fuel properties and alter gas composition. Experiments were conducted under oxygen-limited conditions at 280 to 390°C with catalyst loadings between 1 and 4 percent by mass. Solid products were analyzed for moisture content, ash content, and higher heating value, while permanent gases were quantified using gas chromatography. The results show that catalyst type and loading significantly influence fuel upgrading performance. Zeolite promoted stronger deoxygenation reactions, reflected in increased CO formation and improved higher heating value at optimal loading. Bentonite exhibited a more moderate effect, with stable fuel quality and controlled ash increase. The combined assessment of solid fuel enhancement and gas phase distribution provides a practical basis for selecting low-cost catalysts in torrefaction systems. The findings support catalyst-assisted torrefaction as a controlled pathway to improve biomass-derived biofuels.

TECHNO-ECONOMIC ASSESSMENT OF NOVEL BEAM DOWN CSP- BASED CO₂ POWER CYCLE WITH LIQUID CO₂ ENERGY STORAGE SYSTEM

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While the global push for renewable energy faces grid stability challenges due to its intermittent and volatile nature, liquid carbon dioxide (CO₂) energy storage (LCES) has recently been recognised as a highly promising solution to overcome this hurdle. To advance current LCES technology, this research proposes an LCES system enhanced by integrating a beam-down solar collector. A transient analysis is conducted to study the dynamic thermal behaviour of the system under variable ambient conditions. A detailed 4E (energy, exergy, environmental, and economic) model is developed to assess the techno-economic performance of the integrated system. The key performance indicators, including net power output, round-trip efficiency (RTE), and exergy efficiency, are evaluated. Component-level exergy analysis identifies major irreversibilities within turbines, compressors, and heat exchangers. The economic evaluation includes capital cost estimation, operational cost analysis, and levelized cost of electricity. The results indicate that combining a beam-down solar collector with the LCES system yields RTE, exergy efficiency, and net power output of 72%, 65%, and 13 MW, respectively. The study demonstrates that the proposed system is technically viable and enviro-economically promising for large-scale renewable energy storage applications.

ALL-BACK-CONTACT N-TYPE SILICON SOLAR MODULES: PERFORMANCE, DEGRADATION AND BIPV INTEGRATION ADVANTAGES OVER TOPCON AND HJT

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The n-type All Back Contact (ABC) crystalline silicon solar cells represent a new class of high-efficiency devices that systematically address the key limitations of mainstream PERC, TOPCon and HJT technologies. These cells relocate all metallization to the rear side, leaving the illuminated front surface completely free of busbars and fingers, which maximizes the optically active area and eliminates front-side shading losses. This all-back-contact configuration, combined with advanced surface passivation and n-type monocrystalline silicon substrates, enables cell-level conversion efficiencies above 26% and commercial module efficiencies exceeding 24%, with recent products reaching deliverable module efficiencies of about 25% in mass production. In comparison with state-of-the-art TOPCon modules, All Back Contact devices achieve significantly higher annual energy yield per installed watt, driven by improved low-irradiance and partial-shading response, a superior temperature coefficient on the order of $-0.26\%/^{\circ}\text{C}$, and strongly suppressed light-induced and thermal degradation, typically $\leq 1\%$ in the first year and $\approx 0.35\%$ annually thereafter.

All Back Contact modules outperform both TOPCon and HJT in real-world energy yield degradation primarily due to the combination of n-type base material, fully passivated surfaces, and the absence of front-side metallization. The use of high-quality n-type silicon largely eliminates conventional light-induced degradation mechanisms that are intrinsic to p-type PERC and can still be non-negligible in some TOPCon designs. The all-back-contact layout reduces localized recombination at metal-semiconductor interfaces and lowers the effective series resistance in the current-collection path, which stabilizes operating voltage and fill factor under elevated temperatures and non-uniform illumination. In contrast, TOPCon cells retain front-side fingers that introduce resistive and optical losses and can serve as initiation points for degradation under damp-heat, UV and mechanical stress, while HJT cells rely on complex amorphous/crystalline stacks that, although very efficient, can be more sensitive to process variations, potential-induced degradation and microcracking at the TCO layers. As a result, All Back Contact modules typically show a slower decline of power output over time and maintain a higher fraction of nameplate power in field conditions than comparable TOPCon and HJT products.

The use of n-type silicon and all-back-passivated contacts in these modules enhances carrier lifetime and open-circuit voltage while reducing series resistance, resulting in higher power density and better stability under realistic operating conditions than PERC and TOPCon counterparts. Beyond purely electrical performance, the technology introduces additional advances such as silver-free or silver-reduced rear metallization, improved mechanical crack tolerance due to the absence of rigid front busbars, and optimized interconnection layouts, which together improve module reliability, reduce reliance on critical raw materials, and lower the long-term levelized cost of electricity.

From an architectural and aesthetic perspective, All Back Contact modules offer a nearly homogeneous, busbar-free front surface with a deep-black appearance, which is difficult to achieve with standard TOPCon or HJT designs that expose visible fingers, busbars or differently colored layers. This visual uniformity, combined with the ability to implement full-black frames and back-sheets or glass-glass constructions, makes All Back Contact modules particularly suitable for Building-Integrated Photovoltaics (BIPV). In façades, skylights, canopies and roof systems where visual coherence and color uniformity are critical, the absence of front metallization allows the PV elements to function as an architecturally neutral or intentionally dark design component. At the same time, the high efficiency and favorable degradation behavior of these modules reduce the required active area to meet given energy targets, easing constraints on building envelope design and enabling BIPV solutions that combine stringent aesthetic requirements with high long-term energy yield.

ON ECONOMIC AND ENVIRONMENTAL EFFECTS OF POLAND'S NATIONAL ENERGY AND CLIMATE PLAN

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The energy transition and the shift away from emission-generating technologies (e.g., coal) in favor of non-emission-generating technologies (renewable energy sources or nuclear energy) should be analyzed in terms of economic (impact on production and added value in various sectors), social (impact on employment in various sectors), and environmental (induced GHG emissions) aspects. This paper is the first ever attempt to assess the potential socio-economic and environmental effects of implementing Poland's National Energy and Climate Plan for 2030 and 2040 and its updates. Estimates by the Polish Ministry of Energy indicate that the total cost of implementing the Plan will amount to PLN 2.7-3.5 trillion, or approximately 6% of Poland's total GDP by 2040. The study used a unique technological and economic database developed in cooperation with industry organizations in the energy sector in Poland to parameterize extended input-output models and to assess the potential impact of the implementation of the National Energy and Climate Plan for 2030 and 2040 on sectoral production, added value, employment, and induced greenhouse gas emissions.

THERMAL RESPONSE OF A PCM-PROTECTED GRAIN SILO UNDER OSCILLATORY AMBIENT CONDITIONS

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Grain storage silos in North Africa are exposed to elevated ambient temperatures, which significantly increase the risk of heat accumulation inside the bulk grain. This thermal buildup, amplified by chemical reactions within the stored mass, may lead to deterioration, loss of quality, and in extreme cases, thermal explosion. This work proposes the integration of phase change materials (PCMs) as a passive thermal management strategy for silos. PCMs, through their latent heat storage capacity, can absorb and release large amounts of heat during phase transition, and therefore stabilizing the internal temperature gradient of the grain silo. A coupled energy model is developed, describing the interaction between the heat-generating grain medium and the encapsulated PCM placed along the silo walls. The study focuses on North African storage conditions, with ambient temperatures around 25–40 °C, and evaluates the potential of PCMs to mitigate thermal peaks, delay critical temperature rise, and improve grain preservation. Results are expected to demonstrate that targeted PCM integration can be a sustainable solution to enhance food security and reduce grain losses in hot climates.

PARAMETRIC EFFECTS ON THE NONLINEAR DYNAMICS OF A NUCLEAR- COUPLED HEATING SINGLE PHASE NATURAL CIRCULATION LOOP UNDER HEAVING ACCELERATIONS

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The concept of floating nuclear power plant (FNPP) is one of promising applications of nuclear energy. It is mainly to install small modular reactors (SMRs) on offshore platforms or marines, which can provide the electricity and seawater desalination for remote islands and offshore facilities. This emerging research topic is gradually attracting attentions. However, most SMRs are still in the design stage, their real data is not easily available in public. Thus, the objective of this study is to explore the effects of design parameters on their thermal-hydraulic characteristics of the system. Considering the reference design of NuScale SMR subject to the heaving motions, this study developed the single-phase natural circulation loop dynamic model with heaving accelerations, fuel rod heat transfer dynamic model and point neutron kinetic model, respectively. Based on these dynamic models, this study investigated the parametric effects on the transient responses of a nuclear-coupled heating single-phase natural circulation loop under heaving accelerations. The results illustrated that the operating points in the acceptable operation area of NuScale SMR are very stable. External heaving accelerations will dominate the dynamic behaviors of the system. The greater the peak heaving acceleration, the larger the oscillation of the system. The influence of the heaving frequency is related to the natural frequency of the system. In addition, the effects of heated pipe diameter and inlet flow resistance both stabilize the heaving system, conversely, the heated length, the riser length and operating power all have the destabilizing effects on such a system.

INNOWACYJNE ROZWIĄZANIA TECHNOLOGII ODNAWIALNYCH ŹRÓDEŁ ENERGII W KRAKOWSKIM SYSTEMIE CIEPŁOWNICZYM

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Artykuł przedstawia koncepcję wykorzystania odnawialnych źródeł energii w przedsiębiorstwie ciepłowniczym w Krakowie. System opiera się na kaskadowo pracujących pompach ciepła, gruntowym magazynie energii, dry-coolerze oraz buforach. Zaproponowane rozwiązanie umożliwia jednoczesną produkcję ciepła na potrzeby centralnego ogrzewania, przygotowanie ciepłej wody użytkowej, wytwarzanie chłodu oraz przekazywanie nadwyżek energii do miejskiej sieci ciepłowniczej. Układ cechuje się elastycznością dzięki zastosowaniu algorytmów sterowania zależnych od warunków zewnętrznych tj. temperatura zewnętrzna i bieżące zapotrzebowanie energetyczne. Zakłada się pełne pokrycie potrzeb budynku w zakresie ogrzewania, c.w.u. i chłodu. Wykorzystanie sztucznej inteligencji pozwala na optymalizację i predykcję zużycia energii z różnych źródeł. Rozwiązanie wspiera transformację energetyczną poprzez zwiększenie efektywności, wykorzystanie lokalnych zasobów oraz rozwój magazynowania energii. Rozwiązanie wpisuje się w kierunek transformacji energetycznej miast poprzez zwiększenie efektywności energetycznej, wykorzystania lokalnych zasobów, możliwości magazynowania i stabilizacji energii w systemach ciepłowniczym.

A COMBINED ENERGY STORAGE SYSTEM USING ELECTROLYZERS AND THERMODYNAMIC CYCLES

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Proton exchange membrane (PEM) electrolyzers enable clean, flexible, efficient hydrogen generation, as well as long-duration energy storage. However, their use is less competitive for managing short-term peak loads due to relatively lower round-trip efficiency and higher associated costs. To address these challenges, this paper presents an innovative hybrid thermal–electrochemical energy storage system for hydrogen production and grid balancing. It integrates the PEM electrolyzer with a Carnot battery. The Carnot battery recovers the waste heat from the electrolyzer, upgrades it by a heat pump and store the thermal energy in a high-temperature thermal medium. The stored heat is subsequently converted back into electricity to meet peak demand. The paper focuses on the simulation and analysis of the proposed system. It introduces the design, underlying principles, mathematical modeling, and performance results. The preliminary results show that the Carnot battery can increase the PEM electrolyzer’s efficiency by about 20%.

SMART RENEWABLE ENERGY SYSTEMS IN THE ERA OF CLIMATE NEUTRAL SOCIETIES

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This presentation discusses the concept of Smart Energy in the era of Climate Neutral Societies. The concept of Smart Energy Systems was introduced in 2012 and shortly after received a scientific definition. As opposed to, for instance, the smart grid concept, which puts the sole focus on the electricity sector, smart energy systems include the entire energy system in its approach to identifying suitable pathways to the green transition.

Based on the 3rd edition of "Renewable Energy Systems" a theory of two smart energy systems hypotheses has been formulated. First, that one must take a holistic and cross-sectoral smart energy systems approach in order to be able to identify the best solutions of affordable and reliable transitions of the energy system into a carbon neutral society. Next, that subsector studies (no matter if they consider the role of a specific technology or the role of a region or country) should aim at identifying the role to play in the context of the overall system transition rather than aim at decarbonizing the sub-sector on its own.

The concept and theory have been applied to the analysis of the need for energy storage and electricity balancing in a future climate-neutral society. In five Smart Energy System Integration Levels (SESIL), progressing from a sole electricity sector focus to a fully integrated system of electricity, heating, cooling, industry, transport, and materials, optimal investments in storage and resulting levels of curtailment are identified. It is illustrated how overall least-cost solution is only identified in a fully integrated smart energy system, with affordable types of energy storage and little curtailment that cannot be found in a sole electricity sector approach.

A PHYSICS-INFORMED NEURAL NETWORK APPROACH TO HEAT TRANSFER IN A HEATED MINICHANNEL

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This paper presents the application of Physics-Informed Neural Networks (PINNs) to a two-dimensional heat transfer problem in a rectangular minichannel with fluid flow, heated on one side by a thin plate with a constant volumetric heat generation rate. The proposed framework incorporates the governing equations and boundary conditions directly into the neural network training process. The method is applied to approximate the relevant physical fields within the fluid and solid domains. The results obtained with PINNs are compared with reference solutions computed using an analytical–numerical approach and with CFD simulations performed in OpenFOAM. The study evaluates the accuracy of the PINN solution and investigates the influence of selected network and training parameters on solution quality and computational efficiency.

INVERSE HEAT TRANSFER ANALYSIS OF SUBCOOLED FLOW BOILING IN MINICHANNELS USING TREFFTZ FUNCTIONS AND TIKHONOV REGULARIZATION

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The main objective of this study was to perform heat transfer calculations for flow boiling in minichannels based on experimental data, using Trefftz functions and Tikhonov regularization. In the regularization process, Morozov's discrepancy principle was applied, taking into account the uncertainty of temperature measurements estimated using the Monte Carlo method. The experimental setup consisted of five parallel minichannels with a depth of 1 mm, sharing a common heated wall. Local heat transfer coefficients at the interface between the working fluid and the heated wall were determined using the finite element method with Trefftz-type basis functions. The regularization parameter was determined according to Morozov's discrepancy principle, assuming the noise level to be equal to the estimated uncertainty of temperature measurements. In particular, it was selected so that the norm of the residual was comparable to the noise level in the experimental data, which prevents overfitting to measurement disturbances and ensures consistency with the quality of the available data.

DEVELOPMENT OF A FORECAST-BASED METHOD FOR SHORT-TERM OPTIMAL OPERATION OF GAS TURBINE COMBINED HEAT AND POWER PLANTS

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This paper addresses the problem of short-term planning for heat and power generation in a gas-fired combined heat and power (CHP) plant, aiming to maximize operating profit while meeting heat demand. The plant includes, among other units, two identical LM6000 gas turbines equipped with water-based heat-recovery boilers and a thermal energy storage unit. A method for hourly operation planning of the CHP plant is proposed, based on heat demand forecasts and the operational characteristics of the gas turbines, including electricity and heat production as well as natural gas consumption. The model is formulated using manufacturer-provided correction curves and thermodynamic relations describing heat recovery from flue gases. An adaptive model calibration approach is developed using operational data within a moving time window. The proposed method is applied to plan the plant operation for selected days during and outside the heating season. The accuracy of the model is evaluated by comparing the predicted values with actual operational data, demonstrating the effectiveness of the proposed approach.

INFLUENCE OF MASS FLOW ON THE DISTRIBUTION OF THERMAL STRESSES IN THE WATERWALL TUBES CONNECTED BY FINS

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The poster presents the results of thermal and flow analysis of the working conditions of neighboring waterwall tubes, loaded with heat streams of different values for two different widths of tube's spacing. The numerical model used for the analysis, allowing to calculate the temperature distribution of the tubes and the fluid flowing through them at each time step depending on the thermophysical parameters of the fluid and the material from which the tubes and fins were made. By using the algorithm it is possible to precisely determine the temperature distribution for tubes, allowing to determine the places where the most divergent temperatures occur and in which thermal stresses of the highest value may occur. Analysis for several adjacent tubes will allow for the effect of temperature differences in the tubes to the temperature of the fin which is connecting them and to collect data that may be used for the determination of stress distribution in the tubes and fins. In case presented below were used 3 smooth tubes connected by fins – the heat flux falling on outer tubes was 50% higher than on the bottom one.

ANALIZA POTENCJAŁU WYKORZYSTANIA RZEKI SAN DO PRODUKCJI ENERGII ELEKTRYCZNEJ PRZEZ TURBINĘ WODNĄ MAŁEJ MOCY

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W pracy przedstawiona została analiza parametrów przepływowych w rzece San pod kątem możliwości zastosowania w niej turbin hydrokinetycznych małej mocy. Na podstawie dostępnych danych przeprowadzono szacunki dotyczące prędkości wody możliwej do uzyskania w poszczególnych lokalizacjach, a także mocy elektrycznej możliwej do uzyskania dla wybranych średnic turbin w zależności od zastosowanego typu turbiny niewymagającej spiętrzenia wody. Analiza obejmuje potencjał wykorzystania układów wielu turbin w wybranych lokalizacjach. Uzyskane wyniki pozwalają na określenie produkcji energii elektrycznej przez układy takich turbin. Analiza jest podstawą do oceny zasadności stosowania turbin hydrokinetycznych jako alternatywę dla turbin wymagających budowy zapór i znaczącej ingerencji w otoczenie rzeki.

SCRUTINY OF MAGNETOHYDRODYNAMICS NATURAL CONVECTION IN NANOFLUID ENCLOSURE WITH WAVY BOTTOM WALL

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For long time, natural convection heat transfer represents the corner stone on the solar thermal systems. The present work focusing on the role of wavy enclosure with four different cases of outer surface (circular, rectangular, trapezoidal and triangular) using finite element method. The nanofluid filled the enclosure under horizontal magnetic field. Different values of Ra-Ha had been tested. The inclination angle along with the number of undulations of the enclosure had been considered as well.

MULTI-PATHWAY THERMOCHEMICAL VALORISATION OF BONE WASTE FOR ENERGY, CATALYSTS, AND FUNCTIONAL MATERIALS

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The rapid growth of the poultry and meat-processing industries has led to a significant increase in bone waste streams, creating both environmental challenges and opportunities for sustainable resource recovery. Bone waste is characterised by a complex mineral matrix rich in calcium phosphates, primarily hydroxyapatite, with residual organic fractions, making it particularly attractive for thermochemical valorisation within a circular economy framework. This project investigates integrated thermochemical conversion pathways for bone waste, with a focus on pyrolysis, microwave-assisted pyrolysis, and steam gasification, and finally on the application of bone waste ash as catalyst supports [1,2]. Conventional and microwave-assisted synthesis routes are compared for producing hydroxyapatite-containing catalysts from bone waste, demonstrating that microwave processing requires lower energy and yields shorter processing times, with improved textural and catalytic properties. Advanced studies on the slow and catalytic pyrolysis of chicken bone waste, supported by kinetic modelling and Py-GC-MS analysis, reveal complex decomposition mechanisms driven by interactions between organic matter and the mineral phase [3]. These interactions strongly influence the distribution of products, enhancing the formation of phosphorus- and calcium-enriched biochars with potential applications as catalysts, catalyst supports, and soil amendments [4]. The integration of enzymatic pretreatment prior to pyrolysis further improves the selectivity toward value-added green chemicals, highlighting the importance of upstream processing in thermochemical systems. Steam gasification investigations demonstrate the feasibility of simultaneous energy and material recovery, yielding hydrogen-rich syngas alongside functional biochar, thereby reinforcing the role of bone waste as a versatile resource rather than a disposal problem. Complementary computational fluid dynamics studies provide insight into heat and mass transfer phenomena in biomass reactors, supporting reactor optimisation and scale-up. The thermochemical behaviour of bone waste was studied using multi-atmosphere kinetic analysis based on thermogravimetric data. Isoconversional and model-based approaches reveal a four-stage reaction mechanism with strongly conversion-dependent activation energies, including a high-temperature char gasification stage governed by nucleation-type kinetics and pressure-dependent oxidation under lean air conditions. In conclusion, the presented research establishes bone waste as a multifunctional renewable resource capable of serving as a feedstock, catalyst precursor, and structural support in advanced thermochemical processes. The results contribute to closing nutrient and material loops, reducing reliance on mined phosphates, and advancing sustainable waste-to-energy and waste-to-materials technologies.

INVESTIGATION OF THE PERFORMANCE CHARACTERISTICS OF A MULTI-PISTON EXPANDER IN A MICRO-CAES SYSTEM USING PWM CONTROL

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Compressed Air Energy Storage (CAES) systems represent one of the promising methods of mechanical energy storage. At the micro scale, this technology addresses challenges related to maintaining stability and security of electricity supply in intelligent distributed power grids. However, the main limitation of micro-CAES systems is their relatively low efficiency, resulting from the insufficiently understood dynamics of the air expansion process. This paper presents computational simulations and experimental investigation of a multi-piston air expander using PWM-based control. The approach is based on the theory proposed by Prof. Hutchinson regarding impinging pressure of injected air into piston expander. The proposed control strategy enables active regulation of thermodynamic cycle parameters. The analyses demonstrated the possibility of achieving a cycle efficiency of 60% at an output power of 0.8 kW.

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CHEMICALLY STRENGTHENED GLASS FOR ENVIRONMENTALLY INTEGRATED PHOTOVOLTAIC (EIPV) SYSTEMS: SURFACE STRESS ENGINEERING AND LONG-TERM FUNCTIONAL RELIABILITY

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Environmentally integrated photovoltaic (EIPV) systems require materials that combine high optical transmittance with superior mechanical durability under demanding service conditions. In these systems, glass functions as a critical structural component, ensuring both efficient light transmission and mechanical integrity during prolonged exposure to UV radiation, temperature fluctuations, humidity, and mechanical impacts such as abrasion and particle erosion. These combined stressors necessitate materials with enhanced resistance to long-term surface degradation.

This study identifies chemically strengthened glass as a highly effective material solution for EIPV applications. Such glass is produced via a controlled sodium–potassium ionexchange process in a molten KNO_3 bath at 400–450 °C. During this process, smaller sodium ions are replaced by larger potassium ions, generating a permanent compressive stress layer. The resulting stress profile is characterized by compressive stress (CS \approx 500–800 MPa) and depth of layer (DOL \approx 40–120 μm), both governed by diffusion kinetics and tunable through process parameters.

The primary degradation mechanism is identified as the initiation and propagation of surface microdefects, which may evolve into critical fractures under mechanical or cyclic loading. The presence of a compressive stress layer effectively suppresses crack initiation by reducing tensile stresses at surface flaws, leading to enhanced mechanical strength, increased surface hardness (HV \approx 600–750), and improved resistance to scratching and contact damage.

In addition, the ion-exchange process reduces the concentration of mobile sodium ions in the near-surface region, thereby limiting ion migration under electrical bias and moisture exposure—conditions associated with potential-induced degradation (PID) in photovoltaic modules. Although PID is a complex system-level phenomenon, reducing alkali ion mobility contributes to improved device reliability.

Compared to thermally tempered glass, which may exhibit surface waviness due to thermal gradients, chemically strengthened glass provides superior optical homogeneity and a well-defined, diffusion-controlled stress profile. This enables the use of thinner substrates (0.7–1.5 mm), resulting in a system mass reduction of approximately 40–70% while maintaining or enhancing mechanical performance. These properties position chemically strengthened glass as a key enabling material for durable and lightweight EIPV systems.

THERMAL ENERGY STORAGE MATERIALS: DESIGN OF HIGH ENERGY STORAGE CAPACITY EUTECTIC SYSTEMS

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The integration of thermal energy storage (TES) systems is crucial for managing the intermittent nature of renewable energy sources, with phase change materials (PCMs) serving as a cornerstone technology.¹ A novel approach combining robust TES materials with emerging technologies like Carnot Batteries can achieve near-perfect energy conversion efficiencies, potentially transforming how we store and utilize renewable energy.²

The design of eutectic mixtures presents a powerful strategy for developing high-performance TES materials with tailored properties. Unlike pure compounds, eutectic systems allow for precise control over melting points and enthalpy of fusion through careful selection of components and their molar ratios. Our research demonstrates how systematic eutectic design can overcome the limitations of conventional TES materials while achieving remarkable energy storage densities.²

This work presents a comprehensive investigation of binary eutectic systems formed between boric acid and various organic acids, with particular focus on achieving high enthalpy of fusion for intermediate temperature applications (100-200°C). Through screening of multiple dicarboxylic acids including malonic, succinic, glutaric, adipic, and aromatic acids, we identified key design principles that govern energy storage capacity in eutectic systems.

The boric acid-succinic acid eutectic system emerges as a superior candidate, exhibiting an exceptional energy storage capacity of 380 J/g at 150°C. This performance stems from a unique trimodal storage mechanism combining latent heat of fusion, sensible heat, and a reversible chemical reaction.

ENERGY AND EXERGY ANALYSIS OF A HYBRID SYSTEM DEPENDING ON OPERATING PARAMETERS

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The article presents an energy and exergy analysis of a hybrid photovoltaic–heat pump–energy storage system whose performance depends on environmental conditions. The dynamic development of renewable energy technologies, particularly photovoltaics and heat pumps, highlights their growing importance in the decarbonization of the building sector. Hybrid PV–HP systems enable increased self-consumption of electricity, reduced demand for grid energy, and lower emissions associated with space heating and domestic hot water preparation. The study considers the influence of PV module temperature, solar irradiance, characteristics of the heat pump’s lower heat source, and operating conditions on the system’s energy and exergy performance. The analysis also includes the identification of exergy losses and the assessment of the degree of perfection of energy conversion processes within the system. The results indicate that an appropriate configuration of PV system capacity, heat pump parameters, and optional energy storage can significantly improve overall system efficiency. The application of exergy methods enables a precise evaluation of the quality of processes occurring in hybrid systems. The study provides a basis for optimizing the operation of PV–HP systems under real conditions and for selecting operating parameters that ensure the highest energy and thermodynamic efficiency.

HYDROTHERMAL CARBONIZATION OF ORGANIC WASTE: THE EFFECT OF TEMPERATURE AND RESIDENCE TIME ON THE PROPERTIES OF HYDROCHAR AND PROCESS WATER

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Brewer's spent grain is a by-product generated during beer production. It is considered waste, and one of the ways it can be managed is through the hydrothermal carbonization process (HTC). This process takes place at high temperatures, usually in the range of 160-280°C and under autogenous pressure. The final products obtained in the HTC process are: solid product (hydrochar), process water, and small amounts of gas (mainly CO₂). In this research, the HTC process was carried out at the temperature 190°C and 210°C and residence time 0.5, 1, 1.5, and 2 hours. The obtained hydrochar was then analyzed for its potential use in the heating industry as an alternative to non-renewable fuels - the carbon content and calorific value were examined. In the process water, the contents of phosphorus and nitrogen were analyzed to assess the possibility of using it as a liquid fertilizer in agriculture industry.

PROTOTYP MOBILNEGO MAGAZYNU CIEPŁA WYKORZYSTUJĄCEGO MATERIAŁY ZMIENNOFAZOWE

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W referacie przedstawiono koncepcję prototypu mobilnego magazynu ciepła (MMC). Celem prac było opracowanie technologii umożliwiającej akumulację i transport ciepła odpadowego oraz jego efektywne oddanie do systemów ciepłowniczych lub odbiorników końcowych. Zastosowanie mobilnego magazynu ciepła pozwala na zagospodarowanie nadwyżek energii cieplnej powstających w procesach przemysłowych lub kogeneracyjnych oraz ich wykorzystanie w lokalizacjach oddalonych od źródła wytwarzania. Rozwiązanie to umożliwia ograniczenie strat energii, redukcję pracy źródeł szczytowych oraz zwiększenie elastyczności systemów ciepłowniczych, szczególnie w obszarach o rozproszonej infrastrukturze lub na końcówkach sieci.

Rozwiązanie prototypowe oparto na materiałach zmienno fazowych (PCM), które w procesie przemiany fazowej magazynują znaczną ilość energii cieplnej przy stosunkowo niewielkich różnicach temperatur. Konstrukcja magazynu została zrealizowana jako modułowy zespół jednostek z wymiennikami ciepła woda-PCM oraz układem hydraulicznym umożliwiającym pracę w różnych konfiguracjach eksploatacyjnych. Prototyp wyposażono w system pomiarowo-kontrolny do monitorowania temperatury, przepływu i parametrów procesowych, co pozwala na śledzenie przebiegu ładowania i rozładowania energii cieplnej w czasie rzeczywistym.

THE NECESSITY OF INTEGRATING NOVEL DIMENSIONLESS PARAMETERS WITH ANN FOR IMPROVED CORRELATIONS: AN APPLICATION TO HEAT AND FLUID FLOW IN 3D LATTICE METAL FRAMES

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The theoretical analysis of heat and fluid flow problems originated in the 19th century through the analytical solution of Navier-Stokes and energy equations, which was expanded by 20th-century's empirical correlations based on fundamental dimensionless numbers. However, the rise of complex applications rendered these analytical and correlational approaches insufficient. While computational methods (CFD) emerged to handle intricate geometries, the increasing complexity of modern systems (such as 3D Lattice Metal Frames) leads to prohibitively long simulation run times. This dependency on expensive and case-by-case thermal analyses necessitates a paradigm shift. This work proposes that defining novel and complex dimensionless parameters, and integrating them with advanced machine learning techniques offers the necessary breakthrough.

The study investigates convective heat transfer in a channel containing 3D LMF structures. The Nusselt number and friction factor were computationally calculated for twelve different LMF geometries such as Pin Fin, Kagome, Octahedron, and Octet. An Artificial Neural Network (ANN) model was subsequently developed using MATLAB based on these numerical results. Crucially, the model employs only six dimensionless input parameters, the Reynolds number and five other novel dimensionless parameters to define the complete geometrical features of all structures.

The developed ANN correlation successfully and accurately predicts both the Nusselt number and friction factor for all studied 3D LMF structures. This outcome verifies the primary aim: the successful development of new and complex dimensionless parameters capable of generalizing geometrical complexity. By combining these parameters with the trained ANN model, the Nusselt number and friction factor values can be determined rapidly, providing a powerful, cost-effective ANN correlation that overcomes the time limitations of traditional numerical simulation.

ANALIZA PORÓWNAWCZA WYBRANYCH WŁAŚCIWOŚCI NOWYCH ZŁĄCZY TYPU MC4

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W artykule przedstawiono wyniki analizy porównawczej dostępnych na rynku polskim nowych złączy typu MC4, stosowanych do łączenia kabli prądu stałego w instalacjach fotowoltaicznych. Ponieważ złącza te stanowią jednoz najczęstszych źródeł pożarów instalacji PV, autorzy postanowili poddać losowo zakupione produkty różnych producentów badaniom w zakresie rezystancji oraz temperatury osiągniętej przy obciążeniu ich prądem stałym natężeniu 10, 20 i 30 A. Jako wartości odniesienia przyjęto wyniki pomiarów wykonanych dla oryginalnych złączy MC4 produkcji Stäubli Electrical Connectors. Przeprowadzone badania wykazały istotne różnice pomiędzy złączami poszczególnych producentów – zarówno pod względem rezystancji, jak i temperatury osiągniętej pod obciążeniem. Autorzy wyrażają nadzieję, że wyniki przeprowadzonych badań przyczynią się do zwiększenia świadomości instalatorów systemów fotowoltaicznych w zakresie doboru stosowanych złączy, co w konsekwencji może wpłynąć na ograniczenie liczby pożarów instalacji PV.

EFFECTIVENESS OF UV-BASED AIR PURIFICATION DEVICES IN COMMERCIAL SPACES

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This study investigates the operation of a fan-coil unit equipped with UV-C lamp. The lamp is installed in order to hygienize indoor air. Air quality, safety in continuous operation, reduction of bioaerosol, airflow resistance, UV-C radiation and acoustic performance were tested and analyzed in actual premises, including hotels, offices, and commercial premises. The results showed that the unit is safe, effectively improves air quality through disinfection. The unit does not increase airflow resistance, and does not reduce the supply air flow rate regardless of room type. Acoustic analysis confirms that introducing the UV-C lamp into the fan-coil unit does not significantly increase noise levels. Furthermore, the positioning of the device influences acoustic activity of the system with optimal noise reduction observed at a 0° installation angle and airflow rates below 700 m³/h. Measurement of UV-C radiation in the rooms showed no emission. The study highlights the unit's operational efficiency, and improved indoor environmental quality,

INCORPORATING THE ITNFS EFFICIENCY FUNCTION IN MODELING OF FLAME-GENERATED TURBULENCE AND COUNTER-GRADIENT DIFFUSION IN STAGNATING TURBULENT PREMIXED FLAMES

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An algebraic model closure of turbulent scalar fluxes is proposed to take into account the flame generated disturbances which are produced by velocity gradients induced by the pressure drop across the combustion zone associated with the density decrease of the gases upon passage through the flame front. The ITNFS (Intermittent Turbulent Net Flame Stretch) which was proposed by Meneveau and Poinso using DNS of flame/vortex interaction is incorporated in order to take into account the reduced ability of small vortices to wrinkle the flame front.

A numerical simulation which corresponds to both classes of flames (flames adjacent to the wall and free standing flames) was done in order to validate the model against a turbulent premixed flame impinging onto a wall where experimental investigations of counter gradient scalar transport were performed and associated with the flamelet regime of premixed turbulent combustion.

PHOTOVOLTAIC TECHNOLOGIES AND PERFORMANCE IMPROVEMENT BY USE OF PHASE CHANGE MATERIALS

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Ongoing energy transition is highly focused on the implementation of the renewable energy technologies, where leading role have photovoltaic (PV) technologies. Current market available PV technologies are silicon based and which are oldest PV technology, however the most reliable, as well as economically suitable. The other potential novel PV technologies are still under development, and not yet ready for the market. Due to significant increase in overall global installed PV capacities, there would be an issue with the PV waste in upcoming years, especially when considering that still recycling methods are not at the desirable level when considering overall cost and their environmental suitability. The overall energy conversion efficiency of the market PV technologies is usually less than 20% in real operating conditions since many factors can affect PV system performance. The possible strategy how overall performance, as well as lifetime of the PV panels can be improved, is to implement phase change materials (PCM). The lecture will first cover status of the market available PV technologies followed with discussion of ongoing issues. Finally, the specific PV-PCM passive cooling techniques will be elaborated and their impact on the PV panel performance.

CARBON CAPTURE AND STORAGE AND ITS ROLE IN DECARBONIZATION OF THE ENERGY SYSTEM

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The lecture will start with a brief overview on carbon capture and storage (CCS) technologies and how CCS can be part of an energy system with a large portion of variable renewable energies both with a Norwegian and a European context. Examples of current and past research from our research group will be shown including thermal power plant flexibility and the effect from CCS on the plant's load following capabilities, process modeling and simulation based on both first-principle and data-driven models, and modifications to the power cycle for optimized operation of the CCS system. Future research paths on CCS will be proposed.

CHARACTERIZING OPERATION ENERGY FLEXIBILITY OF A DISTRICT HEATING SYSTEM LEVERAGING THERMAL INERTIA OF WATER VOLUME AND BUILDINGS

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The ongoing surge in renewable penetration is placing significant strain on the operation flexibility of energy systems. District heating systems are characterized by large water volumes in their distribution networks and substantial thermal mass in the connected buildings. Both provide thermal inertia that can be harnessed to deliver operation energy flexibility, offering significant potential to smooth renewable power fluctuations without the need for dedicated thermal energy storage. In this study, the operation energy flexibility of a district heating system that served six commercial buildings in Oslo was characterized. A thermal-hydraulic model was developed in TRNSYS and MATLAB to evaluate the operation flexibility. Key indicators of thermal storage capabilities, i.e., storage amount, release amount, and round-trip efficiency, were quantified (see figure below). The significance of operation parameters regarding settings of room temperature, hot water supply temperature, and hot water supply flow rate was evaluated, as well as interaction effects between the parameters. Outcomes of this study could enhance the understanding of operation flexibility in district heating systems and inform the design of energy-flexible control strategies.

TECHNO-ECONOMIC ANALYSIS OF SEASONAL ENERGY STORAGE USING GREEN METHANOL IN A HYBRID BIOGAS–SOLAR ENERGY SYSTEM

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Seasonal energy storage is one of the major challenges in modern energy systems, as it enables the utilization of surplus energy generated from renewable energy sources. One promising approach is the storage of energy in the form of synthetic fuels, the production of which requires, in addition to hydrogen, a source of carbon dioxide that may be obtained, for example, from carbon capture and utilization technologies or from the biogas upgrading process. This study presents a thermodynamic and economic analysis of seasonal energy storage in a hybrid system comprising a biogas plant and a photovoltaic installation through the production of green methanol. The analysis focused on a methanol production pathway based on hydrogen generation in a solid oxide electrolyzer cell (SOEC) and the use of carbon dioxide recovered from biogas upgrading. The electricity supplied to the methanol production process was provided by a 500 kWe gas engine and a 100 kWp photovoltaic installation. The results of the analysis demonstrated that the investigated system is capable of producing approximately 420 Mg of green methanol annually, corresponding to the storage of about 4200 MWh of energy. The achieved energy storage efficiency was approximately 28% and could be further improved through the optimization of waste heat integration between the biogas plant cogeneration unit and the methanol synthesis process. Such integration may support, among other purposes, the generation of process steam for the SOEC electrolyzer. A further increase in efficiency may also be achieved by expanding the photovoltaic installation. The proposed hybrid configuration enables a reduction in the unit production cost of green methanol by approximately 20-30% compared with systems operating exclusively in either e-methanol or bio-methanol modes. At the same time, the use of biogenic CO₂ and renewable electricity makes it possible to achieve greenhouse gas emission reductions exceeding 80% for the Advanced Biofuel pathway and 70% for the RFNBO pathway relative to fossil fuels, in accordance with the requirements of the RED III Directive.

NUMERYCZNA OCENA NAGRZEWANIA KABLI NISKIEGO NAPIĘCIA W WARUNKACH INSTALACYJNYCH ODBIEGAJĄCYCH OD ZAŁOŻEŃ NORMATYWNYCH

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W praktyce projektowej obciążalność prądowa kabli niskiego napięcia wyznaczana jest najczęściej na podstawie tabel normatywnych oraz współczynników korekcyjnych uwzględniających sposób ułożenia, temperaturę otoczenia oraz grupowanie torów prądowych. Podejście to jest skuteczne w warunkach referencyjnych, jednak w rzeczywistych instalacjach – zwłaszcza w modernizowanych obiektach przemysłowych czy budynkowych – często występują konfiguracje odbiegające od przypadków tabelarycznych (zagęszczenie w trasach kablowych, ułożenie wielowarstwowe, ograniczona wentylacja koryt/kanatów, zróżnicowane przekroje oraz materiały otoczenia). W takich sytuacjach kluczowe staje się określenie rzeczywistego marginesu bezpieczeństwa termicznego, lokalizacji hotspotów oraz wpływu warunków brzegowych wymiany ciepła na dopuszczalne prądy długotrwałe.

W pracy przedstawiono spójne podejście do analizy cieplnej kabli nN z wykorzystaniem metody elementów skończonych w modelu 2D przekroju poprzecznego, obejmujące przypadki odpowiadające układom normatywnym oraz konfiguracje nienormatywne. Do modelowania zostanie wykorzystany program Agros2D, umożliwiający definiowanie domen materiałowych, źródeł objętościowych ciepła oraz warunków brzegowych dla zadań ustalonych i nieustalonych. Straty Joule'a odwzorowano jako źródło objętościowe ciepła w żyłach przewodzących, natomiast wymianę ciepła z otoczeniem modelowano poprzez warunki brzegowe typu Dirichleta (np. dla ośrodków stałotemperaturowych) oraz Robina (konwekcja), z analizą wrażliwości wyników na przyjęty współczynnik przejmowania ciepła. Rozpatrzono środowiska ułożenia charakterystyczne dla instalacji nN, takie jak powietrze i korytka kablowe, grunt oraz beton, a także układy wielowarstwowe i mieszane, w których klasyczne współczynniki grupowania mogą nie być bezpośrednio stosowalne. Oprócz obliczeń stanu ustalonego (kryterium długotrwałej temperatury dopuszczalnej) przeanalizowano wybrane stany nieustalone odpowiadające przeciążeniom oraz zdarzeniom awaryjnym, pozwalające ocenić przebiegi $T_{max}(t)$ oraz ryzyko przekroczeń termicznych w funkcji czasu trwania obciążenia.

Rezultatem pracy jest zestawienie wpływu konfiguracji ułożenia oraz środowiska na temperaturę maksymalną, wraz z propozycją sposobu wyznaczania praktycznych współczynników redukcyjnych na podstawie modeli MES, przy jednoczesnej identyfikacji hotspotów oraz parametrów o największej wrażliwości. Uzyskane wyniki mogą stanowić uzupełnienie narzędzi projektowych w zakresie doboru kabli nN w sytuacjach, w których warunki instalacyjne odbiegają od scenariuszy tabelarycznych, a także wspierać ocenę bezpieczeństwa termicznego instalacji w stanach przeciążeniowych.

WPŁYW WYDAJNOŚCI WENTYLATORA PODMUCHOWEGO NA WARTOŚĆ BEZWYMIAROWEGO PARAMETRU M PRACY KOTŁA MAŁEJ MOCY WYZNACZANEGO METODĄ CKTI

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W pracy przedstawiono stanowisko badawcze wyposażone w kotły, system akwizycji danych oraz system dystrybucji energii cieplnej. Badany kocioł wyposażony jest w palnik retortowy i przeznaczony jest do spalania węgla kamiennego o granulacji 5÷30 mm. W badanym kotle można także spalać pelety z biomasy drzewnej, które mogą służyć, jako paliwo zastępcze. Praca zawiera analizę procesu spalania peletu w kotle małej mocy z uwzględnieniem temperatury spalin na wylocie z komory spalania t_k oraz bezwymiarowego parametru M, wykorzystywanego w metodzie CKTI. Badania przeprowadzono w warunkach zmiennej wydajności wentylatora podmuchowego oraz współczynnika nadmiaru powietrza λ . Przyjęte podejście umożliwiło ocenę wpływu parametrów eksploatacyjnych kotła na przebieg procesu spalania oraz charakter zmian analizowanych wielkości. Szczególną uwagę poświęcono zależnościom między strumieniem doprowadzanego powietrza, ilością paliwa oraz wartościami wybranych parametrów opisujących warunki cieplno-przepływowe w komorze spalania.

TECHNO-ECONOMIC ASSESSMENT OF RENEWABLE POWER-TO- METHANOL PATHWAYS

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Strict regulations on industrial emissions are driving a shift from emission release to their utilisation as secondary raw materials for producing chemicals such as methanol, urea, and plastics. This study develops and analyses five e-methanol pathways modelled using AspenONE process simulation and economic evaluation tools. The models integrate CO₂ from different industrial point sources, including power plants, aluminium smelters, and cement factories, utilising hydrogen produced via proton exchange membrane (PEM) electrolysis. The pathways rely on renewable energy inputs, with e-methanol production powered by solar photovoltaics (PV), grid surpluses, and a biomass-based combined heat and power (CHP) plant. In addition to technical feasibility, economic viability is assessed based on equipment installation costs. The results show that CO₂ source characteristics significantly influence investment costs and overall economic performance. These findings provide a basis for a subsequent holistic sustainability assessment of the environmental and economic impacts of the proposed pathways.

VIOLATIONS OF THE ENTROPY INEQUALITY IN FLUIDS AND GRANULAR MEDIA

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J.C. Maxwell had already recognized that the "*Second Law is a law of high probability... and not of absolute certainty.*" Nevertheless, it is only within the last 35 years that results in physics—theoretical, simulation, and experimental—have been obtained that confirm this long-standing assertion. Fundamentally, there exists a non-zero probability of a negative rate of entropy production in systems comprising a small number of elements (typically at very small length scales) and over (relatively) short time intervals, in such cases, the Second Law must be supplanted by the so-called "Fluctuation Theorem." As the size of the system increases, the observation time lengthens, or statistical averaging is applied, these fluctuations vanish, consequently, the probability of such violations occurring drops to zero, and the conventional picture of the thermodynamics of continuous media is restored. We discuss the implications of these results for the flows of molecular fluids and granular media.

MULTI-OBJECTIVE OPTIMAL SIZING OF DISTRIBUTED THERMAL ENERGY STORAGE IN A DISTRICT HEATING NETWORK

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Distributed thermal energy storage (TES) can improve flexibility and reduce peak demand in district heating (DH) networks. This study examined the optimal sizing of six hot-water storage tanks integrated into selected buildings within a DH system serving 24 substations. While larger storage volumes enhance peak shaving and reduce required main substation capacity, they also increase investment costs and standing heat losses. The problem was formulated as a multi-objective optimization, minimizing network peak load, the total capital cost, and annual thermal losses. A dynamic thermo-hydraulic model was developed in Modelica to simulate time-dependent charging and discharging under realistic operating conditions. The NSGA-II algorithm was applied to identify Pareto-optimal storage configurations. Results revealed that marginal benefits decrease once a specific storage capacity was reached, and a balanced design was found to effectively reduce peaks at a moderate expense with minimal losses. A balanced design refers to a storage configuration that achieves an appropriate trade-off between technical performance and economic feasibility. The balanced solution corresponds to the knee-point region of the Pareto front, where substantial peak shaving can be achieved with moderate additional cost and limited loss penalties. Pareto-optimal solutions suggest that 150–300 m³ of distributed storage (six tanks) can reduce the network peak by 5–15%. Beyond this, the extra peak reduction per added m³ drops quickly, while cost and losses keep rising. The proposed approach provides practical guidance for integrating distributed TES into existing DH networks.

EXPERIMENTAL STUDY ON THE EFFECT OF STATE OF CHARGE (SOC) ON THERMAL RUNAWAY BEHAVIOR IN EV BATTERY MODULE

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This study quantitatively investigates the onset conditions of thermal runaway, the transition time to adjacent cells, and the evolution of temperature distribution in pouch-type lithium-ion cells at different states of charge (SOC). Thermal runaway was induced by contact heating (UL 1642, 5°C/min) in battery modules. Three 200 W-class pouch cells with SOC levels of 30%, 50%, induced 70%, and 100% were considered, with the 70% SOC case tested three times to ensure reproducibility. An infrared camera was used simultaneously to visually analyze the timing of off-gas release, ignition, and the surface temperature distributions as well as heat diffusion. Experimental results showed that no visible flame was observed up to a SOC of 30%. At 100% SOC, the battery exhibited the shortest thermal runaway duration, and the maximum temperature reached approximately 900 °C.

Acknowledgements

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ENHANCED H₂ GENERATION VIA CATALYTIC CO-GASIFICATION OF BIOMASS AND PLASTIC USING NI-LOADED CATALYSTS

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Hydrogen gas (H₂), as an efficient and clean energy source, has gained significant attention due to its zero carbon dioxide emissions during combustion, higher engine efficiencies, and greater heating value compared to fossil fuels. In this context, the present study aims to produce H₂-enriched gas through catalytic steam co-gasification of paper waste (PW) and low-density polyethylene waste (LDPE). Ni-loaded Mo-based perovskite catalysts, with the general formula Ni/CeMoO₃, were prepared and used to improve tar cracking, gas yield, and H₂ selectivity. The use of Ni/CeMoO₃ and Ca(OH)₂ greatly increased the gas yield (80.4 wt%) and H₂ selectivity (49.9 vol%) compared to the non-catalytic case (56.3 wt% and 28.2 vol%, respectively). Additionally, the synergistic effects of different PW/LDPE ratios were assessed. Overall, this study demonstrates a sustainable, practical, and eco-friendly method for H₂ production through catalytic steam co-gasification of PW and LDPE.

PROCES TERMICZNEJ KONWERSJI ODPADÓW POWSTAJĄCYCH W PROCESIE PRODUKCJI PAPIERU DLA ODZYSKU DRUTU STALOWEGO

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Artykuł przedstawia wyniki badań nad odzyskiem stalowych drutów z odpadu po hydropulperze powstającego w zakładach papierniczych. Badany materiał ma postać silnie sprasowanej, zbrylonej mieszaniny frakcji papierowych, plastików oraz sporej ilości, trwale zespolonego drutu stalowego, stanowiącego blisko 60% masy. Wysoki stopień zagęszczenia i sklejenia składników uniemożliwia skuteczną separację przy użyciu separatorów magnetycznych. W celu rozwiązania tego problemu zaproponowano proces pirolizy prowadzący do rozkładu części organicznej i uzyskania kruchego karbonizatu, z którego drut może być łatwo oddzielony mechanicznie. Kluczowym zagadnieniem było określenie możliwie najniższej temperatury zapewniającej skuteczną separację przy jednoczesnym zachowaniu właściwości materiałowych drutu, tak aby mógł on zostać ponownie wykorzystany np. jako wsad hutniczy. Badania prowadzono w temperaturach 500°C i 600°C, bez dodatków oraz z 5% dodatkiem związków renu. Oceniano właściwości karbonizatów oraz wpływ procesu na twardość i mikrostrukturę drutów z wykorzystaniem badań metalograficznych i analiz SEM/EDS. Stwierdzono, że piroliza w 500°C umożliwia skuteczną separację drutu przy zachowaniu jego podstawowych właściwości mechanicznych. Wyższa temperatura, szczególnie z dodatkiem renu, powoduje zmniejszenie twardości odzyskiwanego metalu. Wyniki potwierdzają, że proces prowadzony w 500°C umożliwia odzysk pełnowartościowego surowca metalowego z odpadów przemysłu papierniczego oraz wartościowy karbonizat.

CAVITATION BUBBLE DESTRUCTION CRITERION

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To investigate bubble behavior in cavitation devices, numerical simulations were performed to analyze the dynamics of bubble clusters in a compressible fluid, taking into account interphase heat and mass transfer. The influence of operating and system parameters on the intensity of cavitation processes is examined. Physicochemical transformations occurring during the cavitation treatment of liquids are caused not only by shock waves and emitted pressure pulses but also by extreme thermal effects. At the stage of maximum bubble compression, the vapor inside the bubble and the surrounding liquid enter a supercritical state. The proposed model analyzes the nature of microflows in the interbubble region and quantitatively evaluates the local velocity and pressure field parameters. To assess dynamic effects, a bubble collapse criterion is proposed.

PORÓWNANIE PROCESU SPALANIA WYBRANYCH PALIW ALTERNATYWNYCH Z PALIWAMI WĘGLOWYMI

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W pracy przedstawiono porównanie wyników badań spalania węgla kamiennego i brunatnego z paliwami biomasowymi oraz paliwami typu RDF (Refuse-Derived Fuel). Badania przeprowadzono na wybranych ziarnach poszczególnych paliw, których masa < 1,0 g. Ze względu, iż badania były związane z analizą procesu spalania w warstwie fluidalnej temperatura w komorze spalania wynosiła 850°C dla wszystkich paliw a dla paliw alternatywnych dodatkowo w temperaturach niższych tj.: 750°C i 650°C. Wyniki badań wskazują na istotne różnice w poszczególnych fazach analizowanego procesu badanych paliw, które mogą odgrywać kluczową rolę w procesie ich spalania i współspalania zarówno w paleniskach przemysłowych jak i zawodowych. Poznanie różnic w kinetyce i mechanizmie spalania nowych paliw alternatywnych przy ich wysokiej wartości opałowej może przyczynić się do właściwej homogenizacji odpadów komunalnych a następnie do ich zastosowania w skali przemysłowej. Jak przedstawiono w pracy paliwa RDF mogą być ważnym uzupełnieniem paliw energetycznych przy jednoczesnej ich utylizacji, która w znacznym stopniu przyczyni się do ograniczenia składowania odpadów komunalnych.

OPTIMIZATION OF HYDROGEN SUPPLY NETWORK UNDER VARIABLE RENEWABLE ENERGY SUPPLY

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Hydrogen is widely considered a promising energy carrier for reducing CO₂ emissions in industrial and transport sectors, particularly when produced in an environmentally sustainable manner. However, its large-scale deployment requires the establishment of complex and economically viable infrastructure systems under variable renewable energy supply. This study investigates the optimal design and operation of hydrogen supply systems in Slovenia using a multi-period mixed-integer nonlinear programming (MINLP) model that simultaneously optimizes the process flowsheet and the supply chain network. Hydrogen production is considered both at renewable electricity generation sites and at demand locations, based on proton-exchange membrane (PEM) or alkaline (AEL) electrolysis, powered by wind or solar energy. The superstructure captures multiple hydrogen storage and transport options, including compressed and liquefied hydrogen, pipeline transport, and intermediate compression stages. Using economic objectives, the model determines the cost-optimal process and supply chain configurations to meet demand in transport and energy-intensive industries.

OCENA MIESZANIN HFE-7200/OE ORAZ HT-55/FC-72 DO ZASTOSOWAŃ W MINIKANAŁOWYCH WYMIENNIKACH CIEPŁA

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W pracy przedstawiono ocenę mieszanin HFE-7200/OE oraz HT-55/FC-72 pod kątem ich potencjalnego zastosowania jako mediów roboczych w wymiennikach ciepła. Analizie poddano trzy udziały masowe składników: 25/75, 50/50 oraz 75/25. Zestawiono podstawowe właściwości termofizyczne mieszanin: gęstość, lepkość kinematyczną, ciepło właściwe, współczynnik przewodzenia ciepła oraz pozorną temperaturę początku wrzenia przy ciśnieniu zbliżonym do atmosferycznego. Na podstawie danych wejściowych wyznaczono również parametry pochodne: lepkość dynamiczną, objętościową pojemność cieplną, dyfuzyjność cieplną oraz liczbę Prandtla. Wyniki wskazują, że skład mieszaniny istotnie wpływa na jej charakterystykę materiałową. Układ HFE-7200/OE charakteryzuje się niższą gęstością i niższą lepkością dynamiczną niż HT-55/FC-72, co może być korzystne z punktu widzenia oporów przepływu. Najkorzystniejsze wartości ciepła właściwego i współczynnika przewodzenia ciepła uzyskano dla mieszaniny HFE-7200/OE 25/75. Mieszaniny HT-55/FC-72 wykazują natomiast wysoką objętościową pojemność cieplną, wynikającą głównie z większej gęstości. Przedstawiona analiza ma charakter wstępnego screeningu materiałowego i stanowi podstawę do dalszych badań cieplno-przepływowych, w tym obliczeń numerycznych oraz eksperymentów. Wymienniki ciepła są stosowane w układach wymagających intensywnego odbioru ciepła przy ograniczonych wymiarach urządzenia. W takich warunkach właściwości medium roboczego mają istotny wpływ na efektywność transportu ciepła, opory przepływu oraz stabilność pracy układu. W przypadku mieszanin cieczy chłodniczych ważna jest nie tylko analiza pojedynczych parametrów, lecz także ocena kompromisu między pojemnością cieplną, przewodnością cieplną i lepkością. Zmiana udziału składników może poprawiać jedną właściwość, a jednocześnie pogarszać inną. Dlatego wstępna selekcja materiałowa jest niezbędnym etapem przed badaniami CFD i eksperymentami przepływowymi.

RANDOM-FOREST MODELLING OF LOCAL HEAT TRANSFER COEFFICIENTS DURING FLOW BOILING IN MINICHANNELS: A REPRODUCIBLE PYTHON PIPELINE AND TIME-BLOCKED VALIDATION

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This study presents a reproducible, Python-based pipeline for estimating and modelling local heat transfer coefficients (HTC) in minichannel flow boiling experiments. The workflow was applied to two datasets covering different working fluids and module orientations (horizontal multi-channel and vertical few-channel configurations). Local HTC was computed from Newton's law using a regime-dependent reference temperature. To handle uncertainty near saturation, a temperature-difference deadband was introduced to assign three labels (subcooled/ambiguous/saturated), with ambiguous samples excluded from training and reporting. Random-Forest regression was trained in log-space and evaluated using time-blocked cross-validation to avoid leakage across transient operating ramps. Under this scheme, saturated-regime predictions remained consistently accurate across stable time blocks (R^2 on $\log_{10}(\text{HTC}) \approx 0.97$), whereas subcooled performance was more variable. These findings suggest that regime-specific reporting can improve the robustness of HTC models derived from flow boiling data.

OCENA WPŁYWU DODATKÓW USZLACHETNIAJĄCYCH DO BENZYN SILNIKOWYCH NA EFEKTYWNOŚĆ ENERGETYCZNĄ ORAZ EMISJĘ SPALIN TŁOKOWEGO SILNIKA SPALINOWEGO O ZAPŁONIE ISKROWYM

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W artykule przedstawiono wyniki badań tłokowego silnika spalinowego zasilanego benzyną z różnymi dodatkami uszlachetniającymi jej skład, a mającymi wpłynąć na wartość wielkości i przebieg krzywych opisujących parametry operacyjne pracy silnika oraz emisję spalin, ze szczególnym uwzględnieniem składników toksycznych. Do badań użyto mieszanek konwencjonalnej benzyny z dodatkami na bazie eteru, butanolu oraz etanolu o różnych udziałach objętościowych poszczególnych składników. Dokonano pomiarów badań właściwości energetycznych przygotowanych mieszanek a następnie wykonano pomiary laboratoryjne dla opracowania charakterystyk prędkościowych silnika zasilanego każdą z przygotowanych mieszanek. Badania eksperymentalne wykonano zgodnie z normą PN-ISO 1585 i zrealizowano na hamowni silnikowej wyposażonej w czterosuwowy silnik spalinowy. Na podstawie uzyskanych wyników badań sformułowano wnioski o wpływie poszczególnych składników uszlachetniający na wartość parametrów operacyjnych pracy silnika.

MODELOWANIE I BADANIA EKSPERYMENTALNE PROCESU ROZŁADOWANIA SORPCYJNEGO MAGAZYNU CIEPŁA WYPEŁNIONEGO ZEOLITEM

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W referacie przedstawiono porównanie wyników modelowania numerycznego sorpcyjnego magazynu ciepła z wynikami otrzymanymi z pomiarów laboratoryjnych. Badania eksperymentalne wykonano na zbudowanym stanowisku laboratoryjnym składającego się z magazynu ciepła wypełnionego zeolitem. Nowością było rozdzielanie czynnika roboczego od złoża zeolitu, co wydłuża jego trwałość. Laboratoryjny magazyn ciepła został odwzorowany w modelu numerycznym zaimplementowanym w oprogramowaniu COMSOL. Ze względu na ograniczenia możliwości symulacji wynikające z wielkości laboratoryjnego magazynu ciepła, opracowano jego uproszczony model charakteryzujący się wielokrotnie niższymi wymaganiami w mocy obliczeniowej w porównaniu z pełnym modelem. Porównanie wyników symulacji i eksperymentu pokazuje, że uproszczony model odwzorowuje najważniejsze parametry sorpcyjnego magazynu ciepła takie jak temperatury czynnika roboczego, złoża zeolitu, strumienie ciepła.

ROLA ODNAWIALNYCH ŹRÓDEŁ ENERGII W TRANSFORMACJI ENERGETYCZNEJ KRAKOWSKIEGO SYSTEMU CIEPŁOWNICZEGO

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Artykuł analizuje proces transformacji krakowskiego systemu ciepłowniczego opartego na wdrażaniu rozproszonych źródeł OZE przez MPEC S.A. Przedmiotem badań jest opłacalność dla odbiorcy taryfy OZE na zakup ciepła z pomp ciepła oraz ocena obecnego stanu rozwoju instalacji odnawialnych w strukturach Spółki. Kluczowym elementem pracy jest analiza planowanego zastosowania rozliczeń „wirtualny prosument” we współpracy z operatorem sieci elektroenergetycznej, mająca na celu optymalizację kosztów energii elektrycznej z systemów fotowoltaicznych zasilających pompy ciepła. W artykule przedstawiono strukturę bilansu energetycznego pilotażowej instalacji hybrydowego węzła ciepłego, określając udział ciepła pochodzącego z pomp ciepła oraz z miejskiej sieci ciepłowniczej. Wyniki badań dowodzą, że integracja innowacyjnych technologii hybrydowych z nowoczesnymi formami rozliczeń energii stanowi fundament budowy efektywnego systemu ciepłowniczego.

A PWR NUCLEAR POWER PLANT WITH COUPLED STEAM ACCUMULATOR AND PEBBLE BED THERMAL ENERGY STORAGE

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A flexible operation of nuclear power plants (NPPs) is needed to balance electricity generation against demand, especially in cases with a large share of intermittent solar and wind energy sources. The NPP flexibility can be upgraded by thermal energy storage (TES). In addition, the TES application in the NPP contributes to the plant economy by storing energy in off-peak hours of electricity demand and increasing power during peak hours. The research on TES systems in NPPs was mainly based on the application of molten salts as TES medium. In this paper a novel TES design is presented based on the steam accumulator coupled with the pebble bed filled with solid alumina. An application of such TES is investigated for the NPP with the pressurized water reactor (PWR). The live steam from the steam generator is used for the TES charging, while the TES discharging is used for the feedwater heating, which leads to an increase of live steam generation and greater steam turbine power. The TES based on the steam accumulation leads to a lower investment cost and a more acceptable operation compared to the molten salt TES design.

ASSESSING DECARBONISATION OPTIONS FOR CZECHIA: BIOMASS FROM AGRICULTURAL LAND, LARGE-SCALE CARBON CAPTURE AND STORAGE, AND GREEN HYDROGEN

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The paper assesses decarbonisation options for Czechia using the TIMES-CZ energy system optimisation model in seven scenarios that vary the availability of agricultural biomass, low-emission hydrogen imports and CO₂ export infrastructure. The baseline scenario leaves 30 Mt CO₂eq of residual emissions in 2050, failing to achieve climate neutrality. Allocating up to 10% of agricultural land to energy crops adds 50 PJ, but limited domestic CO₂ storage limits the emission reduction to 27 Mt CO₂eq in 2050. Climate neutrality can be approached only when offshore CO₂ storage is available through a European pipeline network, removing the bottleneck and allowing BECCS and industrial CCS to operate at scale. Low-emission hydrogen is complementary rather than substitutive, primarily serving sectors difficult to electrify. Sensitivity analyses confirm that low carbon prices delay the CCS investment, hydrogen's role is strongly price sensitive, and high storage costs undermine both BECCS and conventional CCS.

SOLUTION COMBUSTION SYNTHESIS AND ELECTROSPINNING OF $\text{La}_{0.7}\text{Sr}_{0.3}\text{Co}_{0.5}\text{Mn}_{0.5}\text{O}_3$: IMPACT OF MORPHOLOGY ON ELECTROCHEMICAL ENERGY STORAGE PERFORMANCE

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This study investigates the influence of solvent and morphology of perovskite on the electrochemical properties of $\text{La}_{0.7}\text{Sr}_{0.3}\text{Co}_{0.5}\text{Mn}_{0.5}\text{O}_3$ (LSCoMn), a promising perovskite material for supercapacitor (SC) electrodes. LSCoMn powders were synthesized via the solution combustion method using dimethylformamide (DMF) and deionized (DI) water as solvents. Additionally, LSCoMn nanofibers (NFs) were fabricated via electrospinning, utilizing polyvinylpyrrolidone (PVP) as a polymer precursor. All samples were calcined at 800 °C for 3 h to achieve the desired perovskite crystalline phase. The effect of solvent on the structure and morphology was analyzed using X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy-dispersive X-ray spectroscopy (EDX) and X-ray absorption near edge spectroscopy (XANES) analysis. Electrodes were prepared by coating the LSCoMn powders and by the direct deposition of NFs on Ni substrate during electrospinning and the impact of morphology on energy storage performance was studied in detail.

XRD analysis confirmed the formation of a perovskite phase. SEM analysis of LSCoMn powders revealed an irregularly shaped morphology, whereas NFs exhibited a highly entangled fiber network, with an average diameter of ~130 nm and lengths extending several microns, obtained under an applied potential of 18 kV, a flow rate of 0.6 mLh⁻¹, and a chamber temperature of 25 °C. TEM analysis confirmed the similar morphology and high resolution (HR)-TEM validated the XRD analysis results. Electrochemical performance was assessed using cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), and galvanostatic charge-discharge (GCD) in 1 M KOH electrolyte. The LSCoMn (NFs) electrode exhibited a maximum specific capacitance (C_{sp}) of 542 Fg⁻¹ at 1 Ag⁻¹, with an energy density of 27.07 Whkg⁻¹ and a power density of 0.30 kWkg⁻¹, significantly outperforming LSCoMn powders (412 Fg⁻¹ for LSCoMn synthesized in DI water). Furthermore, the NF-based electrode demonstrated excellent cyclic stability, retaining 91.6% of its initial capacitance after 5000 charge-discharge cycles. EIS measurements confirmed a low charge transfer resistance, indicative of efficient charge storage kinetics. LSCoMn (NFs) sample, when tested as an anode in asymmetric supercapacitor device, possessed energy density of 63.20 Whkg⁻¹ and power density of 2.40 kWkg⁻¹ at current density of 3 Ag⁻¹.

These findings establish LSCoMn (NFs) as a high-performance electrode material, exhibiting superior charge storage capability, high energy and power density, and excellent long-term stability, making it a promising candidate for next-generation SC applications.

METODA TOPSIS W ANALIZIE HYBRYDOWYCH INSTALACJI OZE – STUDIUM PRZYPADKU WSPÓŁPRACY OZE Z INSTALACJĄ ZGAZOWANIA

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W 2023 roku wprowadzono nową definicję hybrydowej instalacji OZE. Taka instalacja musi spełniać warunki dotyczące wartości czasu wykorzystania mocy przyłączeniowej oraz udziału magazynu energii. Studium przypadku obejmuje instalację składającą się z paneli fotowoltaicznych, turbin wiatrowych, magazynu energii oraz uzupełnianą przez układ zgazowania frakcji energetycznych odpadów komunalnych z agregatem silnikowym. W referacie przedstawiono metodę wielokryterialnego doboru parametrów znamionowych instalacji hybrydowej przy wykorzystaniu matematycznego modelowania oraz metody TOPSIS. Metoda pozwala na utworzenie rankingów preferencji analizowanych rozwiązań. W pracy zdefiniowano sześć kryteriów decyzyjnych, pozwalających na holistyczną ocenę instalacji w zakresach: technicznym, ekonomicznym i środowiskowym. Zaprezentowano wpływ wag kryteriów na rankingi preferencji oraz przedstawiono szczegółowe wyniki w wybranych wariantach rozkładu wartości wag kryteriów.

SCENARIOS FOR THE TRANSFORMATION OF THE HEATING SECTOR TAKING INTO ACCOUNT THE TEMPORAL AND SPATIAL DISTRIBUTION OF HEAT DEMAND - NET-ZERO POLAND PROJECT

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The transformation of the heating sector toward zero emissions is one of the most challenging tasks facing the Polish energy system. The future integration of this sector with renewable energy sources (RES), characterized by high variability in electricity production, also requires detailed forecasts of heat demand for individual regions with hourly resolution.

This study proposes an algorithm that enables the generation of detailed heat demand profiles, taking into account variable meteorological data for different scenarios of the heating sector's transformation. These scenarios include significant electrification of the heating sector associated with the deployment of heat pumps, as well as the direct production of heat from electricity. This applies both to individual households and to district heating systems.

The obtained results made it possible to determine forecasts of the growing electricity demand of the heating sector. The research was conducted as part of the Net-Zero Poland project, whose primary objective is to develop scenarios for the development of the Polish energy system and economy toward zero emissions by 2050.

RELIABILITY ASSESSMENT OF ENERGY SYSTEMS UNDER NET-ZERO POLICY CONSTRAINTS

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The climate policy of the European Union forces its member states to transition their economies in accordance with the net-zero policy. This task is especially challenging in the energy sector, which is responsible for the majority of emissions as new power systems will be based primarily on renewable sources. These sources, although clean, are weather-dependent and, therefore, lower the reliability of the power system. The investigations presented herein aim to develop a stochastic model to assess the reliability of the system, that complies with the net-zero policy. The failure rates of power units are estimated using Fault Tree Analysis in the case of the renewable sources, or provided by the grid operator in the case of conventional units. Load and generation are treated as stochastic processes. The model also includes energy storage units and demand-side response (DSR). Reliability is assessed by Loss of Load Probability (LOLP) and Loss of Load Expectation (LOLE). The model supports long-term decision-making when energy forecasts are uncertain.

PROGNOZOWANIE CEN MOCY BILANSUJĄCYCH Z WYKORZYSTANIEM METOD UCZENIA MASZYNOWEGO

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Wraz z wprowadzeniem II etapu reformy Rynku Bilansującego (RB) prowadzonego przez Polskie Sieci Elektroenergetyczne (PSE), nastąpiła zmiana sposobu wyceny rezerw mocy bilansujących. Zgodnie z nowymi zasadami, PSE nabywa energię i moc bilansującą. Moc jest nabywana dla każdej godziny doby oddzielnie dla pasma w górę i w dół: rezerwy utrzymania częstotliwości (FCR), rezerwy odbudowy częstotliwości z aktywacją automatyczną (aFRR) i nieautomatyczną (mFRR) i rezerwy zastępczej (RR). Taka zmiana stworzyła dodatkowe możliwości przychodowe dla wielu elektrowni, w tym także wiatrowych i fotowoltaicznych oraz magazynów energii. Aby skorzystać z dodatkowych benefitów konieczne jest złożenie oferty w oparciu o warunki techniczne i prognozowaną cenę. W artykule zaprezentowane zostały wyniki badania z wykorzystaniem metod uczenia maszynowego dla modeli prognostycznych cen poszczególnych mocy bilansujących. Najlepsze wyniki osiągnięto dla rezerwy FCRd osiągając współczynnik dopasowania $R^2=0,95$ i średni błąd bezwzględny $MAE=11,85$.

LEVERAGING UNDERGROUND AND BROWNFIELD INFRASTRUCTURE FOR NEXT-GENERATION ENERGY SYSTEMS

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Rising demand for critical minerals and deeper, lower-grade ore bodies is driving increases in mine-site energy needs. Nuclear power offers firm, carbon-free energy that can reduce diesel dependence, stabilize remote operations, and support electrified material-handling systems. Historical underground nuclear plants demonstrated enhanced seismic resilience, security, and containment performance due to surrounding rock mass. Abandoned limestone mines provide favorable geomechanics, established access tunnels, and room-and-pillar geometries that can accommodate reactors and support systems with reduced excavation cost. Surface mine brownfields offer existing industrial footprints, grid connections, and improved public acceptance relative to greenfield sites. Co-locating reactors with energy-intensive facilities—such as AI-driven data centers—further strengthens the economic case and grid resilience. Collectively, these pathways support a “Mines to Megawatts” strategy that repurposes mining infrastructure into secure, long-lived clean-energy assets.

POWERPLEX: AN INTEGRATED NUCLEAR ENERGY AND ADVANCED MANUFACTURING ECOSYSTEM FOR NEXT-GENERATION POWER SYSTEMS

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The PowerPlex initiative at Missouri University of Science and Technology integrates nuclear energy research, advanced manufacturing, and applied energy systems into a unified development platform. Centered on the MINER research reactor, PowerPlex couples university-scale experimentation with commercial-scale validation to accelerate next-generation reactor technologies and hybrid energy systems. This framework enables detailed performance studies, advanced materials evaluation, and flexible grid-integrated operation within a single research ecosystem. PowerPlex's colocated manufacturing and prototyping facilities expand its capabilities beyond reactor science, supporting multiphysics modeling, diagnostics, and technology translation for industrial applications. The project also strengthens the regional workforce pipeline by linking reactor operations training with hands-on energy system deployment. Through this integrated approach, PowerPlex serves as a national platform for clean-energy innovation, enhancing energy resilience and advancing the performance and applicability of modern power systems.

PRZEGLĄD MODELI SYMULACYJNYCH SYSTEMÓW OZE Z WYKORZYSTANIEM WODORU JAKO NOŚNIKA ENERGII

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W artykule przedstawiono analizę wybranych narzędzi do modelowania systemów energetycznych z uwzględnieniem wodoru jako nośnika energii. Temat ten wpisuje się w aktualne kierunki transformacji energetycznej, wynikające z regulacji międzynarodowych, unijnych oraz krajowych, które zakładają stopniowe odchodzenie od paliw kopalnych na rzecz odnawialnych źródeł energii.

Szczególną uwagę zwrócono na znaczenie modelowania w planowaniu lokalnych systemów energetycznych, w tym w strategiach samorządowych, działaniach sektora prywatnego, funkcjonowaniu małych przedsiębiorstw oraz projektach miejskiej transformacji energetycznej. Omówiono również rolę zintegrowanych rozwiązań, takich jak systemy PV, PV-T, pompy ciepła, sezonowe magazynowanie ciepła oraz technologie wodorowe. Uwzględnienie zielonego wodoru w narzędziach modelowania może wspierać ocenę różnych scenariuszy produkcji, magazynowania i wykorzystania energii w systemach opartych na OZE.

QUANTIFYING THE IMPACT OF TEMPORAL FEATURES ON WIND ENERGY CLASSIFICATION USING MACHINE LEARNING

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This paper presents a machine learning-based classification framework for wind energy output using a two-year dataset from the Sotavento Galicia wind farm in Spain. The study evaluates the impact of temporal dependencies by comparing models trained with and without lagged energy features. Five supervised algorithms: Decision Tree, Random Forest, Support Vector Machine, k-Nearest Neighbors, and Naive Bayes are assessed using accuracy, Cohen's kappa, and multiclass AUC. Without temporal features, the best model (Random Forest) achieves 77.24% accuracy and an AUC of 0.915. With lagged and rolling features, performance improves significantly across all models, with Random Forest reaching 98.08% accuracy, kappa of 0.9712, and AUC of 0.9991. These results demonstrate that short-term temporal dependencies are the dominant factor in wind energy classification. The findings highlight the importance of incorporating historical system behavior in predictive models for short-term operational decision-making.

NET-ZERO POLAND - HIGH-RESOLUTION ENERGY SYSTEM MODELING AND STAKEHOLDER-DRIVEN PATHWAYS TO CLIMATE NEUTRALITY

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The Net-Zero Poland (NZP) project is a comprehensive research initiative aimed at identifying cost-effective and socially robust pathways for Poland to achieve net-zero greenhouse gas emissions by 2050. Building on advanced energy system modeling frameworks and international best practices, the project develops high-resolution, sector-coupled scenarios covering all sectors of economy. The study leverages state-of-the-art tools inspired by global decarbonization analyses, combining demand-side modeling with system-wide optimization to identify least-cost transition pathways under net-zero constraints. The results provide insights into infrastructure needs, technology deployment, and investment priorities, while also addressing socio-economic implications such as industrial competitiveness and regional transition challenges. By bridging advanced analytics with inclusive dialogue, NZP contributes to the development of a transparent, actionable, and widely supported roadmap for Poland's transition to a climate-neutral economy.

THERMAL CONDUCTIVITY MEASUREMENTS OF FLAT INSULATING MATERIALS BY GUARDED HOT PLATE APPARATUS

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Energy is widely recognized as one of the most important needs and foundations of the modern world, driving the economy, technology, and everyday life. Both when producing and consuming it, we should be guided by sustainable development policy, the aim of which is, among other things, to save energy. Proper thermal insulation is key to energy savings, reducing heating and cooling costs by 30-50% annually. Using modern insulating materials eliminates thermal bridges, improves thermal comfort, and significantly reduces emissions. Investing in insulation offers a quick return on investment. Therefore, it provides financial and ecological benefits.

This paper provides a brief analysis of thermal conductivity measurements using the shielded hot plate method. The paper presents test results for a sample using the shielded hot plate method. A GHP 900 S plate apparatus with a shielded heating plate was used according to PN-ISO 8302:1999.

The article deals with issues related to the measurement of thermal conductivity coefficient of flat insulating materials by guarded hot plate apparatus in the temperature range -5 to 60°C.

SELECTIVE CHEMICAL DEPOLYMERIZATION OF POLYESTER IN POLYCOTTON BLENDS VIA ALKALINE SOLVOLYSIS

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Alkaline solvolysis was investigated as a chemical recycling route for polycotton textile waste (50% polyester/50% cotton) based on a design of experiments (DoE) methodology. More than 30 experimental runs were conducted to evaluate the effectiveness of the process in a glycol-based reaction medium, with a mixture of propylene glycol and ethylene glycol selected for detailed investigation. ANOVA, based on experimental data, allowed the determination of optimal process conditions conducive to maximizing polyester depolymerization from the textile blends. Under optimized conditions, selective depolymerization of the polyester component was achieved, resulting in solvolysis yields exceeding 50%, even at high fiber to-liquid (20 wt.%) and a short reaction time of 10 min., combined with an elevated temperature of 180 °C and a low alkaline catalyst dosage (0.5 wt.% KOH). The chemical transformations of the dissolved polyester fraction were confirmed using Fourier transform infrared spectroscopy (FTIR). Due to the widespread use of polycotton in textile waste streams and the complexity of processing blended textile materials, the results obtained contribute to research into solvolysis as a promising method for the selective depolymerization of polymers for subsequent recovery of chemical compounds.

REINFORCEMENT LEARNING OPTIMIZE CONTROL OF A CO₂ HEAT PUMP SYSTEM: CASE STUDY IN OSLO

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Model-based price-aware control typically requires an explicit plant model and calibration, simplified models may deviate from real dynamics, increasing implementation effort and reducing robustness. In this study, a TD3-based reinforcement learning controller was developed for continuous heat pump power modulation, leveraging short-horizon future electricity price features to shift electricity use to low-price periods while meeting temperature requirements. Validation was performed on a CO₂ ground-source heat pump with a water storage tank in a school building in Oslo, Norway. Training uses 24-hour episodes with an hourly control interval, followed by offline evaluation in the coldest month, January. Tank-temperature safety was enforced via hard constraints of 20–90°C, comfort was represented by a 60°C target with a 12 K band. Performance was benchmarked against PI control using monthly cost, energy, tracking error, and constraint satisfaction. Results showed stable convergence and ~10% lower total monthly electricity cost than PI while satisfying the required tank temperature range.

DYNAMICS HEAT- MASS TRANSFER IN HEAT PIPE CONDENSATION ZONE

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A mathematical model and a numerical method for calculating heat transfer dynamics in the condensation zone of a cylindrical heat pipe have been developed. It describes the coupled problem of heat and mass transfer and phase transformations in the capillary-porous layer in contact with the moist saturated steam of the working body of the pipe, and thermal conductivity in the pipe wall, from the outer surface of which the heat of steam condensation is transferred to the cooling coolant. The equation system is closed by formulas for the phase transformations intensity, diffusion coefficients of liquid and vapor phases, saturation pressure, and capillary pressure, under the action of which condensate is removed to the evaporation zone. The results of numerical experiments testify to the adequacy of the mathematical model, the effectiveness of the calculation method, and the possibility of their application for managing heat removal processes to organize effective thermal stabilization of thermally stressed surfaces during the operation of heat pipes, and also at the stage of their design.

WSTĘPNE BADANIA WYMIANY CIEPŁA DLA PROTOTYPOWEGO WYMIENNIKA ZINTEGROWANEGO Z PANELEM FOTOWOLTAICZNYM PV

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W pracy przedstawiono wstępne wyniki badań wymiany ciepła w przepływie w prototypowym wymienniku ciepła zintegrowanym z panelem fotowoltaicznym (PV). Stanowisko badawcze obejmuje: obieg czynnika roboczego FC-72, moduł testowy z grupą minikanatów i panelem PV, system akwizycji i przetwarzania danych pomiarowych oraz układ oświetlenia halogenowego. Głównym elementem stanowiska jest prostokątny moduł testowy zawierający 18 minikanatów zintegrowany z panelem PV o wymiarach 540 × 670 mm. Każdy minikanat posiadał wymiary: głębokość 1,5 mm, szerokość 20 mm oraz długość 460 mm. Temperaturę na zewnętrznej powierzchni wymiennika rejestrowano za pomocą kamery termowizyjnej. Na wlotach i wylotach z modułu mierzono temperaturę za pomocą termopar typu K i ciśnienie z zastosowaniem przetworników ciśnienia. Na podstawie otrzymanych wstępnych danych pomiarowych określono temperaturę na poszczególnych warstwach modułu oraz wyznaczono lokalne współczynniki przejmowania ciepła w programie numerycznym CFD Star CCM+ .

UPRAWNIENIA KRAJOWYCH ORGANÓW REGULACYJNYCH W ZAKRESIE ZWALCZANIA NADUŻYĆ RYNKOWYCH NA HURTOWYCH RYNKACH ENERGII PO WEJŚCIU W ŻYCIE REMIT II

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Rozporządzenie UE nr 1227/2011 w sprawie integralności i przejrzystości hurtowego rynku energii (REMIT) wprowadziło zakazy nadużyć rynkowych, tj. manipulacji na rynku oraz wykorzystywania informacji poufnych, w odniesieniu do tzw. hurtowych produktów energetycznych, nakładając na państwa członkowskie obowiązek wyposażenia krajowych organów regulacyjnych (NRA) w uprawnienia w zakresie prowadzenia dochodzeń i egzekwowania ww. zakazów. Kompetencje NRA w zakresie zwalczania nadużyć rynkowych zostały dodatkowo wzmocnione przez niedawną nowelizację REMIT wprowadzoną rozporządzeniem UE nr 2024/1106 w sprawie ochrony Unii przed manipulacją na hurtowym rynku energii (REMIT II). Celem artykułu jest analiza przedmiotowych uprawnień NRA po wejściu w życie REMIT II na tle dotychczasowej praktyki w zakresie zwalczania nadużyć rynkowych, w szczególności w kontekście przewidzianego w REMIT II modelu sankcji administracyjnych (w tym administracyjnych kar pieniężnych). Przedmiotem analizy będą również planowane zmiany dotyczące modelu sankcji za nadużycia rynkowe, przewidzianego w ustawie – Prawo energetyczne, z perspektywy wymogów jakie stawiają państwom członkowskim przepisy REMIT II.

ANALIZA KONSTRUKCJI ORAZ ŚLADU WĘGLOWEGO PANELI FOTOWOLTAICZNYCH W OPARCIU O BADANIA NISZCZĄCE

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Rozwój fotowoltaiki w Polsce w ostatniej dekadzie doprowadził do bardzo szybkiego wzrostu liczby prosumenckich instalacji domowych, stając się jednym z kluczowych elementów transformacji energetycznej kraju. Wraz z tym rozwojem rośnie znaczenie rzetelnej oceny środowiskowej modułów fotowoltaicznych, obejmującej nie tylko etap eksploatacji, ale pełny cykl życia – od produkcji, przez użytkowanie, aż po recykling. W tym celu przeprowadzono badania niszczące uszkodzonego panelu w celu określenia emisji CO₂ związanych z produkcją modułu. Na potrzeby bilansu masowego wykonano pomiary masy badanego modułu BEP-265. Panel został zważony w całości przed demontażem, a następnie określono masę poszczególnych materiałów wykorzystanych w panelu. W oparciu o wyznaczone masy poszczególnych materiałów i ślad węglowy związany z ich wytworzeniem oszacowano ślad węglowy wytworzenia panelu fotowoltaicznego, a następnie określono czas zwrotu długu węglowego w oparciu o różnicę między emisją CO₂ związaną z wykorzystaniem paneli PV do produkcji energii elektrycznej i emisjami określonymi dla polskiego systemu elektroenergetycznego.

HYDROGEN PRODUCTION FROM LIQUID ORGANIC HYDROGEN CARRIERS IN A DIATOMACEOUS EARTH-BASED CATALYTIC FLUIDIZED BED

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Liquid Organic Hydrogen Carriers (LOHCs) offer a promising route for balancing energy systems, however, their commercialization is hindered by low TRL levels and insufficient reactor-scale engineering solutions. Efficient LOHC-to-hydrogen conversion requires continuous reactor operation, low process complexity, and straightforward scalability challenges that can be effectively addressed using fluidized-bed reactor technology. Methanol and formic acid are among the most attractive LOHCs due to high hydrogen content and favorable handling properties, yet their catalytic decomposition demands mechanically robust and fluidizable catalysts.

In this work, three catalysts - Cu@diatomaceous earth, Co₃O₄@diatomaceous earth, and NiO@diatomaceous earth were synthesized via impregnation and characterized using XRD, SEM, BET, and ICP-OES. Their minimum fluidization velocities were determined to verify suitability for fluidized-bed operation. Catalytic performance was evaluated during the decomposition of methanol and formic acid in the temperature range of 150 - 450 °C.

For the first time, a fully synchronized FTIR-GC-PDHID analytical platform was implemented for continuous, real-time monitoring of LOHC conversion. Infrared-active species were identified by FTIR, while hydrogen was chromatographically separated and quantified using a pulsed discharge helium ionization detector. The proposed diatomaceous-earth-based catalytic systems demonstrate competitive performance compared to state-of-the-art LOHC catalysts, highlighting their potential for scalable hydrogen production.

MEASUREMENT OF UNSTEADY FLUID TEMPERATURE USING FLAT, CYLINDRICAL, AND SPHERICAL THERMOMETERS

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Controlling the transient temperature of a fluid is crucial in heat transfer research and in the diagnosis and control of energy processes (e.g. during sudden load changes, start-ups and transient states). Under such conditions, conventional temperature measurement, which is subject to the sensor's thermal inertia, results in significant errors and delays in response. The article presents a method for determining the actual fluid temperature from a temperature measurement inside the thermometer (at its centre or axis) by solving the inverse heat transfer problem.

The developed formulas for reproducing the fluid temperature and determining the surface heat flux are based on Burggraf's analytical solution to the inverse heat transfer problem. Three thermometer geometries were considered: a plate (slab), a solid cylinder, and a sphere, with the temperature measured at the central point (on the axis of the cylinder or in the centre of the sphere). A generalised mathematical model of the thermometer was proposed and developed using the finite-volume method, enabling accurate calculation of its response to time-dependent changes in the fluid temperature.

An important element of the method is determining the heat transfer coefficient on the thermometer's outer surface from the sensor's response to a sudden change in fluid temperature. The heat transfer coefficient is determined by minimising the sum of the squares of the differences between the measured and calculated temperatures at the thermometer's axis/centre. Then, using the assumed heat transfer coefficient, the fluid temperature is reconstructed from first-, second-, and third-order thermometer models.

The accuracy of the reconstruction was verified in two stages:

- numerically, using 'artificial measurement data' obtained from the reference model,
- experimentally, by comparing the calculated and measured temperature curves.

The root-mean-square error (RMSE) between the calculated and measured thermometer temperatures was used as a measure of the quality of the fit and the reliability of the reconstruction.

THERMAL CALCULATIONS FOR STEAM SUPERHEATERS IN LARGE POWER BOILERS USING THE P-NTU METHOD

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This paper presents thermal calculations for three steam superheaters with complex flow configurations using the P-NTU method. The pressure drops on the steam side of the superheaters were also determined. The outlet steam temperature was calculated for superheaters operating under crossflow-cocurrent and crossflow-countercurrent configurations, as well as for a third design combining cross-flow, cocurrent, and countercurrent flow relative to the flue gas. The results of calculations of the mass-averaged steam temperature at the superheater outlet and the flue gas downstream of the superheater were compared with measurement results and CFD modelling results. The heat transfer coefficient on the flue gas side was calculated by accounting for both convective and radiative components. The total convective heat transfer coefficient on the flue gas side at the tube surface was calculated, accounting for cross-flow and parallel-flow relative to the tube axis. The radiative heat transfer coefficient on the flue gas side was determined by a formula derived using the P1 approximation of the spherical harmonics method. Heat transfer correlations for calculating the convective heat transfer coefficient for turbulent steam flow inside the tubes and parallel flue gas flow outside the tubes were derived from numerical solutions of the momentum and energy conservation equations for turbulent fluid flow. The calculated average outlet steam temperature and the pressure drops in the individual superheaters were compared with the measurement results.

THERMAL AND STRENGTH MONITORING OF PRESSURE VESSELS BASED ON TEMPERATURE MEASUREMENTS OF THE EXTERNAL, THERMALLY INSULATED SURFACE AND INTERNAL PRESSURE

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A new method for monitoring the thermal and pressure stresses of thick-walled pressure vessels is presented. Thermal stresses are evaluated based on temperature measurements on the external, thermally insulated surface. The stresses due to pressure are determined using internal pressure measurements. The paper will present a new method for solving the inverse transient heat conduction problem. Based on the temperature measured at the circumference of the pressure vessel's external surface, the temperature distribution across the vessel's cross-section will be determined, followed by the resulting thermal stresses. The determination of thermal stresses on the internal surface of the component from temperature measurements on its external surface will be tested using computational simulations. The method is particularly suitable for nuclear power plants, as no holes need to be drilled in the pressure components to determine the stresses on their internal surface. Knowing the stress history over time, it is possible to determine the degree of component wear caused by low-cycle thermal fatigue and its residual life. The developed method for monitoring the thermal-strength condition of a pressure component can be applied in thermal power plants, such as nuclear and fossil-fuel-fired power plants, combined-cycle power units, and others.

**COMBINED CARBON CAPTURE AND ENERGY STORAGE
AS A WIN-WIN OPPORTUNITY?
TECHNO-ECONOMIC EVALUATION AND OPTIMIZATION OF A NOVEL
CARNOT BATTERY CONCEPT WITH INTEGRATED CO₂ CAPTURE**

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The transformation of conventional energy and industrial production systems towards climate neutrality requires both the integration of high-capacity energy storage as well as the efficient carbon capture from CO₂-rich gas streams, such as from thermal back-up power plants as well as from industrial processes with unavoidable CO₂-emissions (e.g. cement production). Plus, electrification of the chemical industry will lead to an increasing demand for carbon sources. Yet, large-scale energy storage and carbon capture solutions are not economic as stand-alone-solutions in most application scenarios. Therefore, we present a novel Carnot Battery concept based on a modified Brayton cycle, which operates directly with the flue gas from power or industrial plants and separates the CO₂ from the gas stream through re-sublimation. The aim of this work is to evaluate the technical and economic feasibility of this concept. For this purpose, a multi-step optimization procedure is developed. First, the thermo-dynamic cycle is optimized, yielding the Pareto front of energy storage round-trip efficiency and CO₂-capture rate. Building on this, the energy storage operation within a real dynamic power market (German day ahead trade 2024) is optimized for maximum arbitrage. Considering scale-dependent investment and operation costs, diverse economic key indicators are finally derived and evaluated. With minimum CO₂ capture costs of less than 50 €/ton the concept promises a highly economic energy storage and carbon capture operation.

ODZYSK LITU Z ODPADÓW HORNI STANKOV

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W artykule przedstawiono możliwości pozyskania litu z odpadów górniczych ze złoża antropogenicznego (odpady kopalniane) w lokalizacji Horni Stankov, w Czechach. W składowisku odpadów poflotacyjnych Horní Stankov zgromadzone są odpady z wzbogacania rud cynowo-wolframowych. Eksploatacja została zakończona w 1945 roku, pozostate składowisko odpadów ma objętość 430 tys m³. Głównymi minerałami litonośnymi są miki i cynwaldyd. Badania wzbogacalności odpadów prowadzi zespół VSB Tu w Ostrawie i AGH w Krakowie. W artykule przedstawiono mineralogię odpadów oraz wyniki wzbogacania grawitacyjnego, flotacyjnego, oraz piro i hydrometalurgicznego. W Cinovcu (Czechy), blisko granicy z Niemcami, znajduje się jedno z największych złóż litu w Europie, stanowiące 3-5% zasobów światowych Projekt odzysku litu w miejscowości Cinovec w Czechach realizuje European Metals Holdings. Przewiduje wydobycie 2,25 mln ton rudy rocznie, produkując 30 tys. ton wodorotlenku litu.

ANALYSIS OF THE CAUSES OF CORROSION IN THE AIR PREHEATER OF A BOILER FIRED WITH BLAST FURNACE GAS

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The blast furnace process is the foundation of modern iron metallurgy and a key stage in steel production, from iron ore to finished products. In the blast furnace process, mineral matter is transformed into metallic iron through complex thermal, chemical, and flow phenomena. A by-product of this process is blast furnace gas (BFG), generated during coke combustion and reduction. It has a low calorific value and consists mainly of CO, CO₂, N₂, water vapor, and trace sulphur compounds. After dust removal in gas cleaning systems, BFG is reused in industrial units such as Cowper stoves, rolling mills, coke ovens, or combined heat and power plants, where it is often co-fired with other fuels to produce steam or electricity. This work analyses the causes of corrosion in an air preheater and damage to blast furnace gas heater tubes in gas-fired boilers. Deposit analysis confirmed sulphur corrosion. CFD modelling and experimental studies identified zones prone to condensation of water vapor in flue gases. In the presence of sulphur, this leads to sulfuric acid formation, causing corrosion of both air preheater tubes and downstream water heater tubes. An innovative aspect is the use of the ε -NTU method to determine flue gas temperature before the air preheater. CFD results agreed with measurements, enabling precise identification of corrosion zones and rates in the heat exchangers.

OPTIMIZATION OF STEAM CONDENSER CLEANING INTERVALS BASED ON THERMAL PERFORMANCE MODELING AND SIMULATION OF A CHP PLANT

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This article examines the impact of turbine condenser tube fouling on power plant unit performance and steam cycle efficiency. Using operational data and numerical simulations, it demonstrates that deposits impair heat transfer, leading to increased fuel consumption, reduced cycle efficiency, and higher operating costs while maintaining constant energy output. The study proposes a methodology for assessing fouling levels based on the heat flow rate absorbed by the cooling water. A key improvement involves using the existing pipeline's segment elbow as a flow-measurement element, thereby enhancing heat balance accuracy without additional instrumentation. The developed numerical model enables the precise determination of fuel energy losses and identifies optimal cleaning intervals. Ultimately, this approach serves as a comprehensive diagnostic tool to support operational and maintenance planning based on energy and economic criteria.

WPŁYW ZASTOSOWANIA WAPORACJI ZASOBNIKÓW I PODAJNIKÓW WĘGLA NA NIEZAWODNOŚĆ PRACY KOTŁÓW OP 430 ORAZ EFEKTYWNOŚĆ ENERGETYCZNĄ BLOKU CIEPŁOWNICZEGO

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W artykule przedstawiono doświadczenia eksploatacyjne związane z zabudową instalacji waporacji zasobników i podajników węgla na kotłach OP 430/K-2 i K-3 w Elektrociepłowni Wrocław. Zastosowane rozwiązanie pozwoliło na skuteczne wyeliminowanie zjawisk zawieszania i sklejanie się węgla, poprawę niezawodności układu nawęglania oraz ograniczenie awaryjnych odstawień kotłów. W efekcie uzyskano zachowanie ciągłości produkcji energii elektrycznej i ciepła, redukcję zużycia mazutu oraz zmniejszenie kosztów eksploatacyjnych i emisji CO₂.

ASSESSMENT OF INDUSTRIAL EMISSIONS AND MITIGATION SCENARIOS FOR SMALL- AND MEDIUM-SIZED FACILITIES IN SKOPJE USING ADMS-URBAN

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Air pollution during winter in the metropolitan city of Skopje represents a major environmental concern due to increased emissions of PM and NO_x from anthropogenic sources. Atmospheric dispersion modelling was applied using ADMS-Urban to simulate pollutant concentrations originating from small- and medium-sized industrial facilities in the city of Skopje. A total of 22 industries holding B-Integrated Environmental Permits were included in the analysis, representing diverse industrial activities, including food and beverage production, electrical equipment manufacturing, and construction material production. The modelled concentrations were evaluated using measurements from urban monitoring stations operated by the Ministry of Environment and Physical Planning (MOEPP) to assess model performance. A mitigation scenario involving a reduction in industrial production capacity was analyzed. The results indicate how limiting the capacity of industrial plants can contribute to a decrease in particulate matter concentrations, highlighting the importance of industrial emission control for urban air-quality management.

LOCAL SPATIAL CONVECTIVE HEAT TRANSFER COEFFICIENT: TOWARD OPTIMIZED DESIGN OF HEAT TRANSFER SYSTEMS

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The optimal design of heat transfer systems directly determines the energy utilization efficiency of industrial processes and plays a critical role in advancing energy conservation, emission reduction, and thermal energy storage technologies. Conventional heat transfer equipment is typically designed using lumped parameter methods, relying on averaged convective heat transfer coefficients for performance evaluation. However, such approaches are unable to capture the inherent spatial nonuniformity of local convective heat transfer, often resulting in excessive design margins that limit improvements in system performance and economic efficiency. From the perspective of energy streamtubes, the present study traces the pathways of energy flow within the domain and introduces a local spatial convective heat transfer coefficient referenced to the inlet temperature. A unified characterization framework for local heat transfer in single phase forced convection, applicable to both internal and external flows, is established. By integrating the spatial distribution of the local convective heat transfer coefficient with the energy flow trajectories defined by energy streamtubes, and through analyses based on local specific thermal resistance and equivalent thermal resistivity, regions of deficient heat transfer can be accurately identified. On this basis, flow channel structural parameters are optimized and local flow conditions are regulated, leading to enhanced heat transfer performance. The proposed method provides a new theoretical perspective and analytical framework for the refined design and performance enhancement of industrial heat transfer equipment and systems.

AMBURN – AMMONIA FOR LPG REPLACEMENT IN MEDIUM SIZE BOILERS

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Currently ~4.5 million tonnes of oil are consumed in the off-mains industrial market annually in the UK. These energy intensive processes contribute to point source emissions of 14.2 MtCO₂/y. Businesses and industries in these locations often cannot rely solely on electricity to satisfy their process heating requirements. Decarbonisation of these sites therefore presents a significant and pressing challenge. Therefore, the Amburn project has developed and demonstrated a 500 kW ammonia-fed steam boiler to help decarbonise off-grid businesses across the UK, Europe and beyond. Funded by the Department for Energy Security & Net Zero as part of the UK Government's £55m Industrial Fuel Switching Competition, Flogas Britain, ERM, Poznan University of Technology and Cardiff University have proven that ammonia is a viable, cost-effective renewable fuel for large energy users off the mains gas grid. As part of the program, a novel burner has been designed and commissioned to use stratified hydrogen/ammonia combustion to mitigate NO_x emissions. Radical interactions enable a full decontamination of the product gases, whilst temperature control ensures that flames are stable and powerful to provide enough energy for steam production. Thermal crackers are also implemented to produce hydrogen that ensures a faster fuel reactivity, thus stabilizing the process whilst recovering waste heat. Finally, some Health and Safety details about running these units will be presented with an interesting case study of an explosion recently recorded in our laboratory.

FUEL-FLEXIBLE ZERO-EMISSION POWER PLANT WITH OXY-FUEL COMBUSTION AND INDIRECT SCO₂ CYCLE

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Power generation is facing challenges that require fundamental changes and technological advancement in terms of fuel and operational flexibility, efficiency, decarbonization, stringent emission limits and a limited number of operators on the plant. The development of combustion systems integrated with CO₂ capture has been recognized as necessary for energy transition and to support the increasing implementation of renewable systems for stable energy supply. In this context, a novel design of a thermal power plant is investigated, with oxy-combustion and an indirect supercritical carbon dioxide (sCO₂) cycle for the recovery of heat and power from the exhaust gases. The system has been developed for sustainable offshore operation, with the target of producing economically viable power onsite with zero emissions and a compromise between thermal efficiency, footprint, and weight.

The system is described in Figure 1. It consists of an oxy-fuel combustion unit supplied with fuel and high-purity oxygen, where thermal energy is released and transferred to an indirect power cycle through the primary heat exchangers. The indirect cycle enables heat recovery without direct contact between the working fluid and combustion products, allowing flexibility in fuel composition. The high-pressure exhaust gases from the combustor are mainly composed of CO₂ and water vapor and remain under pressure, as they are not expanded in a gas turbine, like it usually happens in direct oxy-fuel combustion cycles. Consequently, post-combustion carbon capture systems are not needed. A simple cooling and condensation stage is enough to obtain a highly pure and pressurized CO₂ stream ready to be injected into geological storage facilities in the vicinity of the plant. In this way, zero-emission electricity is obtained for the offshore facility or to be exported. A broader fuel range is allowed by the indirect power cycle, introducing the possibilities of negative emissions with the use of biogas, or economic savings on sites with, for example, stranded gas and natural gas with high CO₂ content.

The target of this study is to analyze and optimize the innovative power plant through process modelling and simulation. A sensitivity analysis was performed to evaluate the impact of turbine inlet temperature and ambient conditions on the net plant efficiency. An additional target is to benchmark it against a conventional natural gas combined cycle (NGCC) designed for offshore application, with an aero-derivative gas turbine and post-combustion carbon capture.

The most important conclusion of the analysis is that the innovative power plant allows us to produce fuel-flexible and zero-emission electricity with an efficiency that is lower but still comparable to traditional offshore power plants. The results indicate that the proposed configuration represents a promising pathway for low-carbon and zero-emission power generation in offshore environments, supporting both energy security and decarbonization goals.

BADANIE DEGRADACJI DROBNOZIARNISTEGO MATERIAŁU ANODOWEGO YSZ–NiO PODCZAS REDUKCJI W WODÓRZE I PONOWNEJ UTLENIANIA W POWIETRZU

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W pracy zbadano wysokotemperaturową redukcję tlenku niklu oraz reoksydację niklu metalicznego w drobnoziarnistym materiale anodowym YSZ–NiO wytworzonym metodą odlewania taśmowego. Materiał w stanie po spiekaniu wykazywał wytrzymałość na zginanie ok. 209 MPa. Po jednorazowej redukcji w czystym wodorze (4 h, 600 °C, 0,15 MPa) nastąpiły istotne zmiany mikrostruktury – powstały aglomeraty cząstek (ok. 5 μm) z dominacją fazy cyrkonowej oraz obszary drobnych cząstek (1 μm) z równomiernym rozkładem niklu i cyrkonu, wytrzymałość spadła do 40 MPa, a dominował mechanizm pęknięcia międzyziarnowego. Po pięciu cyklach redox w wodorze i powietrzu w 600 °C wytrzymałość wyniosła 85 MPa. Na powierzchniach przetomu stwierdzono porowaty rdzeń i gęste warstwy zewnętrzne z podwyższoną zawartością niklu w warstwie powierzchniowej (prawdopodobnie skutek dyfuzji). Cykl redox spowodował degradację rdzenia przez tworzenie dużych porów, ich koalescencję w pęknięcia i utratę spójności materiału. Osiągnięty poziom przewodności elektrycznej oraz pozytywny wpływ obróbki na wytrzymałość wskazują na potencjał materiału, zwłaszcza przy redukcji w mieszaninie Ar–5 obj.% H₂ zamiast czystego wodoru.

DESIGNING BUILDING-INTEGRATED PV-POWERED HYDROGEN SYSTEMS: A MULTI-OBJECTIVE APPROACH

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With the increasing share of photovoltaic (PV) generation, the work presents a multi-objective optimization for the sizing of a power-to-power (P2P) system for green hydrogen production from PV surplus, including hydrogen and electrochemical storage and fuel cell power generation, applied to an Italian university building. Current and future climate conditions are considered. The optimization minimizes total cost (capital and operational expenditures), interaction with the electricity grid, and greenhouse gas emissions. Decision variables include PV peak power, electrolyzer/fuel cell rated power, lithium-ion battery capacity, and hydrogen storage capacity based on metal hydrides. Results show trade-offs, i.e., cost/grid-oriented solutions favor low PV (~9 kW), large battery storage (~100 kWh), and minimal hydrogen storage (~0.08 kg), while emission-oriented solutions maximize PV (~90 kW). The global optimum features ~47 kW PV, a 4-kW fuel cell, 58 kWh battery storage, and 0.8 kg hydrogen storage. Under the high-emission climate scenario RCP8.5 for 2080, electrical demand increases by 27% and grid exports decrease by ~49%.

HOURLY HVAC DEMAND ASSESSMENT BASED ON GENERATOR PERFORMANCE DEGRADATION AND OUTDOOR CONDITIONS: A CASE STUDY ANALYSIS

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This paper presents an algorithm to estimate the energy demand of HVAC systems using only generator nameplate data and age, together with climatic data, without building modeling and without relying on utility bills or historical measurements. The approach is intended for cases where an energy audit according to the UNI CEI EN 16247 series cannot be carried out or is affected by high uncertainty due to missing consumption data or difficulties in disaggregating HVAC end uses. The method performs an hourly calculation: generator behavior is represented through nominal parameters and an age/condition-based degradation law, while the load is reconstructed from hourly outdoor temperature, system operation schedules, and derived variables. Outputs include time series of power and energy, seasonal energy use, peak loads, and equivalent full-load hours, supporting screening analyses and comparisons of generator replacement scenarios. Validation on a case-study building compares the algorithm estimates with reference consumption/measurement data to quantify accuracy and applicability limits.

ZINTEGROWANA OCENA ŚRODOWISKOWA I ENERGETYCZNA SYSTEMÓW PAKOWANIA NAPOJÓW

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W obliczu rosnącego znaczenia zagadnień związanych z transformacją energetyczną, efektywnością wykorzystania energii oraz wpływem przemysłu na środowisko, szczególnego znaczenia nabiera kompleksowa ocena systemów produkcyjnych w ujęciu środowiskowym i energetycznym. Jednym z istotnych obszarów pozostaje sektor opakowań dla przemysłu spożywczego, w którym dominują tworzywa sztuczne, a procesy technologiczne charakteryzują się znacznym zapotrzebowaniem na energię. Pomimo wdrażania zasad gospodarki o obiegu zamkniętym oraz systemów kaucyjnych, odpady opakowaniowe nadal stanowią wyzwanie środowiskowe i energetyczne. Celem niniejszej pracy jest zintegrowana ocena środowiskowa i energetyczna systemu pakowania napojów w całym cyklu życia, z uwzględnieniem zmienności źródeł zasilania procesów technologicznych oraz scenariuszy zagospodarowania użytkowego. Analizę przeprowadzono metodą LCA w granicach „od kotyski do grobu”, obejmujących etapy wytwarzania materiałów i elementów opakowania, produkcji butelek, napełniania i pakowania, dystrybucji, użytkowania oraz użytkowego zagospodarowania. Jednostkę funkcjonalną stanowi dostarczenie 1,5 l napoju do konsumenta na rynku polskim. Ocenę oddziaływań środowiskowych wykonano metodą ReCiPe 2016, a modelowanie recyklingu przeprowadzono w podejściu cut-off. W pracy przyjęto podejście scenariuszowe (bazowy-aktualny-przyszły), odzwierciedlające kierunki rozwoju systemów energetycznych oraz zmiany w gospodarce odpadami. Analizie poddano wpływ udziału materiałów pochodzących z recyklingu, zmian w krajowym miksie energetycznym (w tym wzrostu udziału OZE) oraz różnych wariantów zagospodarowania użytkowego, takich jak recykling, spalanie z odzyskiem energii czy składowanie. Uwzględniono również znaczenie efektywności energetycznej procesów produkcyjnych oraz rolę przemysłu w racjonalizacji zużycia energii. Uzyskane wyniki wskazują, że redukcja oddziaływań środowiskowych systemów pakowania napojów wymaga zintegrowanego podejścia, łączącego działania w obszarze materiałowym, energetycznym i systemowym. Szczególne znaczenie ma zwiększenie udziału odnawialnych źródeł energii w zasilaniu procesów technologicznych, rozwój recyklingu oraz wdrażanie zasad ekoprojektowania.

ANALIZA PRACY PALNIKA PIROLITYCZNEGO ISA NA PALIWO STAŁE

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Globalne uwarunkowania geopolityczne oraz restrykcyjna polityka klimatyczna determinują konieczność optymalizacji procesów konwersji paliw stałych w jednostkach małej mocy. Rozwiązania te sprzyjają autonomii energetycznej i stanowią kluczowe źródło ciepła w regionach pozbawionych dostępu do infrastruktury scentralizowanej. Niniejsza praca prezentuje innowacyjny, niskoemisyjny palnik pirolityczny ISA dedykowany do kotłów o małej mocy. Analizę pracy urządzenia oparto na badaniach eksperymentalnych oraz zaawansowanym modelowaniu numerycznym z wykorzystaniem sprzężonych metod CFD-DEM. Podejście to umożliwiło szczegółowe odwzorowanie przepływu fazy gazowej oraz dynamiki ruchu złoża stałego. Wyniki przeprowadzonych testów dokumentują istotną redukcję emisji CO oraz NO w odniesieniu do konwencjonalnie stosowanych palników retortowych.

EVALUATION OF VHTR CYCLE EFFICIENCY THROUGH KNOWN BRAYTON CYCLE ENHANCEMENTS AND SOLAR ENERGY UTILISATION

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The efficiency of the Very High Temperature Reactor (VHTR) power conversion system can be enhanced through the application of established thermodynamic improvement techniques. This study investigates selected Brayton cycle enhancements, namely intercooling between compressor stages and intermediate reheating during turbine expansion, which are evaluated as independent methods for increasing cycle efficiency. In addition, the integration of an Organic Rankine Cycle (ORC) is considered as a bottoming cycle to recover waste heat and further improve overall plant efficiency. A zero-dimensional (0D) thermodynamic model of the reference VHTR Brayton cycle was developed and validated using commercial Epsilon software. Based on this validated baseline, the proposed modifications were implemented and systematically analysed. The results demonstrate that both Brayton cycle enhancements and the ORC integration lead to improved cycle performance relative to the reference configuration. The study confirms that the application of well-established thermodynamic concepts provides an effective pathway for optimizing VHTR power conversion systems.

ODZYSK CIEPŁA W SYSTEMACH VRF JAKO CZYNNIK POPRAWY EFEKTYWNOŚCI ENERGETYCZNEJ BUDYNKÓW I OBIEKTÓW PRZEMYSŁOWYCH

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Współczesne systemy klimatyzacji i ogrzewania mają realny wpływ na kształtowanie efektywności energetycznej budynków mieszkalnych, biurowców oraz obiektów przemysłowych. Jednym z rodzajów tych rozwiązań są systemy VRF (Variable Refrigerant Flow) 3-rurowe tj. wyposażone w funkcję odzysku ciepła. Zastosowanie tej technologii pozwala na jednoczesne chłodzenie i ogrzewanie przy wykorzystaniu energii w obrębie danego systemu.

Celem pracy jest pokazanie możliwości wykorzystania odzysku ciepła w systemach VRF HR (heat recovery) jako narzędzia do poprawy efektywności energetycznej obiektu oraz ograniczenia zużycia energii pierwotnej. Praca przedstawia zasadę działania systemów VRF z odzyskiem ciepła, w warunkach zmiennego obciążenia cieplnego. Przedstawiono potencjalne zastosowania systemów, takie jak biurowce, hotele, obiekty przemysłowe, gdzie może zaistnieć zapotrzebowanie na jednoczesne chłodzenie i ogrzewanie.

Przy wykorzystaniu analizy literatury oraz własnego doświadczenia wskazano główne korzyści wynikające z zastosowania systemów VRF z odzyskiem ciepła, w tym zwiększenie współczynnika efektywności energetycznej. Wzięto również pod uwagę wyzwania związane w wprowadzeniu takiego rozwiązania jak koszty inwestycyjne oraz poziom złożoności projektu.

Analiza wskazuje, że systemy VRF z odzyskiem ciepła mogą stanowić istotny element transformacji energetycznej budynków.

UTILIZATION OF WATER TREATMENT SLUDGE (WTS) AS A FLUIDIZED BED REACTOR MEDIUM IN HYDROGEN PRODUCTION FROM FORMIC ACID.

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This study investigates the catalytic valorization of water treatment sludge (WTS) for hydrogen production in a fluidized-bed reactor via thermal decomposition of formic acid as a model organic hydrogen carrier. WTS was used simultaneously as the bed material and catalyst support. A selected fraction was processed to obtain three beds: inert WTS and Co- and Ni-loaded catalysts prepared by impregnation with organic metal salts and reduced *IN SITU* in a formic acid stream at 450 °C. The materials were characterized by XRD, SEM, and SEM-EDS. The minimum fluidization velocity for WTS, determined experimentally, was 0,48 cm/s. Formic acid decomposition was studied in the 80–450 °C range, with quantitative products identified by gas-phase FTIR and GC-PDHID. All beds exhibited catalytic activity toward hydrogen formation, including inert WTS, with the highest activity observed for the WTS–Ni catalyst. The results demonstrate the potential of waste-derived catalytic materials and photosynthetic feedstocks as an alternative route for hydrogen production, supporting sustainable catalysis and a circular hydrogen economy.

ONLINE DETERMINATION OF THE TRANSIENT TEMPERATURE AND STRESS DISTRIBUTION IN THICK-WALLED PRESSURE COMPONENTS

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A method for determining thermal stresses in horizontal pressure components insulated on their outer surface is presented. Horizontal components are exposed to high thermal stresses during the start-up and shutdown of a power unit, due to the presence of water in the lower part and the flow of steam through the upper part. Due to the different temperatures of steam and water, and the different heat transfer coefficients in the steam and water regions, the heating or cooling of a pressure vessel is non-uniform across its circumference. Based on the measurement of the transient temperature at a specified radius around the element's circumference, the temperature distribution across the entire cross-section of the element is determined, followed by the thermal stresses. A simplified method for determining thermal stresses suitable for online applications was developed. A formula has been derived to determine the longitudinal thermal stresses arising from the temperature difference at the component's circumference. The total thermal stresses are calculated using the superposition method. Thermal stresses on the inner surface of components with and without holes, determined using approximate formulas, were compared with the results of finite element method calculations.

OZNACZANIE BIOMARKERÓW WWA W PRÓBKACH ŚCIEKÓW METODĄ LC-MS/MS

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Wielopierścieniowe węglowodory aromatyczne (WWA) to grupa związków należących do grupy „nowoczesnych zanieczyszczeń”. Obecność WWA w środowisku jest powszechnie wykrywana. Potwierdzono, że związki te mogą mieć negatywny wpływ na organizmy. Badania wykazały, że WWA podejrzewa się o działanie mutagenne, teratogenne i rakotwórcze. Jedną z grup związków będących biomarkerami narażenia na WWA są ich pochodne hydroksylowe (OH-WWA). Według badań, OH-WWA mogą również negatywnie wpływać na organizmy i środowisko. Dlatego kluczowe jest monitorowanie obecności oraz stężenia WWA i OH-WWA. Niniejsza praca dotyczy oznaczania pochodnych hydroksylowych WWA w próbkach ścieków pobranych z dwóch krakowskich oczyszczalni ścieków. W tym celu zastosowano metodę ekstrakcji SPE, a stężenie OH-WWA zmierzono za pomocą wysokosprawnej chromatografii cieczowej sprzężonej z tandemową spektrometrią mas. Badanymi związkami były: naftole, fluorenole, fenantreny, 1-hydroksypiren i 3-hydroksybenzo(a)piren.

WPŁYW OBECNOŚCI KANAŁÓW POWIETRZNYCH NA WŁAŚCIWOŚCI TERMOIZOLACYJNE PŁYT Z PMMA

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W pracy przedstawiono wyniki pomiarów i obliczeń przewodności cieplnej zmodyfikowanych płyt z polimetakrylanu metylu (PMMA) o grubości 30 mm. Modyfikacja polegała na zastosowaniu poziomych kanałów powietrznych o średnicy 8 i 12 mm, prostopadłych do kierunku przepływu ciepła i osiach odległych od 20 do 80 mm. Przeanalizowano 6 modyfikacji. Przewodność cieplną mierzono za pomocą aparatu FOX 200. Wyniki pomiarów posłużyły do walidacji dwuwymiarowego modelu numerycznego CFD Ansys-Fluent. W modelu analizowano ustalony przepływ ciepła z uwzględnieniem konwekcji i promieniowania w przestrzeniach wypełnionych powietrzem. Maksymalna różnica obliczanej i mierzonej przewodności cieplnej zmodyfikowanych płyt nie przekraczała 4,9%. Stwierdzono, że kanały powietrzne w płytach PMMA poprawiają ich izolacyjność cieplną w zakresie od 5% do 17%, w porównaniu do płyty bez modyfikacji. Największy spadek współczynnika przewodzenia ciepła uzyskano dla płyt z największym objętościowym udziałem powietrza, tzn. dla płyt z kanałami o średnicy 12 mm i osiach odległych o 20 mm. Zwalidowany model numeryczny będzie wykorzystany do analizy termoizolacyjności modyfikowanych przegród budowlanych.

FORMALDEHYDE OLIGOMERS AND POLYMERS AS SOLID HYDROGEN CARRIERS: HYDROGEN PRODUCTION IN A FLUIDIZED BED REACTOR OVER CENOSPHERE-SUPPORTED METAL/AL₂O₃ AND METAL/CACO₃ CATALYSTS

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Cenosphere-supported metal/Al₂O₃ and metal/CaCO₃ catalysts were prepared via simple wet impregnation using aqueous solutions of active metal salts together with aluminum or calcium precursor salts, followed by calcination in a muffle furnace. The obtained catalysts were characterized using SEM, EDS, and XRD techniques to evaluate their morphology, elemental composition, and crystalline structure. Catalytic tests for hydrogen production from formaldehyde oligomers were carried out in a fluidized bed reactor. The composition of gaseous products was continuously monitored using FTIR and GC-PDHID methods, FTIR analysis enabled detection of components such as methane (CH₄), CO, CO₂, and unreacted species, while hydrogen was quantified using GC-PDHID.

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THERMODYNAMIC PERFORMANCE AND CONTROL STRATEGY COMPARISON OF A SOLAR-ASSISTED GROUND SOURCE HEAT PUMP SYSTEM FOR RESIDENTIAL HEATING

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This study evaluates the energy and exergy performance of a solar-assisted ground source heat pump (SA-GSHP) system demonstrated at a 433 m² multi-family residential building in Limanowa, Poland. The system integrates parabolic trough collectors, sun-tracking PV/T modules, a 42 kW water-to-water heat pump, five 100 m borehole heat exchangers, and a 50 m³ non-insulated underground thermal energy storage tank. Transient physical models for each component are developed in MATLAB and validated against the first full monitoring year in 2024-2025, with annual deviations of +1.8 % for solar collector thermal output, +6.9 % and +26.0% for PV/T electricity and thermal output, and -1.7 % for heat pump COP. A 10-year simulation under Kraków TMY conditions yields 48,039 kWh of delivered heating, an electricity self-sufficiency of 122.2 %, and a BHE regeneration ratio of 79.3 %, confirming long-term ground thermal sustainability. Replacing the fixed 55 °C supply setpoint with a climate compensation curve raises the annual SPF from 4.34 to 5.77 and reduces heat pump electricity consumption by 17.2 %. A comprehensive exergy analysis with avoidable/unavoidable decomposition reveals that the solar collectors account for over 90 % of total exergy destruction, yet 99 % is thermodynamically unavoidable. The GSHP subsystem and radiator together contribute over 50 % of the avoidable exergy destruction, and S2 reduces the system avoidable irreversibility by 11.8 %, confirming the supply temperature modulation as the primary lever for thermodynamic improvement.

EXPERIMENTAL INVESTIGATION OF USING A WET STEAM-DRIVEN ROTARY BLOWER FOR ELECTRICITY GENERATION

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The paper discusses an innovative method for utilising waste heat to generate electricity. The innovation involves implementing the wet steam cycle. This means that wet steam-tolerant expanders must be used. The expander analysed in the paper is a rotary blower operating in a reverse cycle. To select the appropriate rotary blower and generator for testing, preliminary simulations were conducted. A design was then created, and a test stand was constructed to cover wet-steam generation and to feed the steam to the expander. The experimental tests included two series of measurements. During the first series, the wet-steam relative pressure at the expander inlet ranged from ~ 2 bar to 2.8 bar, with a steam quality of ~ 0.7 to 0.8. In the second measuring series, the steam relative pressure was from ~ 3 bar to ~ 4 bar, with the steam quality ranging from ~ 0.65 to ~ 0.85 . In both cases, the wet steam mass flow rate was about 420-500 kg/h. The obtained isentropic efficiency values were small, ranging from approximately 3% to approximately 8%. The power values measured at the generator terminals were also small, ranging from approximately 80W to approximately 150W. To date, similar studies have not been conducted. No operating problems related to the expander being fed with wet steam were observed. The research results demonstrate some potential of this type of expander to generate electricity.

SYMULACJE I BADANIA EKSPERYMENTALNE WYKORZYSTANIA SPRĘŻARKI SPIRALNEJ ZASILANEJ PARĄ MOKRĄ DO PRODUKCJI ENERGII ELEKTRYCZNEJ

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W pracy przedstawiono wybrane wyniki badań związanych z innowacyjnym sposobem wykorzystania ciepła odpadowego do produkcji energii elektrycznej. Innowacyjność polega na realizacji cyklu termodynamicznego, który w całości zawarty jest w obszarze pary mokrej. Symulacjom i badaniom eksperymentalnym poddano pracę sprężarki spiralnej pracującej w obiegu odwróconym, jako ekspander. Wykonano dwie serie pomiarowe. W pierwszym przypadku dla prędkości obrotowej ekspandera ok. 1400-1600 obr/min i strumienia masy pary ok. 30-65 kg/h uzyskano moc elektryczną od ok. 800 W do ok. 2400 W przy sprawności izentropowej od ok. 35% do ok. 50%. Podczas drugiej serii prędkość obrotowa ekspandera wynosiła ok. 2800-2900 obr/min przy strumieniu masy pary od ok. 35 kg/h do ok. 90 kg/h. Uzyskano wówczas moc elektryczną, odpowiednio, od ok. 800 W do ok. 4800 W przy sprawności izentropowej od ok. 45% do ok. 72%. Stopień suchości pary w obu przypadkach wahał się od ok. 0,77 do ok. 0,87. Otrzymane wyniki są bardzo obiecujące i wskazują na wysoką efektywność produkcji energii elektrycznej z wykorzystaniem badanego ekspandera i pary mokrej. Podobne badania nie były dotychczas realizowane.

TRANSIENT CROSS-COMPARISON OF A FLAT-PLATE SOLAR COLLECTOR AND A SUN-TRACKED DOUBLE U-TUBE PARABOLIC TROUGH COLLECTOR: MODELLING, VALIDATION, AND TECHNO- ECONOMIC ASSESSMENT

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This paper presents a transient performance comparison of a flat-plate solar collector (FPSC) and a sun-tracked parabolic trough collector (PTC) with a double U-tube receiver. Both collectors were modeled using in-house transient mathematical models and validated against experimental data obtained from a dedicated test stand. After validation, annual simulations were conducted for Kraków, Poland, using hourly meteorological data from the PVGIS database. The analysis focused on the long-term thermal and economic performance of both collector types under identical boundary conditions. The electricity demand of the tracking system was included using a constant motor power assumption. A simplified techno-economic evaluation was performed using the Levelized Cost of Heat (LCOH), accounting for investment costs, operating and maintenance expenses, auxiliary electricity consumption, system degradation, and cost escalation over a 20-year lifetime. For a comparable aperture area, the calculated LCOH amounted to 0.096 EUR/kWh for the sun-tracked PTC and 0.041 EUR/kWh for the stationary FPSC. The results indicate that, despite higher thermal performance, the examined PTC configuration is not economically competitive for low-temperature heat production under the assumed cost structure, mainly due to its higher investment cost.

ANALYSIS OF THE HEAT TRANSFER PROCESS IN A TUBE-IN-TUBE COIL HEAT EXCHANGER USING ARTIFICIAL INTELLIGENCE MODELS AND ANALYTICAL METHODS

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This paper presents an analysis of the heat transfer process in a Tube-in-Tube Coil Heat Exchanger using artificial intelligence methods. The experimental investigations included measurements of the water temperature at the inlet and outlet, as well as the flow rates of both streams. Based on the collected data, predictive models were developed using Artificial Neural Networks (ANNs), including Feedforward Backpropagation (FFBP) and Cascade structures. The aim of the study was to assess the ability of ANN models to predict the outlet water temperature on both sides and to compare the effectiveness of various learning algorithms. The results of the ANN models were compared with the results of numerical calculations in order to assess their accuracy. Models trained using the Levenberg–Marquardt (LM), Broyden–Fletcher–Goldfarb–Shanno (BFGS), Conjugate Gradient Backpropagation with Powell–Beale Restarts (CGB), Resilient Propagation (RP), and Scaled Conjugate Gradient (SCG) algorithms were analysed. The best results were obtained for models using the LM algorithm. The minimum values of the Mean Absolute Percentage Error (MAPE) were approximately 0.36% and 0.44% for the cold side, and 0.26% and 0.33% for the hot side, respectively, for the FFBP and Cascade structures. High correlation coefficients ($R \approx 0.999$) and coefficients of determination ($R^2 \approx 0.999$) confirm the very good agreement of the models with the experimental data and numerical calculations. The obtained results indicate that ANNs are effective tools for modelling and optimisation of heat exchanger operation.

A PRELIMINARY COMPUTATIONAL MODEL AND ASSESSMENT OF THE IMPACT OF A HYBRID SUBSTATIONS ON DISTRICT HEATING SYSTEM DEMAND PROFILES

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In the context of decarbonization of the district heating sector in Poland, driven by climate policies, the introduction of hybrid district heating substations into district heating networks represents a promising solution for integrating multiple renewable energy sources. The work describes the preliminary computational model of the hybrid district heating substations validated by operational data aggregated from the district heating data acquisition system. The results obtained from the hybrid substation model were used to evaluate the behaviour of the district heating network under various simulated operating scenarios, assuming the introduction of some hybrid substations into the network. The analysis demonstrates that the proposed solution enables a reduction in peak heat demand and assesses the feasibility of implementing a hybrid district heating substation into the district heating system.